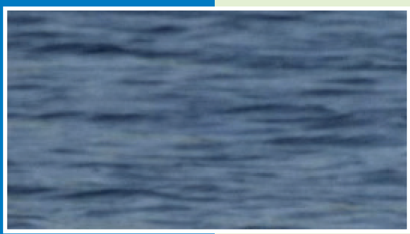
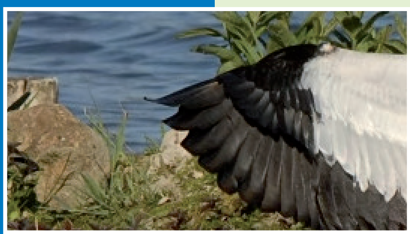
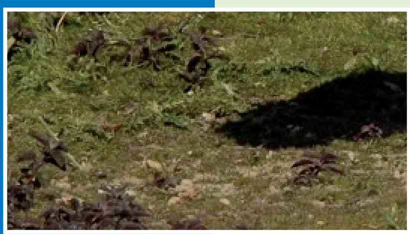
Risk analysis of the Egyptian Goose in The Netherlands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Preface

Since 1967, when Egyptian Geese *Alopochen aegyptiaca* bred for the first time in the wild in The Netherlands, this exotic species has largely colonized the country and spread to the surrounding countries as well. In order to understand the success of this species and any possible ecological, economical and social impacts it causes, the Invasive Alien Species Team of the Ministry of Agriculture, Nature and Food Quality has commissioned Bureau Waardenburg to carry out a risk analysis.

This risk analysis was carried out by:

A. Gyimesi	report;
P.W. van Horssen	GIS;
R. Lensink	project management and report;
T.J. Boudewijn	internal check.

Dr. T.M. van der Have, Invasive Alien Species Team (LNV), supervised this study. The authors thank all who contributed.

SOVON Vogelonderzoek Nederland kindly provided data on Egyptian goose from the:

- National breeding census (BMP);
- National winterbird census (PTT);
- National waterbird census (Watervogeltellingen);
- The atlas on breeding birds 1998-2000;
- A special goose census in July 2009.

We thank Hans Schekkerman, Chris van Turnhout, Berend Voslamber from SOVON for their cooperation in delivering data and discussions in early stages of the project. Popko Wiersma build a model based on habitat suitablity indices, analogues to the model build for other non-native goose species, as done by SOVON in commission of the Invasive Alien Species Team (Ministery of LNV).

We were happy to be able to rely on data provided by species experts (A. Bloomfield, F. Majoor, B. Sage, W.R. Siegfried and D. Vangeluwe).

We want to thank the following foreign experts for providing information on the status of Egyptian Geese in other countries:

- Belgium: Anny Anselin : Research Institute for Nature and Forest;
- France: Carol Fouque and Vincent Schricke: Office National de la Chasse et de la Faune Sauvage;
- Denmark: Vicky Knudsen: Dansk Ornitologisk Forening;
- Switzerland: Verena Keller, Schweizerische Vogelwarte.

Table of contents

Summary

The Egyptian Goose *Alopochen aegyptiaca*, an African waterfowl species, was introduced to parks in England in the 17th century due to its ornamental features. Escaped individuals established a free-living population, which exists up till today in East Anglia. Similarly, escaped birds from parks in The Hague and Groningen started to breed (in 1967 and 1980, respectively) in the wild in The Netherlands. Since then, the species has colonized most of the suitable habitats in the country. Moreover, due to further spreading from The Netherlands, the species has nowadays viable populations in Germany and Denmark and by escapes in Brussels also in Belgium and France. Currently, the size of this introduced population in Northwest Europe is estimated to be at least 65.000 birds.

This report summarizes the current knowledge on the species, with special attention to its ecological features characteristic for The Netherlands. Furthermore, the current distribution and absolute numbers, but also the development in numbers since the introduction are reported for The Netherlands, as well as for other Northwest-European countries. Based on the collected information, a risk analysis was carried out to investigate the possible ecological, economical and social impacts the presence of Egyptian Goose causes in The Netherlands and the possible management options.

The success of the Egyptian Goose in The Netherlands can mainly be attributed to its feeding behaviour (i.e. relies mostly on grass, which is abundantly available) and the extensive availability of suitable habitats (i.e. presence of freshwater nearby grasslands with a few trees). This is underlined in the high preference towards habitat types dominated by grasslands. Severe winters negatively affect numbers, and a survival analysis revealed that dry summers negatively affect survival rates. However, in The Netherlands winters are commonly mild and summer conditions wet, which makes it possible that the birds usually find enough food. Besides having a few natural enemies, likely these qualitatively good and in large amount available grasslands play an important role in the high breeding success of Egyptian goose in The Netherlands.

The breeding population of the Egyptian Goose in The Netherlands is estimated at approximately 10.000 breeding pairs in 2009, while the total population in July 2009 at approximately 50.000 individuals. Both the breeding and the non-breeding population have exponentially increased since the establishment of the species in the wild in 1967 (until 1999 by 28% and 40%, respectively). However, the increase has slowed down in the last ten years. The species has likely colonized most of the suitable habitats in the lower parts of The Netherlands, but further growth of the breeding population is expected in the higher parts. Populations in the surrounding countries, especially in Germany, are also rapidly growing.

The Egyptian Goose is mainly resident; the distribution in the breeding period and in the winter is similar. Mostly, individuals occur solitary or in pairs, but during moulting in large aggregations. Due to the population growth, such aggregations not

uncommonly consist of hundreds, eventually thousands of birds. Such moulting groups cause considerable damage to crop producers in South Africa, and conflicts with farmers are increasing also in Europe. In addition, these groups raise further concerns for economic, ecological and social impacts. The occurrence of avian influenza or other pathogenic diseases in large groups of waterfowl may threaten poultry farms in the vicinity.

Eutrophication processes may be intensified by the defecation in smaller standing waters, promoting the development of *blue algae* and bacterial loads. Defecation of a large number of geese on public roads and in recreational swimming waters can also cause annoyance to humans. Furthermore, during breeding they may eventually behave fiercely to protect their nests. Their aggressive behaviour is generally known, which may also negatively affect native bird species. The main food source, i.e. grass, is abundantly present in The Netherlands, and hence problems of food depletion are unlikely. However, large groups of Egyptian Geese might be avoided by other species, which may be forced to switch to suboptimal habitats. Considering the competition for breeding sites, the aggressive behaviour of Egyptian Geese may be disadvantageous to other species also on the individual level.

Two risk analysis methods (i.e. the Bomford method and the ISEIA method) underlined the high dispersal and colonization potential of the species. Scientific studies on ecological impacts are scarce, but the general outcome of the risk analyses opts for management action against the species. Culling of the Egyptian Goose is already allowed in England, Belgium, Germany and Denmark, but mainly due to its status as an exotic species not protected by law, rather than its economic, ecological or social impact.

In order to avoid further spread of the species in Europe, eradication in the early stages is the most cost-effective option, as once settled, Egyptian Goose can increase quickly in numbers. Due to the large number of birds in The Netherlands, eradication is difficult. Considering management steps, culling of the species seems to be an effective measure to stop further growth of the population. Without culling since the nineties, the total numbers would have increased up to 60.000 breeding pairs, i.e. 280.000 birds in July 2009 (under ongoing exponential growth, matrix Tab 3.6)). Calculations based on Habitat Suitability Indices pinpoint towards a maximum population size of 28.000 pairs (Appendix 2). In order to reach a stable population level, the culling has to be around 27% of the population size in July. Regarding the large populations in the surrounding countries, culling schemes should optimally be organized on an international level.

Nederlandse samenvatting

De nijlgans *Alopochen aegyptiaca* is een Afrikaanse watervogelsoort. De soort is in de 17e eeuw geïntroduceerd in Engeland, vooral vanwege zijn decoratieve uiterlijk. Ontsnapte individuen vormen in East Anglia (Engeland) al twee eeuwen een vrij levende populatie. Ook in Nederland zijn vanuit parken in Den Haag en Groningen vestigingen in het vrije veld ontstaan (achtereenvolgens in 1967 en 1980). Sindsdien heeft de soort veel geschikt habitat in ons land gekoloniseerd. Daarnaast heeft de soort als gevolg van toename en uitbreiding vanuit Nederland, Duitsland en Denemarken gekoloniseerd. Deze populatie vormt nu een geheel die in België. Deze vogels hebben hun oorspong in een park bij Brussel. Van daaruit reikt de kolonisatie inmiddels tot in Frankrijk. Momenteel bedraagt de omvang van de geïntroduceerde populatie in Noordwest-Europa ten minste 65.000 vogels.

Dit rapport geeft een overzicht van de huidige kennis over de soort, met speciale aandacht voor ecologische karakteristieken in Nederland. Daarnaast wordt een overzicht gegeven van aantallen en verspreiding alsook de ontwikkelingen hierin, zowel voor Nederland als de ons omringende landen. Op basis van de verzamelde informatie is een risicoanalyse uitgevoerd om de mogelijke ecologische, economische en sociale gevolgen van de aanwezigheid van de nijlgans in Nederland te duiden en de mogelijke opties voor beheer te formuleren.

Het succes van de nijlgans in Nederland kan vooral worden toegeschreven aan de voedselkeus (vooral gras dat overvloedig beschikbaar is) en het grote aanbod aan geschikt leefgebied (open water nabij graslanden met een paar bomen). Strenge winters hebben een negatief effect op het aantal (verhoogde sterfte) alsook droge zomers. Met een gematigde klimaat (milde winters en relatief natte zomers) zijn de omstandigheden voor de soort in Nederland gemiddeld genomen evenwel gunstig waardoor een snelle toename mogelijk is. De soort kent in Nederland geen natuurlijke vijanden, waarbij predatie van nesten evenmin een factor van betekenis is.

De broedpopulatie van de nijlgans in Nederland wordt in 2009 geschat op ongeveer 10.000 broedparen en de totale populatie in juli 2009 op ongeveer 50.000 individuen. De broedpopulatie is sinds de eerste vestiging in 1967 exponentieel toegenomen (tot 1999 met 28%/jaar, nadien 8%/jaar). Voor de niet-broedende populatie bedragen deze waarden achtereenvolgens 40% en 15%/jaar. De afname in groei is vermoedelijk vooral het gevolg van afschot sinds eind jaren negentig. De soort heeft in Laag-Nederland veel geschikt habitat gekoloniseerd; doch ook hier vindt nog altijd een toename plaats. Populaties in de omringende landen, met name Duitsland, nemen ook snel in aantal toe.

De nijlgans vertoont in Nederland geen gerichte trek; de verspreiding van de soort in de broedperiode komt sterk overeen met die in het winterhalfjaar. De soort leeft paarsgewijs of in kleinere groepen. In de nazomer kunnen grote concentraties (honderden tot meer dan 1.000 ex) in waterrijke gebieden ontstaan. Dit valt samen met de rui van veel vogels. In de loop van de het najaar lossen deze concentraties ten dele weer op. In Zuid-Afrika kunnen deze groepen aanzienlijke schade veroorzaken. Ook In Nederland neemt het aantal meldingen van schade toe. Een goed overzicht ontbreekt; schade wordt niet geregistreerd omdat er voor deze soort geen schaderegeling bestaat. Desondanks neemt de vrees toe voor economische, ecologische en sociale gevolgen.

Het optreden van vogelgriep of andere pathogene ziekten in grote groepen van watervogels kan bedreigend zijn voor de pluimveehouderij. Ontlasting in kleine stilstaande wateren kan leiden tot eutrofiëring waarin de balans verschuift naar een overmaat aan fosfaat. Hierdoor wordt de ontwikkeling van blauw algen bevorderd alsook enkele soorten bacteriën. Ontlasting van ganzen in de openbare ruimte (wegen, fietspaden, ligweiden, stranden) en in zwemwateren kan ook leiden tot overlast voor de mens.

Tijdens het broedseizoen kunnen nijlganzen hun nest en jongen met verve beschermen. Dit gedrag kan nadelig uitpakken voor andere soorten die eenzelfde habitatkeus hebben (nestplaats, foerageerplaats). Voor zover bekend heeft dit agressieve gedrag in West-Europa nog niet tot negatieve effecten op soorten geleid. Een Afrikaanse studie laat echter zien dat de nijlgans het broedsucces van een roofvogels, via nestconcurrentie, negatief beïnvloed. Dergelijke processen kunnen zich ook hier voordoen.

De eventuele gevolgen van de aanwezigheid van nijlganzen is met twee methoden van risicoanalyse in beeld gebracht: de Bomford methode en de ISEIA methode. Uit beide volgt dat de soort een groot potentieel kent voor vestiging (reeds bewezen) en uitbreiding en toename (reeds bewezen). Onderzoeken naar ecologische, economische en sociale effecten zijn schaars. De schaarse gegevens duiden op een hoog risicoprofiel van de soort; maatregelen worden daarom wenselijk geacht. Een toegenomen afschot van nijlganzen sinds eind jaren negentig heeft in Nederland al geleid tot een (bijna) stabilisatie van het aantal. In omringde landen wordt ook afschot gepleegd: Engeland, België, Duitsland en Denemarken. In deze landen (en ook Nederland) vindt afschot vooral plaats vanwege de status als niet-beschermde uitheemse soort en niet vanwege economische, ecologische of sociale schade.
Indien het toegenomen afschot sinds eind jaren negentig achterwege was gebleven, dan laten modelberekeningen zien dat het aantal inmiddels zou zijn toegenomen tot 60.000 broedparen of 280.000 vogels in juli (onder voortdurende exponentiele toename, matrix in tabel 3.6). Berekeningen aan de van Habitat Geschikheid Indexen (HSI-indices) duiden op een maximale broedpopulatie van 28.000 paar (bijlage 2). Gezien het talrijke en wijd verspreide voorkomen van de nijlgans in Nederland zullen maatregelen in eerste instantie moeten leiden tot een afname van het aantal. Afschot ligt hierin het meest voor de hand. Vogels verliezen tijdens de rui hun vliegvermogen maar ten dele. Hierdoor is vangen en doden van ruiende groepen erg lastig. Om een stabiele populatieniveau te bereiken zou het afschot percentage ongeveer 27% van de populatie in juli moeten bedragen.

1 Introduction

The Egyptian Goose *Alopochen aegyptiaca* is a native species in Africa south of the Sahara (Brown *et al.* 1982). It was introduced into England in the 17th century as an ornamental waterbird (Sutherland & Allport 1991). Since then a free-living population developed in East-Anglia (Gibbons *et al*. 1993). On the European continent the species has been kept in captivity at several places since the second half of the 20th century. In the sixties, escapes at different localities and different moments have lead to the development of a free-living breeding population in the Netherlands.

The Egyptian Goose was introduced to parks around The Hague as an ornamental species. Escaped individuals were reported to breed freely in 1967 for the first time. Since then, the introduced population of Egyptian Geese has expanded and colonised basically all parts of The Netherlands and spread further into Germany, Switzerland and Denmark. Another introduced population, originating from Belgium, spread also into France, making it a species common in Northwest-Europe. This raises questions on the ecological, economic and social impact of this invasive species. This technical-scientific report contains the results of an analysis on the impact of the Egyptian Goose on biodiversity and economy and the possible future management scenarios. Compared to an earlier analysis of the risk of Egyptian goose (Lensink & Van den Berk 1996) today's one is much more formalised and complete.

1.1 Goals and terms of reference

This project aims to conduct a detailed risk assessment of the presence of the Egyptian Goose in The Netherlands, including economic, social and ecological risks. The risk assessment will be based on the hypothetical situation that no preventive, counteractive or management measures are taken against the species; hence the eventual risks will be evaluated in case the species can spread without being managed.

According to the requirements, the following sections will also be discussed in this report:

1. Risk assessment:
   - 1a Probability of introduction;
   - 1b Probability of establishment;
   - 1c Probability of spreading;
   - 1d Vulnerable areas;
   - 1e Impact;
   - 1f Risk assessment score (according to the ISEIA and the Bomford method).
2. Risk management:
   - 2a Prevention;
   - 2b Eradication;
   - 2c Management.

In order to gain insight in these above-mentioned areas of interest, a literature review was conducted and experts and locally involved parties were consulted.

1.2 Methods

The risk analysis relied to a large extent on the consultation of scientific, peer-reviewed publications. This was mainly done through *ISI Web of Science*, but other non-peer reviewed published material of Dutch and foreign origin was also consulted.

Egyptian Goose numbers and trends in The Netherlands were analyzed based on data provided by SOVON, Netherlands:

- Breeding Bird Monitoring Project (BMP) from 1990 to 2008;
- Waterfowl census from 1975 to 2008;
- Point Transect Counts (PTT) from 1983 to 2008;
- Data of a nation wide special goose survey in July 2009.

In addition, the distribution maps were also realized based on data provided by SOVON, Bird Census The Netherlands.

Information on Egyptian Goose numbers outside The Netherlands was collected from published sources and for the most recent figures by personal communication with local experts.

Statistical analyses were done using Microsoft Excel and Statistica 8.0. (Statsoft Inc.).

1.3 Structure of the report

Chapter 1 provides an introduction, inclusive information on the goals, the terms of reference and the methods used. In chapter 2, an extensive overview of the current knowledge of the biology and ecology of the Egyptian Goose is given. Chapter 3 illustrates the development of the non-native populations established in Europe, the emphasis being on the situation in The Netherlands. Besides relying on the information presented in chapter 2 and chapter 3, expert judgement was used to formulate the risk analysis and risk management possibilities presented in chapter 4. Finally, the conclusions and recommendations are provided in chapter 5 and the list of literature used in chapter 6.

2 Biology and ecology

2.1 Introduction

The Egyptian Goose *Alopochen aegyptiaca* L. belongs to the family *Anatidae* (swans, geese and ducks) and the subfamily *Tadorninae* (shelducks, South American geese and relatives). Recently, the scientific name of the species has been adjusted from *Alopochen aegyptiacus* (Sangster *et al.* 2003). Its two closest relatives, the Mauritius Shelduck A*lopochen mauritianus* and the Reunion Shelduck *Alopochen kervazoi* are extinct, likely due to heavy hunting (Del Hoyo *et al.* 1992*)*. Its closest relatives also occurring in The Netherlands are the Common Shelduck *Tadorna tadorna* and the Ruddy Shelduck *Tadorna ferruginea*; the latter is considered to be an introduced species but also occurs in a wild state in Europe (Lensink 1996).

According to contemporary eye-witnesses, the Egyptian Goose was some centuries ago a naturally occurring species in Southeast-Europe up to Hungary (Schenk 1918; Brehm 1927; Cramp & Simmons 1978), but for unknown reasons disappeared from this region. It got introduced later to Northwest-Europe due to its ornamental features. It is a conspicuous, large, rather long-legged, goose-like duck species. Most distinctive is its chestnut eye-patch and patch on lower breast (Cramp & Simmons 1978). The legs and the bill are pink. In flight the characteristic white fore-wings are clearly visible. Sexes are similar but female is marginally smaller with less pronounced head colours and breast patch (Cramp & Simmons 1978). No seasonal plumage differences occur, only a swelling at base of bill during the breeding season. Juvenile and immature are distinctive from adults. Swims well and will also dive readily, but lives mainly on land, and walks easily if sedately. Often perches and roosts on trees and other prominences. Its flight is strong and fast, though with relatively slow wing-beats, recalling goose rather than duck. Unlike true geese, (*Anser* and *Branta* species), flies freely within and over forests.

In its natural range (Western, Eastern and Southern Africa of approximately 17.500.000 km^2), the Egyptian Goose is a widespread species (Brown *et al.* 1982) (Fig. 2.1). The population in West Africa has been estimated at 10.000-20.000 birds (Scott & Rose 1996) with diminishing numbers (Gore 1990; Elgood *et al.* 1994). In East and South-Africa the population is estimated at 205.000-510.000 individuals, increasing rapidly in numbers (i.e. more than 10% increase per year on average) (Banks *et al.* 2008). It is categorized as a species with “least concern” by Birdlife International (2009). The European introduced population was estimated at around 10.000 breeding pairs in 2007 (Banks *et al.* 2008).

2.2 Biology and ecology

2.2.1 Distribution

The Egyptian Goose originates from Africa, breeds nowadays at mainly sub-tropical regions south of the Sahara up to and including the Upper-Nile area in Egypt (Brown *et al.* 1982), but as winter visitor may occur as north as Cairo in Egypt (Goodman *et al.* 1989) (Fig. 2.1). Until the end of the 17th century, early 18th century, the northern distribution range reached into Algeria, Tunisia, Turkey, the western part of the Middle-East and even southern Hungary in Europe (Schenk 1918; Brehm 1927), but for unknown reasons disappeared from these areas (Cramp & Simmons 1978). Lately, the species became scarcer in the northern Nile Valley but has largely increased in southern Africa (especially in South-Africa), due to intensified irrigation schemes (Blair *et al.* 2000).

Already in the 17th century, the species was introduced as an ornamental bird to parks in East-England, and soon after escaped birds established wild populations around Norfolk (Sutherland & Allport 1991). Since 1979, the population extended its range to Essex, since 1982 to Somerset and since 1988 to Cambridgeshire and Suffolk (Gibbons *et al.* 1993). Similar introductions occurred in The Netherlands in the surroundings of The Hague and Groningen and in the 1970's near Brussels in Belgium. In The Netherlands, the first registered case of breeding by escaped individuals in natural areas dates from 1967 in The Hague (Teixeira 1979) and from 1980 in Groningen (Lensink 1996, 1998). Populations breeding in the wild and originating from these two sites spread north and south, respectively, and reached each other around 1994 near Zwolle. In Belgium, breeding in the wild started in 1982, and around 1998 the spreading Belgian population reached the Dutch border (Anselin 2004). Nowadays, the breeding range of introduced Egyptian Geese in Northwest-Europe also extends to Denmark, Germany, Switzerland and North-France. Until the first escapes of Egyptian Goose in the Netherlands, no birds were observed here in the wild, suggesting that there were no vagrant individuals of the English population occurring on the European mainland. Newly established ringing programs in The Netherlands could verify whether there is still no exchange between the two introduced populations.

Egyptian Goose has been introduced to the United Arab Emirates (1976, now breeding between Dubai and Bahrein) and the United States (in different states breeding in the wild expected, in Florida documented) (Blair *et al.* 2000; Braun 2004).

The species is largely sedentary in its natural range, and seasonal nomadic or dispersal movements are related to water availability (rainfall). In addition, after the breeding period, annual migrations to moulting sites also occur (Del Hoyo *et al.* 1992). Normally, individuals occur solitary or in pairs, but during moulting in large aggregations of hundreds, eventually thousands of birds both in the introduced and native range (Gerritsen 2001; Kear 2005). In Europe, such aggregations also occur in winter.

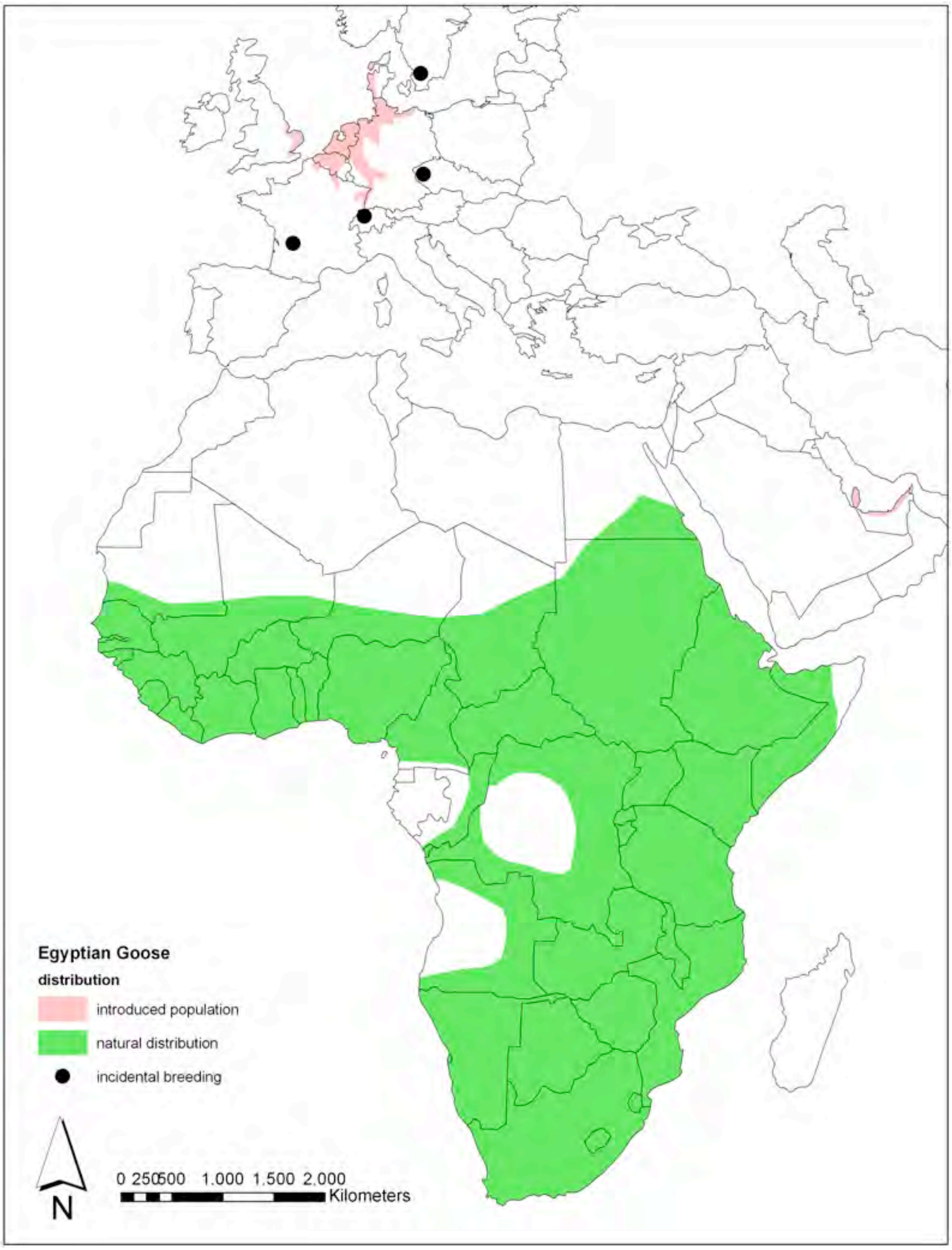


Figure 2.1 *Current distribution of the Egyptian Goose; natural and introduced populations (Brown* et al. *1982, Banks* et al. *2008, this report).*

In The Netherlands, the Egyptian Goose is mainly resident, although outside the breeding period dispersal occurs op to hundreds of kilometres away from the breeding area (Lensink 1999a). In its original range, longer distances are also recorded, especially before the moulting season: based on ringing recoveries, the medium distance of these moves was more than 200 km, and the maximum 1.164 km, mainly induced by rainfall in relation to food availability (Maclean 1997).

- *The Egyptian Goose is a generalist species. It has a large geographic distribution range and is largely sedentary. Based on evidence from the past, the species has a high colonization and dispersion potential. Large aggregations occur mainly during moulting and to a lesser extend also in winter.*

2.2.2 Breeding biology

Breeding habitat
Breeding starts at the age of two (Lensink 1996) and partners are chosen for life. Flocks often consist of small family groups. Pairs are well dispersed, each maintaining relatively large, discrete territory of variable size (in open water situation *c.* 1 ha), which is used for feeding, courtship, mating, and nesting, occasionally for pair-formation. This latter, however, normally occurs in flocks. Families share large waters, each tending to remain within its own territory (pers. comm. W.R. Siegfried).

Nesting site
The Egyptian Goose is well-known for its wide range of preferred nesting sites e.g. under vegetation, in cliffs and caves (Harrison 1978), but usually not far (several hundred meters up to one kilometre) from water (Pitman 1963). Nests are built exclusively by females and may be found in a wide variety of locations but most commonly in trees, old nests of other birds, tree cavities (van Dijk 1997; Lensink 1998; van Dijk 2000). In the dune areas in The Netherlands usually Magpie *Pica pica* and Carrion Crow *Corvus corone* nests are used, as well as self-made nests (i.e. shallow depression in plant matter) on the ground (especially on islands and peaty areas) or in trees, whereas in the eastern part of the country Buzzard *Buteo buteo* and Goshawk *Accipiter gentilis* nests are often used (Lensink 1998). Interestingly, nest boxes of Kestrels *Falco tinnunculus* and Tawny Owls *Strix aluco* are also preferred (Lensink 1996). In addition, man-made constructions, such as church towers and water towers (of up to 50m high in a Peregrine Falcon *Falco peregrinus* nest (van Dijk 1997) or poles for White Stork *Ciconia ciconia* nests are also occasionally used as nest sites (van Dijk & Hoek 1989; Lensink 1993).

Breeding behaviour
In its natural range, egg laying may occur throughout the year (Maclean 1997), but mainly concentrates at the spring period or at the end of the dry season (Del Hoyo *et al.* 1992). The Dutch population has a breeding season of six months (Lensink 1999a), but can basically breed throughout the year if environmental conditions are favourable. Nevertheless, the bulk of the population is breeding from April to June: egg-laying starts usually in the second half of March until the end of May, but occasionally already in February or at the latest at the end of August (Lensink 1996, 1999a). In urban environments, breeding also occurs in November-January, with youngsters as early as December (pers. comm. F. Majoor).

The average clutch size is 6,7 eggs (with a range of 5-11 eggs) in its native home range, South-Africa (Maclean 1993). In The Netherlands, mean clutch size is higher, i.e. 7-8 eggs, with a maximum of 16 (Lensink 2002).The incubation time is 28-30 days, conducted exclusively by females (Cramp & Simmons 1978; Maclean 1997). Eggs are creamy white of colour and are rounded at both ends with an average size of 68,4 × 51,3 mm (ranging 57,9-75,8 × 46,0-57,7) in South-Africa (Maclean 1993), and slightly larger in The Netherlands: 70,2 × 51,9 (63,5-79,8 × 44,3-55,5) (R. Lensink, unpubl. data). The weight of the eggs is on average 98 g (with a range of 78,5 – 110) (Maclean 1993).

Young
The onset of incubation is positively related to the severity of the winter (Lensink 1999a). Most young hatch between the end of April and the beginning of July (Lensink 1999a). In The Netherlands, breeding success was measured to be on average 40% and positively correlated with the severity of the winter and along the rivers negatively with the number of flooding days (Lensink 1998) . Both parents guard the young, which fledge at approximately 55 days (Maclean 1997). In The Netherlands, an average successful breeding pair can raise 5,25 ± 2,05 chicks in the area of the larger rivers but only 3,8 ± 1,9 in the dune area (Lensink 1999a). The mortality among young birds (non-fledged) is 20% in riparian areas and 15% in the dune area (Lensink 1996). In England and Africa breeding success is lower (Eltringham 1974; Sutherland & Allport 1991), underlining the rapid increase of the species in The Netherlands.

Breeding couples with offspring stay at, or in the vicinity of, the breeding sites till autumn, others gather in large groups in June-August at moulting sites, which are usually large water bodies with an open shoreline (Halse 1984; Lensink 1999a). Moult lasts approximately 40 days (Halse 1984), after which the groups break up usually in August-September (Lensink 1996). Family bonds are maintained throughout the pre-fledging period and afterwards for at least 6 weeks. Juveniles tend to associate in groups within non-breeding summer flocks (pers. comm. W.R. Siegfried).

Survival
Based on an analysis carried out on data of a local population in The Netherlands (Arnhem) in the period 1999-2010, Van der Jeugd & Majoor (2010) estimated the annual survival of Egyptian Goose for three age classes. For adults, this resulted in an annual survival rate of 83%, comparable to other many other goose species. The survival rate for 2^{end} calendar year birds was 71,8%, whereas for juveniles only 41%. Dry summers negatively influenced survival of Egyptian Geese: the amount of summer rainfall was positively correlated to the survival of both adult and young animals, likely by promoting grass growth, and hence the abundance of food (Van der Jeugd & Majoor 2010). Those figures seems to be un underestimation of the survival rate (especially for young), due to the exceptional situation in the Arnhem (see Appendix 1 for explanation).

- *Egyptian Geese have a wide range of breeding habitats and nesting sites but mostly build nests in trees or holes. The species has a higher breeding success in The Netherlands than in their original home range or in England. Severe winters negatively affect numbers, but positively the breeding success. A survival analysis of marked birds revealed that dry summers negatively affect survival rates.*

2.2.3 Habitat, diet and feeding behaviour

The species occurs in a wide range of habitats, with a requirement for nearby freshwater (i.e. reservoirs, dams, pans, lakes, ponds, rivers, channels, marshes, sewage works and estuaries) (Del Hoyo *et al.* 1992). It is generally absent from coastal regions (Brown *et al.* 1982). Most typically it is found in areas (of up to 4.000 m) with a combination of water bodies with an open shoreline and meadows, often with a few trees (Del Hoyo *et al.* 1992). It feeds commonly at meadows and flees to water. It generally avoids densely forested areas (Del Hoyo *et al.* 1992). Introduced populations along the coast of United Arab Emirates mainly breed in mangroves because suitable nesting sites are lacking more inland. Egyptian Geese in England are mainly found around ornamental waters in parklands and in managed aquatic and riparian habitats, such as alder-willow swamp woodlands, pastures, and meadows (pers. comm. B. Sage). In The Netherlands, the species is mainly found in wet dune valleys, pools, lakes, streams and canals in the western part, usually in river floodplains, whereas creeks, channels, gravel and sand pits, pools and ponds in wet heather *Erica* fields provide suitable habitats in the sandy areas (Lensink 1996). In the urban environment it breeds in and around city parks and at other green landscape elements with water bodies.

The Egyptian Goose is mainly herbivorous. In its diet preference it can be regarded as a generalist: it may rely purely on grass, but its diet is adjusted to the locally available sources and may vary from aquatic plants (i.e. algae, leaves, stems and seeds of e.g. pondweed *Potamogeton* species) to agricultural crops: corn and sunflower seeds or germinating wheat and barley in the autumn (Halse 1984). It is also recorded to forage on oats, lucerne, groundnuts and barley fields (Kear 2005), as well as potatoes (Del Hoyo *et al.* 1992). Occasionally, it may consume animal matter, such as worms, locusts and termite alates (Kear 2005). In The Netherlands, the species mainly feeds on grasslands and in arable areas also on grain.

Both in its native range and in Europe, the Egyptian Goose feeds mainly terrestrially, by grazing in pairs, family parties, and large(r) flocks (Maclean 1997). In The Netherlands, Egyptian Geese are almost exclusively observed to feed on grasslands, which tendency is also typical for birds in England (63% of observed birds in the period 1987-1997 was grazing on pastures; pers. comm. A. Bloomfield). Especially with young or during the moulting period, birds stay at foraging sites adjacent to water bodies. However, as birds are still able to fly in this period, these sites may be a few kilometres from the water (Gerritsen 2001).

In South-Africa, the birds seem to prefer to feed on the food source with the highest metabolizable energy content and the lowest fibre content when given the choice (Halse 1984). On these easy to digest food sources, Egyptian Goose require no more than 4,5 hours foraging per day, with feeding intensity peaks early in the morning, around noon and in the evening. Most of the birds spend the rest of the day with sleeping on the shore (Halse 1985). When feeding on grass, a food source which is more difficult to digest due to the high fibre content, geese may need much more time spent with foraging per day (approximately 50-64%; pers. comm. A. Bloomfield).

- *The Egyptian Goose easily adapts to a wide range of habitats. They are mainly herbivorous with a broad preference. In The Netherlands they mainly forage on grasslands.*

2.2.4 Predators, diseases and other causes of death

In its natural range, the most important predators are lions *Panthera leo*, cheetahs *Acinonyx jubatus*, hyenas (subfamily *Hyaeninae*), crocodiles (genus *Crocodylus*) and raptors (family *Accipitridae*). In Europe the risk of natural predation of adult birds is small (e.g., red foxes *Vulpes vulpes* (Lensink 1998)) but nest predation by Carrion crows and small mammals may reach high levels (Havekes & Hoogkamer 2008).

In South-Africa, an outbreak of H5N2 avian influenza at an ostrich farm was related to contact with Egyptian Geese (Thompson *et al.* 2008). In Israel, Egyptian Geese were shown to be the first species of the order Anseriformes to carry the avian paramyxovirus, serotype 3 (Shihmanter *et al.* 1998).

In its natural range, Egyptian Geese numbers are reported to decline with increasing winter and spring rainfall (Harebottle *et al.* 2008). In contrast, the survival of Egyptian geese in The Netherlands was positively related to summer rainfall. This difference could be explained by the herbivorous feeding habit of Egyptian Geese. In The Netherlands, the species mainly relies on grass consumption, and hence dependent on the growth of grass. Winter or spring floods and dry summers may inhibit grass growth and therefore negatively influence the available amount and quality of food for the geese. This may affect the survival of both young and adult birds (Van der Jeugd & Majoor 2010).

In addition, severe winters may reduce population size, although the species is capable of compensation by extending its breeding season, while density-dependent regulation leads to higher breeding success after such winters (Lensink 1999a).

- *In The Netherlands, the species has few natural enemies. Environmental conditions (e.g. rainfall, severity of winter) can negatively affect numbers but due to density-dependent regulation breeding success may increase afterwards.*

2.2.5 History as a pest species

Recently, the South-African population has increased dramatically, which causes considerable damage on agricultural fields, especially around water bodies used for moulting (Maclean 1993). Especially, a lot of damage is reported to young wheat, but Egyptian Geese seemed to prefer surface seeds to growing plants (Mangnall & Crowe 2002). Here, barley and wheat farmers regard Egyptian Geese as a serious agricultural pest (Mangnall & Crowe 2001). In two years, the mean annual yield loss was estimated to be 64,5%. Fields within a distance of 600 m of the roosting sites of the geese had the highest losses, especially on crops less than 25 cm tall. Above this height the birds seemed to behave uneasy perhaps because of the limited view for predators (Mangnall & Crowe 2002). In addition to actual consumption, the trampling effect of a large number of geese can also cause substantial damage to young, sprouting plants, which may be unable to recover (Mangnall & Crowe 2002). On the other hand, a short period of grazing (less than four days) may encourage plant growth (Kear 1970). So far, in Europe no such records of agricultural damage are available, but facts are lacking. Recently, farmers have begin to express their worries if larger flocks of Egyptian geese appear on their grassland.

In The Netherlands crop damage is registered by the Faunafonds, but only for native and protected species (such as Greylag Goose, White-fronted Goose and Brent Goose), and not for non-native, unprotected species (such as Egyptian Goose, Indian Goose). However, these latter are also registered if they accompany the damage by protected species. This amount is only a small part of the total damage caused by the Egyptian Goose but from those figures it is clear that their damage increases in The Netherlands, concerning euros as well as hectares (Fig. 2.2).

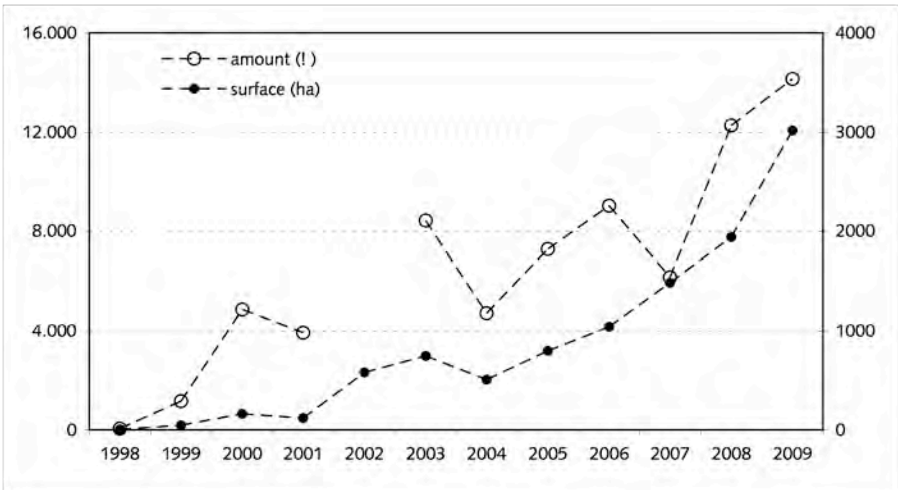


Figure 2.2 *Crop damage by the Egyptian Goose in The Netherlands 1998-2009 (*data *Faunafonds).* NB *only if the damage was part of damage by protected species. In 2002 insufficient data on euros.*

Most of the crop damage was noted in grasslands. This pattern was even more pronounced in area (ha) than in the amount of money. Nevertheless, from those figures it is clear the Egyptian geese are herbivorous, mainly feed on grassland and does not deny other green matter (Tab 2.1).

A large number of geese could also cause problems by defecating on public roads, public footpaths, public bike paths and standing waters (Beck *et al.* 2002).

As the species is mainly resident in the Northwest-Europe, extensive movements are not common. Therefore, flocks can stay for longer periods in the vicinity of airports. Around Schiphol Amsterdam Airport and Rotterdam Airport, the species became more numerous in de previous decade and control measures are taken (Lensink *et al.* 2003; Lensink *et al.* 2010).

Table 2.2 *Crop damage by Egyptian goose in The Netherlands 1998-2009.* NB *only if the damage was part of damage by protected species; this is only a small part of the total damage by this species).*

	costs (€)	hectares	costs (€) (%)	hectares (%)
winter grain	7.944	285		
summer grain	765	19		
corn	2.602	47		
others	3.363	114		
arable land	14.674	465	17,2	4,5
sown grassland	334	31		
grassland	69.685	9.909		
grass seed	548	24		
grassland	70.567	9.964	82,8	95,5

- *In South Africa the species is locally becoming a serious pest species to crop farmers. In The Netherlands, conflicts with farming interests and flight safety on airports are currently increasing.*

3 Established introduced populations

The introduced populations of Egyptian Geese occurring in Northwest-Europe originate from four main sources: birds escaped from parks in East Anglia (England), in The Hague and in Groningen (The Netherlands) and in Brussels (Belgium). Escapes at other locations (e.g., Germany) are not excluded. The population in England has grown slowly since their establishment more than 300 years ago, whereas on the mainland of Europe a rapid exponential growth was achieved shortly after the first breeding. Exponential growth is typical for populations of invasive alien species in newly colonized areas. Thereafter, often a period of little or no increase occurs (Lensink 1999a). In this chapter the development of the introduced populations in Europe is described.

3.1 The Netherlands

The highest breeding density (at least ten pairs up till more than 25 per 100 hectares) occurs in the Lower Netherlands and along the larger rivers. In the Northern and Western parts of The Netherlands as well in Flevoland the breeding density of the species is lower, likely due to the presence of large-scale agricultural areas with fewer waterbodies, trees and grass meadows. Generally, Pleistocene soils are experienced as lower quality breeding habitat for Egyptian Geese (Lensink 2002). In newly colonised areas, the breeding success is much higher (i.e. 60-70% of nests successful, from which an average of 4,5 chicks are raised), compared to established populations (i.e. 15-30% of nests successful, from which an average of 4,5 chicks are raised) (Lensink 1996). The expansion of the breeding range had an average speed of 3,0 km per year until 1994 (Lensink 1998); which continued in the following years (Lensink 2002).

3.1.1 Breeding population

Distribution

The colonisation of The Netherlands started in 1967. Currently, the whole country has been colonized, due to the exponential growth and a constant speed of the colonisation front. The following historical moments in the colonization process are documented (Lensink 1996, 2002).

<u>1967: 1 pair</u>

Individuals escaped from parks in Rijswijk and Wassenaar bred for the first time successfully close to The Hague (Tirion 1969).

<u>1977: 48 pairs</u>

Mainly concentrated around The Hague and Leiden. First successful breeding along the Waal in the eastern part of the country (Brouwer *et al.* 1983).

<u>1981</u>

Start of a second colonisation kernel in Groningen (Lensink 1996).

<u>1989: 345 pairs</u>
The colonization of the Delta-region started. By this time registered as breeding species along the rivers IJssel, Rhine, Waal and Meuse.

<u>1998-2000: 4500-5000 pairs</u>
By this time also the whole eastern and northern part of The Netherlands, as well as the Wadden Sea islands were colonized. The first Dutch birds meet their Belgian relatives on the border of the two countries. Further spread into Germany (Rhine, Eems).

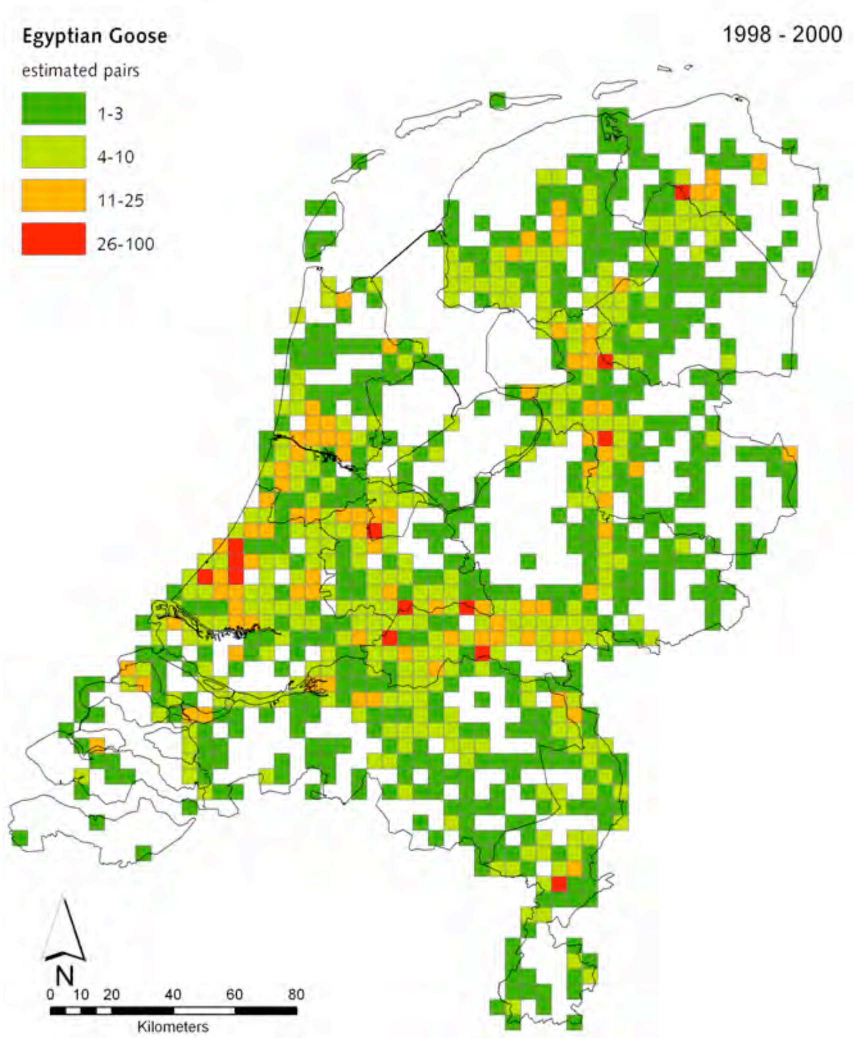


Figure 3.1 *Breeding distribution of Egyptian Goose in 1998-2000 (Source: Atlas of breeding birds, SOVON 2002).*

The most recent and complete distribution of breeding birds is available from the period 1998-2000 (Lensink 2002, Fig. 3.1). In those years, the species was found breeding in 61% of the 1.660 atlas squares (5x5 km) of The Netherlands. In recent years, the colonisation has continued. Exact data are lacking but the available evidence suggests colonisation of all squares with a suitable habitat. Nonetheless, in these squares the numbers can still increase for many years. The species is also a regular breeder in the urban environment. However, it is absent in heavily forested areas such as the Veluwe and the Achterhoek or in Twenthe and Brabant where water bodies are virtually absent, as well as in the open clay polders in the north and southwest without any tree or water.

The highest densities of breeding birds are noted in the cities of The Hague and Haarlem, in peat meadow areas in the lower parts of the country and along the larger rivers (>5 p/100 ha). In agricultural grassland areas densities are 1-5 p/100 ha; elsewhere <1 p/100 ha.

Numbers

The last complete estimate based on a nation wide census of breeding pairs dates from 1998-2000. The total estimated number was over 4.900 pairs (Lensink 2002), and hence the breeding population in 2000 was approximately 4.500-5.000 pairs (Table 3.1). The number of breeding pairs in 2009 was derived in two ways, both based on the number of birds counted in 2000:

- based on the annual increase in the number of breeding pairs according to the breeding bird census, rate of increase calculated per province (Estimate 1 in Table 3.1);
- based on the annual increase of bird number in the nationwide waterfowl census, i.e. 8,8% (Estimate 2 in Table 3.1; see § 3.1.2).

According to these two calculations, the number of breeding pairs can be estimated at 9.400-10.500 in 2009. Data on the number of breeding birds could be used to build a realistic population model in which the number of culled birds was taken into account (Lensink *et al.* 2010). In recent years, the Royal Netherlands Shooting Association (KNJV) organized spring-counts of geese in the Netherlands within census-areas. These data are independent from those by SOVON. Knowing the proportion of sub-adult en adult birds at the beginning of the breeding season, the numbers counted by the KNJV could also be translated into an estimated number of 11.621 breeding pairs in 2008. The similarity between both estimations is strikingly good (Fig. 3.2). The only dissimilarity occurs by the province Noord-Brabant. Here the estimated number of pairs based on the KNJV figures is twice as high as derived from SOVON figures. The SOVON estimation for 2009 is derived form observed numbers in 1998-2000, whereas the KNJV estimation is derived from field-data in 2008. Between 2000 and 2009 Noord-Brabant was colonised from two sides: from the North (The Netherlands) and from the South (Belgium), possibly explaining the substantially higher increase. A second possibility might be a bias in the KNJV census (double counts). Therefore the best estimate for 2008 from the KNJV data is 10.500-11.500 pairs.

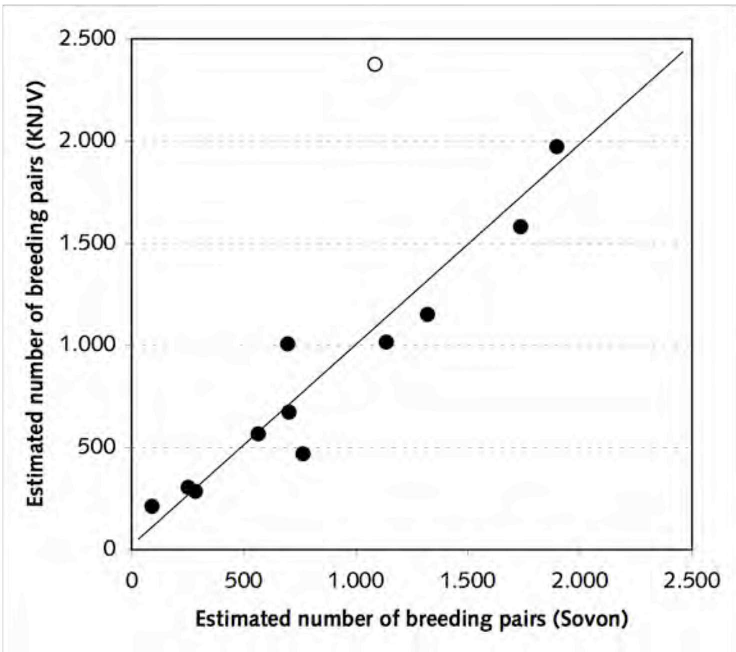


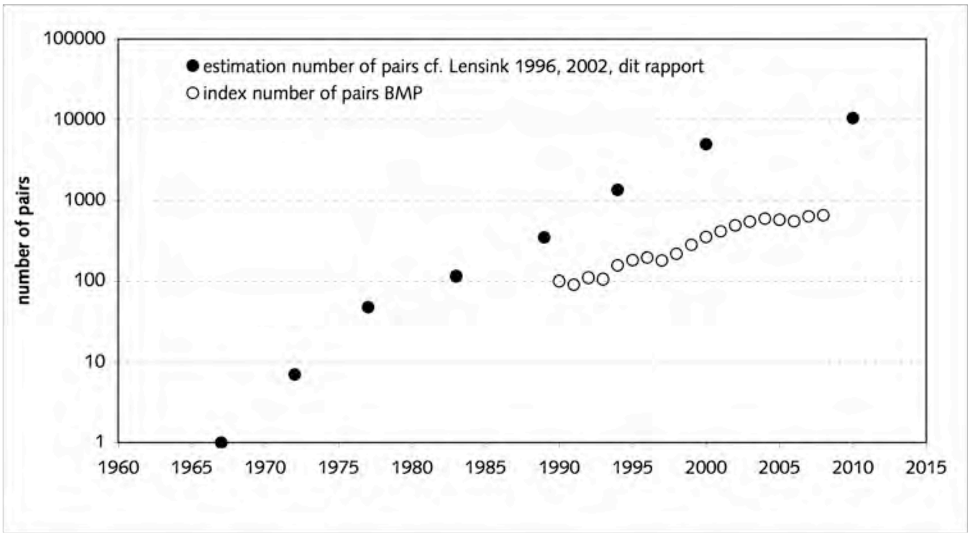
Figure 3.2 *Estimation of the number of breeding pairs in The Netherlands per province based on SOVON data (breeding bird census BMP; Table 3.1) and KNJV data (April count by Game Management Units; WBE's). Open dot = Noord-Brabant. line gives x = y.*

Table 3.1 *Number of breeding pairs per province in 1967-2009 in The Netherlands (data from Lensink 1996, 2002, this report). The rate of increase 2000-2009 derived from the breeding bird census (BMP) provided estimate 1. Estimate 2 is derived from the waterfowl census.*

	1967	1972	1977	1983	1989	1994	2000	% increase 2000-09	2009 estimate 1	2009 estimate 2
Groningen	0	0	0	0	10	28	133	10,3	322	284
Friesland	0	0	0	0	2	55	359	4,9	553	765
Drenthe	0	0	0	1	11	46	265	14,9	925	565
Overijssel	0	0	0	4	16	105	534	4,8	814	1.137
Gelderland	0	0	2	15	70	365	815	4	1.160	1.736
Utrecht	0	0	0	5	27	104	326	6,7	585	695
Flevoland	0	0	0	0	1	6	43	8,8	91	91
Noord Holland	0	0	3	16	59	190	620	11,8	1.691	1.320
Zuid Holland	1	7	43	72	128	290	891	6,4	1.557	1.897
Zeeland	0	0	0	0	1	10	119	5	184	253
Noord Brabant	0	0	0	2	19	60	510	7,3	961	1.086
Limburg	0	0	0	0	1	45	330	6,5	582	703
totaal	1	7	48	115	345	1.345	4.944	7,0	9.425	10.532

Trend

Based on nationwide estimates (Lensink 1996, 2002), the breeding population has shown a general strong increase (i.e. 28.2% per year) in The Netherlands between 1967 and 1999 (Fig. 3.3). However, the rate of increase slowed down: in the period 1989-1999 it amounted to 12.1%, very similar to the rate of increase based on the breeding bird census (BMP) indexes for the same period (i.e. 12.7%; Fig. 3.3). These



latter indexes reveal that the increase further slowed down between 2000 and 2008 to 7% per year (Fig. 3.3), probably due to density-dependent effects and the increasing culling effort.

Figure 3.3 *Development of the breeding population in The Netherlands between 1967 and 2008, based on nationwide counts or estimates of breeding pairs (Lensink 1996, 2002, this report; filled dots) and indexes from the breeding bird census (BMP; open dots).*

Between 1990 and 2008, breeding populations in only two (i.e. the dunes exclusive on the Wadden Sea islands and the marsh areas around the large rivers) of 13 physical-geographical regions increased moderately (on average 6%), all the others strongly (on average 17%). The population achieved the largest increase in the areas: 1) dunes and tidal areas on Wadden Sea islands and the northern marine clay salt marshes, and 2) high sandy areas in the North (Table 3.2), probably due to the later colonization of these areas, and hence a population still in the exponential growth phase.

Concentrating on the population development in the last ten years according to physical-geographical regions results in strong increases in only four cases (compared with 11, see above): 1) dunes and tidal areas at the Wadden Sea islands, and the northern marine clay salt marshes, 2) high sandy areas in the North, 3) high sandy areas in the middle and southern part of the country, 4) the marshy fen areas. The increase was slower in three of these cases (on average 10.7% compared with 17% between 1990 and 2008). Interestingly, however, the population in the dunes and tidal areas and the northern marine clay salt marshes grew even faster in the last ten years (Table 3.2), suggesting that these regions are still in the colonization phase. Seven regions showed only a slight increase in the last ten years, implying that nearly all the suitable breeding sites were occupied by 1999.

Table 3.2 *Growth of the breeding population (in percentages) per physical-geographical regions for the periods 1990-2008 and 1999-2008. For comparison, the country average is also provided. Data from the breeding bird census BMP.*

Area	Growth 1990-2008	Growth 1999-2008
Netherlands	12,8%	7,0%
Dunes excl. Wadden Sea islands	4,9%	7,7%
Dunes and tidal areas Wadden Sea islands, Northern marine clay salt marshes	25,9%	33,3%
High sandy areas North	22,1%	11,7%
High sandy areas Middle, South	13,9%	9,4%
Marshy fens Holland	15,0%	11,1%
Fens in agricultural areas	15,0%	4,4%
Marshy fens North	15,0%	0,2%
Agricultural areas in riparian areas	9,4%	0,3%
Marshes in riparian areas	6,2%	0,3%
Agricultural areas on marine clay Middle, North	18,5%	0,4%
Marshes on marine clay Middle, North	18,5%	0,5%
Agricultural areas on marine clay South	13,9%	0,6%
Marshes on marine clay South	17,4%	0,4%

Categorization according to the provinces clearly shows that in newly colonized provinces the increase of the population is high, i.e. on average 34% but gradually decreases in the decades after (Table 3.3). The highest increase was reached in the province of Friesland between 1989 and 2000 (i.e. 53,9%), which slowed down to 1,7% in the following decade. This demonstrates how fast the species can colonize a new area and reach saturation of the suitable breeding sites inhibiting further population growth (Table 3.3). The generally slowing rate of increase in the breeding population in the last decade is also obvious in this provincial division. Numbers since 1999 showed a strong increase only in Drenthe (11,0%), Noord-Holland (10,3%) and Groningen (10,2%) but even these figures are lower than in the preceding period (Table 3.3).

In the period 1977-1989, the rate of increase on the national scale was low compared to the period before and thereafter (Table 3.3). In these years, four severe winters occurred (1978/79, 1984/85, 1985/86, 1986/87), which could have a negative impact on the number of birds (see § 3.1.2). Remarkably, in this period the rate of increase slowed down the most in the province Zuid-Holland, which held most of the breeding pairs. Likely the start of local culling efforts played an important role in this phenomenon (see § 3.1.5).

Relying only on the available data of the breeding bird census (BMP), no differences could be detected between severe and mild winters in the rate of increase of breeding bird numbers directly following the winter nor a year later (in order to control for eventual delayed effects). However, within the period that breeding bird data were available, only three severe winters occurred, probably providing a too low sample size to detect any significant winter effects.

Table 3.3 *Growth rate of the breeding population (%/year) per province for the period 1967-2009. For comparison, the country average is also provided. Data 1967-1999 from Lensink 1996, 2002, data 2000-2009 from breeding bird census (BMP, see also Table 3.1).*

	1967-1977	1977-1989	1989-2000	2000-2009	until 1999
Groningen	0,0	49,1	25,6	10,2	32,4
Friesland	0,0	20,1	53,9	1,7	44,1
Drenthe	0,0	23,0	32,6	11,0	28,5
Overijssel	0,0	26,6	36,6	5,5	31,4
Gelderland	24,6	30,2	24,5	4,4	28,5
Utrecht	0,0	32,0	24,9	2,1	28,9
Flevoland	0,0	11,8	32,3	5,6	25,2
Noord-Holland	32,0	25,3	23,6	10,3	25,6
Zuid-Holland	36,2	9,4	19,3	6,5	18,6
Zeeland	0,0	12,2	45,2	2,9	33,1
Noord-Brabant	0,0	28,4	34,5	6,2	31,2
Limburg	0,0	12,2	58,4	4,7	43,9
total The Netherlands	37,7	17,7	27,3	7,0	28,2

- *The breeding population of Egyptian Geese has increased since 1967, more rapidly before 2000 and more slowly thereafter, reaching an estimated size of approximately 10.000 breeding pairs in 2009. The species has likely colonized much of the suitable habitats in the lower part of The Netherlands but further growth of the breeding population is expected in the lower and the higher parts of the country.*

3.1.2 Non-breeding population

Distribution

Based on data from the nationwide waterfowl census in the winter season, large concentrations occur in the lower parts of the country including the riparian areas (figure 3.4). The distribution remained between 2000 and 2009 more or less the same, although overall numbers have increased.

Comparing the number of breeding pairs and the number of birds in January based on a division of physical-geographical regions, the similarity between the number of breeding pairs in 2000 and numbers in January 2000 is striking (Fig 3.5), suggesting that the distribution of birds in the winter reflects the distribution of the breeding birds. Breeding bird numbers account for number of pairs (adults only) whereas a winter census s account for the number of birds ((sub-)adults). This implies that despite showing similar proportional distributions, the number of individuals counted during the winter in a specific region does not directly translate into the number of breeding pairs in their breeding area. Conducting a similar comparison for the waterfowl census in January 2000 and January 2009 also resulted in a good match (Fig. 3.5), suggesting that the relative distribution within this period remained similar. The largest differences occurred in regions with reasonably small numbers.

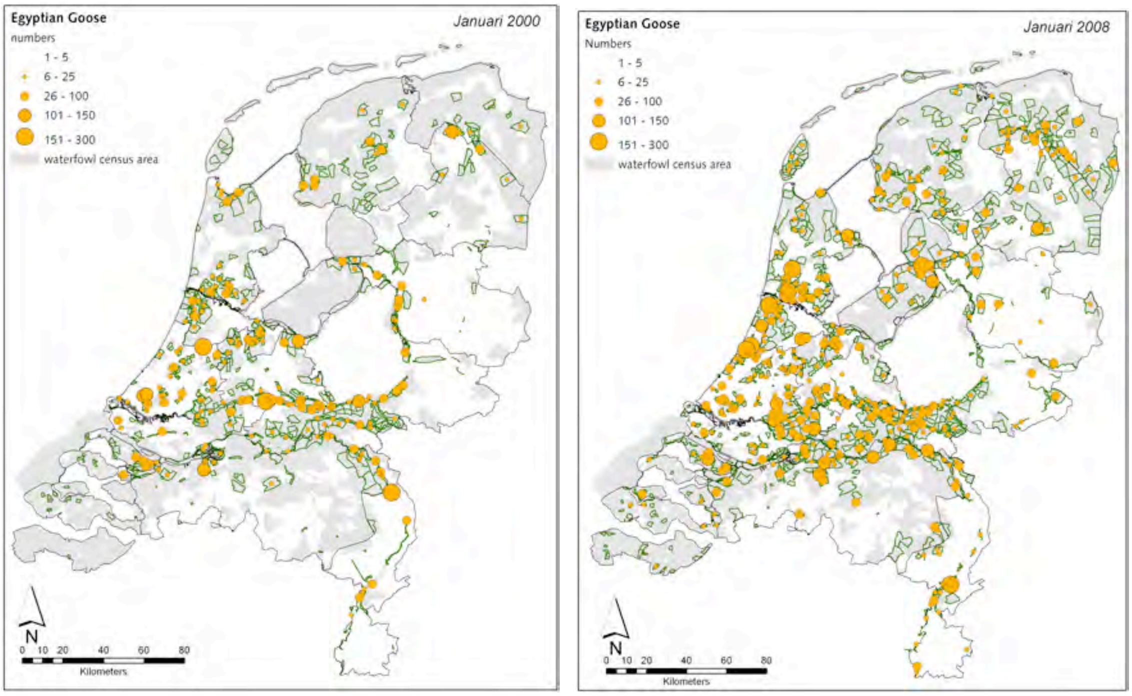
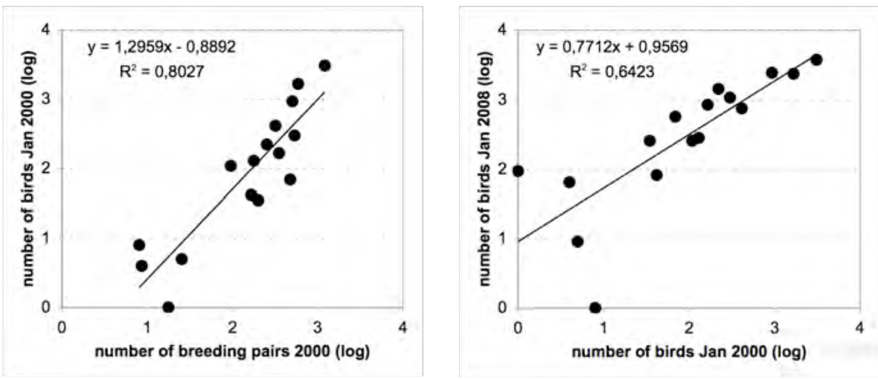


Figure 3.4 Distribution of the Egyptian Goose in The Netherlands in January 2000 (left) and 2008 (right). Census areas in grey and areas with positive observations are marked green.



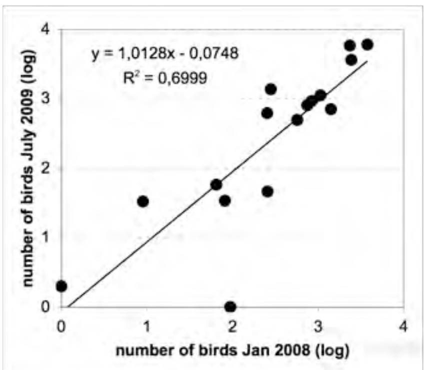


Figure 3.5 Comparison of the number of Egyptian Geese in The Netherlands in January 2000, January 2008, July 2009 and breeding pairs in 1998-2000 16 physical – geographical regions. Source: Atlas of breeding birds (SOVON 2002) and Waterfowl census (SOVON).

In July 2009, a special goose survey was carried out in The Netherlands. The distribution detected during this survey (Fig. 3.6) highly reflects that of January 2008 (Fig. 3.5 right panel). However, the largest concentrations in July 2009 were found along the rivers, suggesting that birds move from breeding grounds without extensive wetlands to moult there.

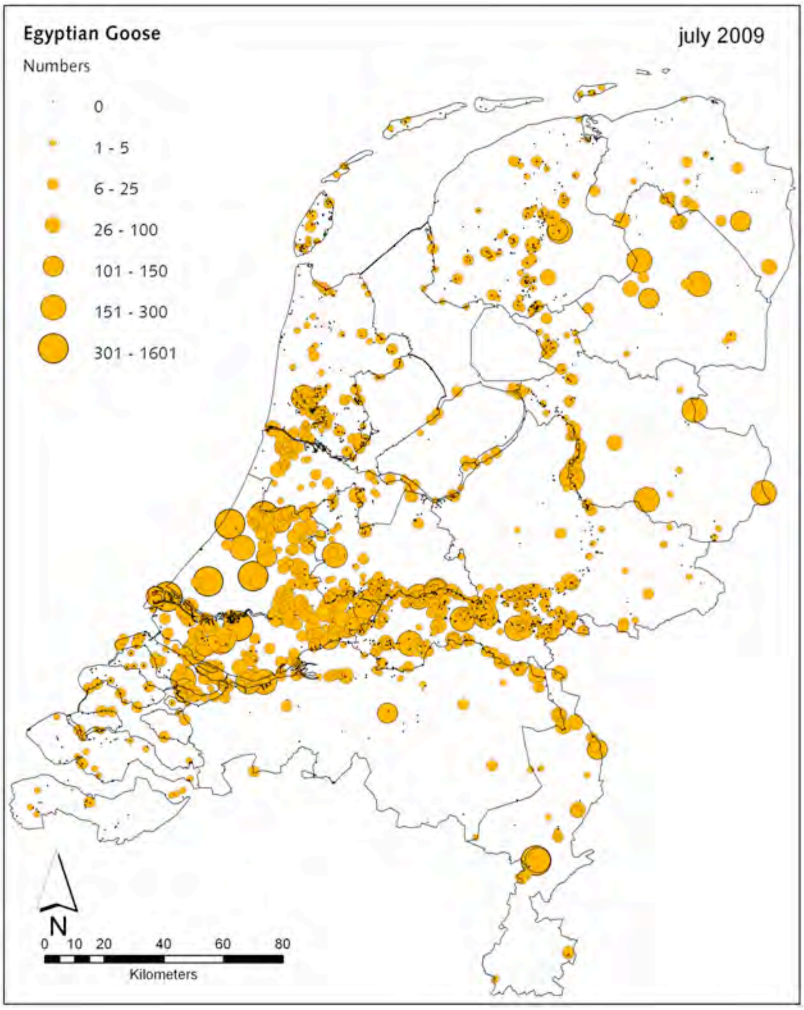


Figure 3.6 *Distribution of Egyptian Goose in The Netherlands in July 2009 (*Data *goose survey SOVON).*

Numbers

Recently, the highest number of Egyptian Geese was reported in September 2007 of 27.595 individuals. In January 2008, more than 14.000 Egyptian Geese were counted, whereas in July 2009 nearly 22.000 individuals. In both cases, large numbers were seen in the lower parts of the country, especially in Zuid-Holland (Table 3.4). The question is to what extent these figures reflect the real size of the population. Based on the breeding bird census (BMP), the breeding population in 2009 was estimated at about 10.000 pairs (Table 3.1). The age classes can be derived from the stable age-distribution resulting from the survival rates of different age classes (Table 3.6). After the breeding season (July) about 65% of the population concerns breeding adults, 37% first-year juveniles (matrix in Table 3.6). With this in mind, the total Dutch population can be estimated in July 2009 at around 50.000 individuals, suggesting that about half of the population has not been detected during the July 2009 survey. A possible reason might be that the urban environment was hardly covered by the census in 2009, although important numbers can be found there (Randstad or Ring City). In addition, lots of solitary pairs could have been missed in the higher parts of the country. This latter is also suggested by the larger variation in the smaller-size populations in Fig. 3.5.

Table 3.4 *Number of Egyptian goose (individuals) in July 2009 (*Data *National goose survey, SOVON).*

	Number observed
Groningen	316
Friesland	735
Drenthe	803
Overijssel	1.213
Gelderland	2.898
Utrecht	1.103
Flevoland	31
Noord Holland	1.506
Zuid Holland	10.078
Zeeland	259
Noord Brabant	1.818
Limburg	1.069
totaal	21.829

Trend

Based on the water bird counts organized by SOVON, taking place from September to April, the number of Egyptian Geese grew considerably (i.e. on average 33%) between 1976 and 2007 (Table 3.5; Fig. 3.7). Splitting the dataset to the initial and final years of this period, reveals that the growth has slowed down: between 1976 and 1987 the growth was 40,1% compared with 10,7% in the period 1999-2007. The growth of the non-breeding population has been much faster than of the breeding population (see § 3.1.1). Likely, this is caused by the saturation of suitable breeding sites, which hampered the further increase of the number of breeding pairs, but the non-breeding fraction of the population could temporarily still grow further.

Looking at the non-breeding population separately in the lower and higher parts of The Netherlands revealed that both populations showed an exponential growth (Fig. 3.8), although the absolute numbers are more than ten times higher in the lower parts of the country (Table 3.5). Considering only the large population in these lower parts, numbers on marine-clay soils showed the most considerable increase, while in the riparian areas relatively the smallest (Table 3.5), probably due to the completion of the colonization process.

Table 3.5 *Rate of increase (%/year) among non-breeding birds in 1976-2007, based on the sum of counted numbers in the period September-April (seasonal total); data waterfowl census (SOVON). For comparison the absolute figures for December 2007 are also provided. 1976 is 1976/77, all rates at p<0,01.*

	1976-1987	1988-1999	1999-2007	1976-2007	2007
Netherlands	40,1	40,6	10,3	33,0	13386
Higher areas (=sandy soils)	43,0	35,2	14,0	37,6	1144
Lower areas	37,3	41,2	10,0	32,9	12242
Dunes	50,1	22,1	17,1	35,9	194
Fens	49,3	39,4	14,8	37,4	2813
Riparian regions	36,3	37,1	6,8	29,9	5544
Marine clay	38,6	54,2	10,9	38,4	3690

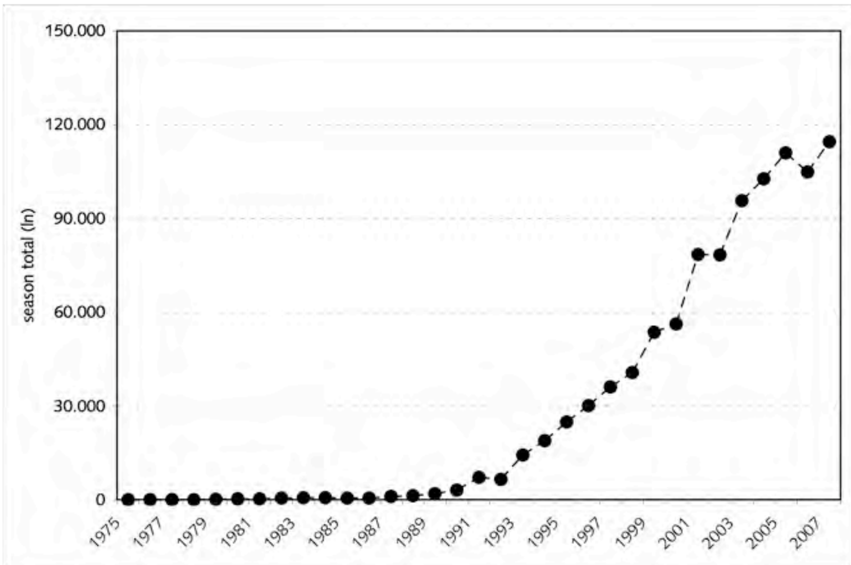


Figure 3.7 *Development of the yearly number of Egyptian Geese based on the Waterfowl censuses of the period 1976-2007, seasonal total (= sum of Sept-Apr).*

The within year variation in the waterfowl counts shows the highest numbers in September, followed by a sharp decreasing trend until January (dropping to approximately half of the numbers in September), and thereafter remaining roughly stable or with a slight decrease until March (Fig. 3.9). This tendency is mainly caused by numerical changes in the populations found in the lower parts of The Netherlands, as numbers in the higher parts, although following the same trend, show less considerable changes throughout the year (Fig. 3.10). However, if a large proportion of the population is not detected during counts (see above under section *Numbers*), the decrease during the autumn (when food limitation is of no substantial level) may be clarified by the spreading of individuals from moulting sites to areas not covered by the counts. This hypothesis is also supported by the smaller numerical differences in the higher parts of the Netherlands, where the population size is generally lower.

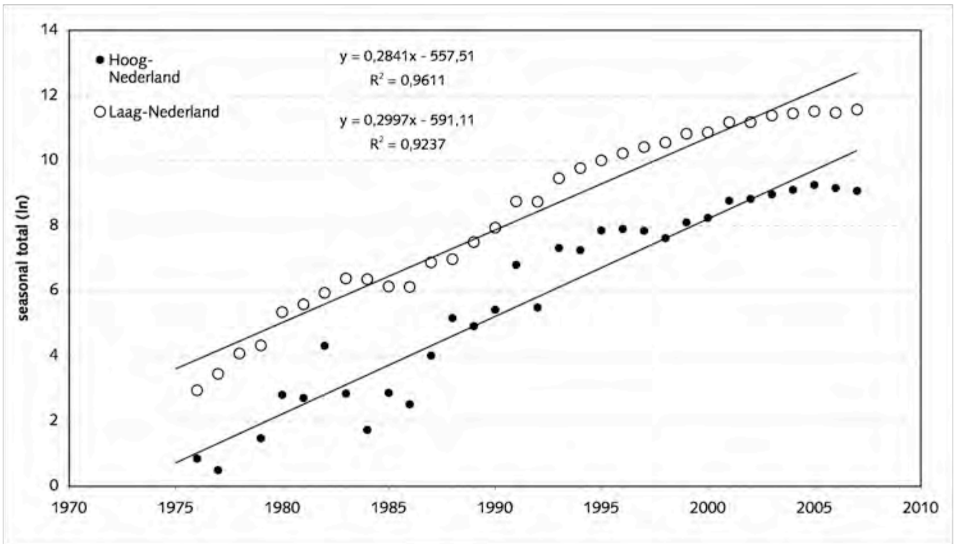


Figure 3.8 *Number of Egyptian Geese counted in different regions per year during waterfowl counts in the period 1976-2007 divided into the higher parts (filled symbols) and lower parts (open symbols) of The Netherlands.*

According to an analysis conducted by Van der Jeugd & Majoor (2010) the amount of summer rainfall significantly affects Egyptian Geese survival (Fig. 3.11). However, this is not directly visible in the number of birds registered during waterfowl censuses. Between 1999 and 2008 (i.e. the period of historic meteorological data availability of the Royal Netherlands Meteorological Institute; KNMI), the amount of summer rainfall did not significantly correlate with the yearly changes in Egyptian Goose numbers (R^2 = 0,07; p = 0,5). Within this period, numbers decreased only from the winter of 2001/02 to 2002/03 and from 2005/06 to 2006/07, whereas dry summers occurred in 2000 and 2003. In fact, 2006 experienced the second most rainfall in that period. Likely, these large-scale rainfall averages and nationwide waterfowl counts mask the effect of drought periods on a small scale, as described by the report of Van der Jeugd & Majoor (2010).

Based on the waterbird counts, the effect of winter severity on Egyptian Goose numbers was also tested. Effects on the yearly population development could not be detected in the period 1975 – 2008: neither by a linear correlation between the winter severity index of IJnsen and changes in the yearly average number of counted birds (R^2 = 0,01; p = 0,58), nor by an ANOVA analysis where winters with severity index above 30 were categorized as severe (n=7) and below 10 as mild (n=15) (F = 0,26; p =0,61). For the years 1975/76 -1998/99, effects of the severity of the winters on the rate of increase are obvious (Lensink 1996, 1998, figure 3.9). In the years there after, such effects are lacking and the correlation is decreasing sharply by adding one or more years into the regression. The years after 1999 stand for an increasing culling pressure where this impact was lacking in the years before

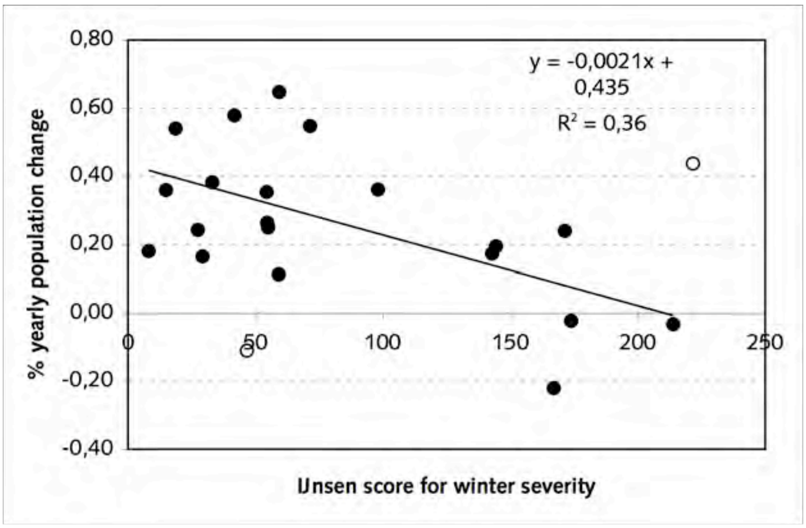


Figure 3.9 *Relation 1977/78 – 1998/99 between the severity of the winter (IJnsen score) and the yearly population change (%). Two years are excluded (outliers) from the regression; 1978/79, 1992/93 (open dots).*

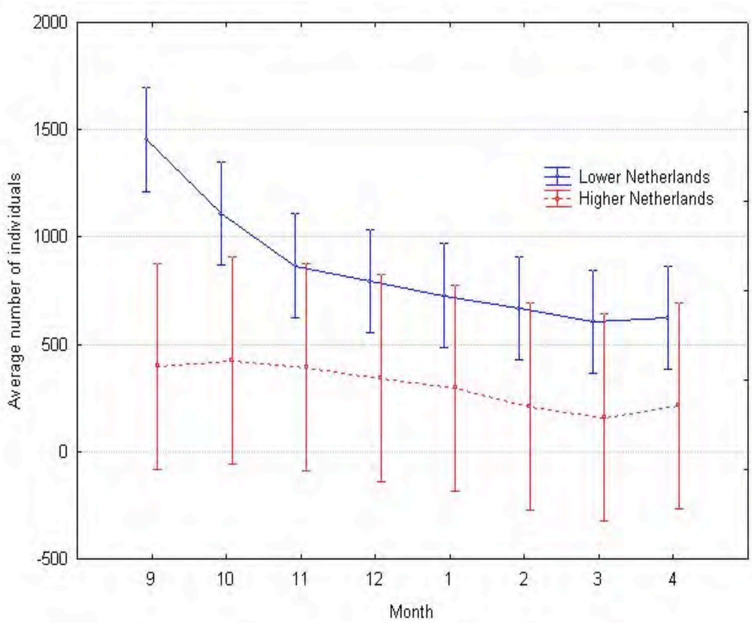


Figure 3.10 *Average number of individuals counted in different regions per month during water bird counts in the period 1975-2008 divided into Lower and Higher Netherlands. Bars refer to 95% confidence intervals.*

Furthermore, a within winter mortality analysis does suggest that Egyptian Geese are sensitive to the severity of winter (data 1975-2007). For this purpose, the average number of individuals counted in November-December and the average number of individuals in January-February was ln-transformed to reach normality and compared between severe and mild winters with a one-way ANOVA analysis. These periods are indicated to have the largest coverage and to contain the least imputed numbers, and hence considered to be the most reliable. The analysis with winter severity as categorical factor revealed that the number of Egyptian Geese show a significantly stronger decrease during severe winters than during mild winters ($F_{1,20}$=9,58; p<0,01). Based on back-transformed data, it is visible in Fig. 3.12 that in severe winters the mean number of individuals in November-December is more than double (approximately 220%) of that in January-February. On the contrary, in mild winters the numbers decrease with only less than 30% (Fig. 3.12). A more detailed analysis revealed that this effect is mainly caused by changes in the riparian regions, as the decrease in numbers on sandy areas was not significant. In fact, this tendency seems to be comparable to the general numerical changes during autumn and winter, and hence, besides mortality, may also be related to more intense spreading of individuals on the available foraging areas in severe winters.

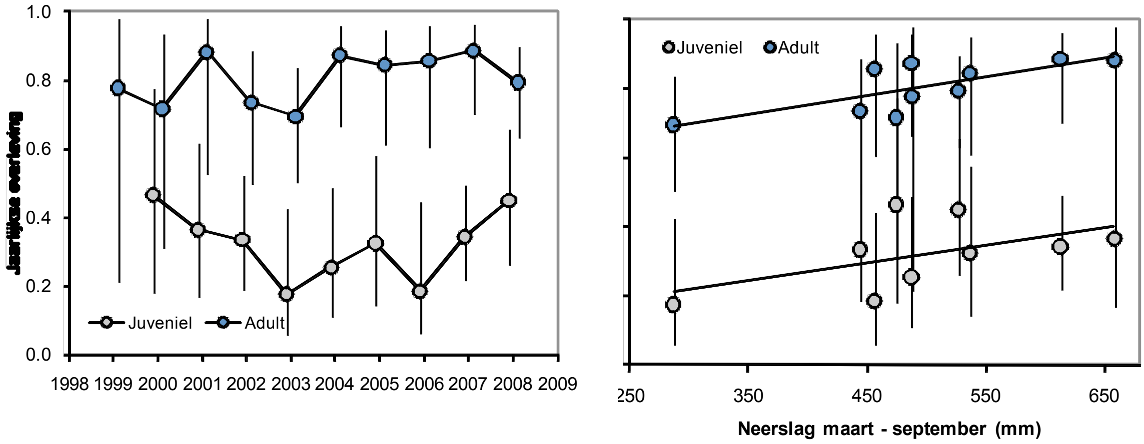


Figure 3.11 Survival of young (until the first summer) and adult (after the first summer) (left) and their relation to the amount of summer rainfall (in mm, right) (Figures from Van der Jeugd & Majoor 2010).

- *The total population of Egyptian Geese in July 2009 could be estimated at approximately 50.000 individuals. The mean population growth since 1967 amounts to 33%, but in the last ten years only to 10%. Summer rainfall and winter severity seem to directly affect survival and numbers. The distribution in the breeding period and in the winter is similar.*

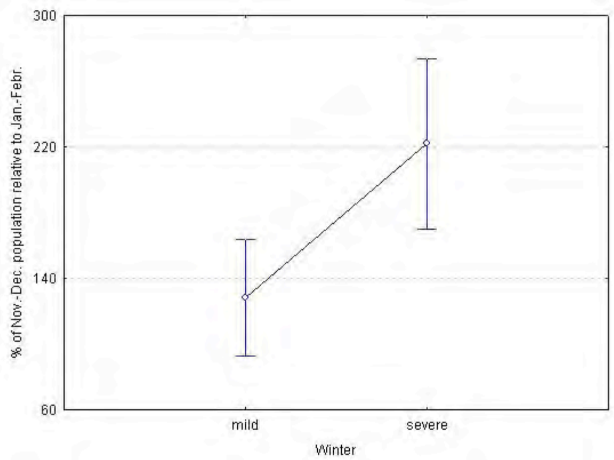


Figure 3.12 Back-transformed proportion of Egyptian Geese during November-December relative to January-February in mild and severe winters in the period 1975-2008 (Bars refer to 95% confidence intervals).

3.1.3 Movements

The high R^2 values (i.e. 0,93, 0,98 and 0,96) of the correlations between the three types of nationwide SOVON indexes relying on counts conducted in different periods of the year (e.g. waterbird counts in the winter period, breeding bird counts in the breeding season) in the period 1990-2008 suggest that Egyptian Geese are not moving large distances (Fig. 3.13). This is in line with the findings of Lensink (1996) concluding that the species does not conduct regular, directed migration in The Netherlands and that only smaller movements occur outside the breeding season. Another study specifically focusing on movements of Egyptian Geese came to the same conclusions (Lensink 1999b): Egyptian Geese behave as resident birds in The Netherlands, with no obvious migration direction. Only local movements were observed, mainly after the finish of the primary moult (i.e. moult migration) and the dispersion of breeding birds and their young (Lensink 1999b). However, recent studies on the movements of ringed individuals revealed that birds from Belgium and Germany are occasionally resighted in The Netherlands.

3.1.4 Habitat

Since Egyptian Goose mainly feed on grass and less on other food sources, it is expected that they concentrate in grassland areas. Analyzing the data from the waterfowl censuses conducted in January 2000 and 2008 revealed that grassland is the dominant habitat type in census areas where more than 50 Egyptian geese were observed (Fig. 3.14). In census areas with no geese, only one third of the surface is grassland. On the contrary, the proportion of arable land decreases as the number of geese is increasing in the census areas.

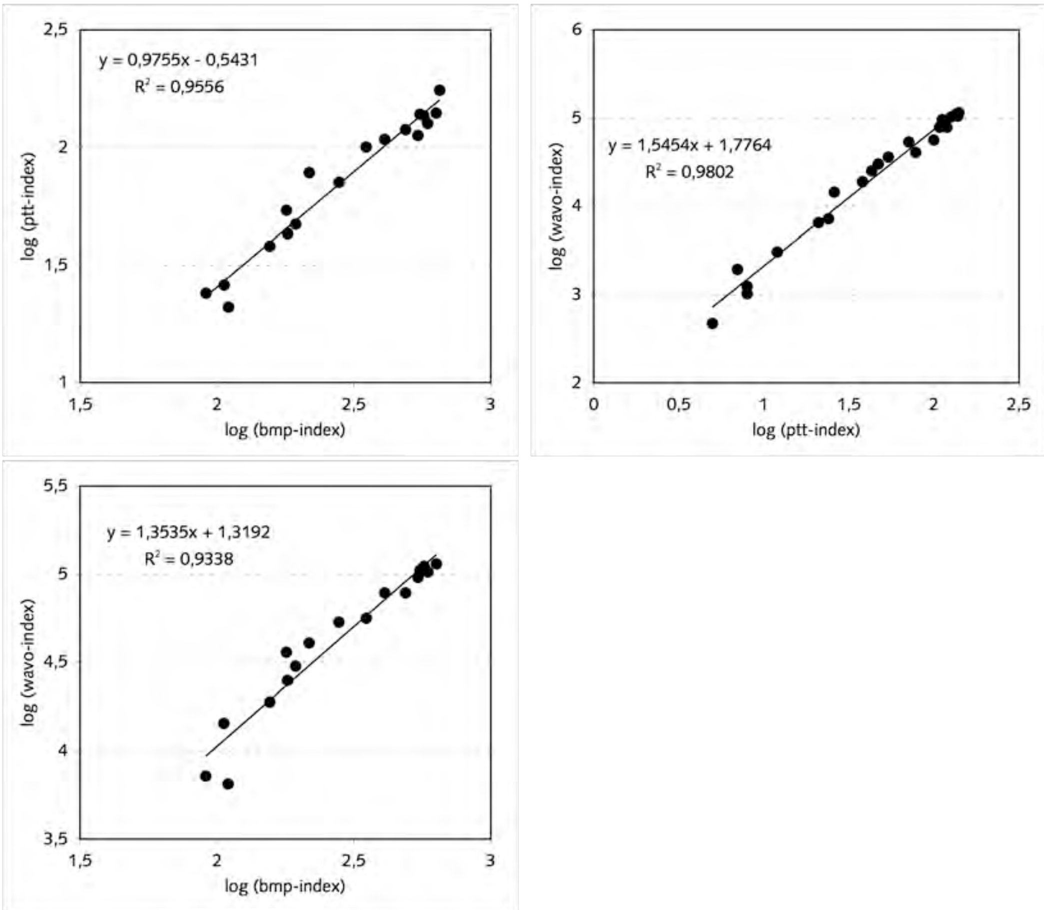


Figure 3.13 Correlations between the three types of SOVON counts (i.e. wavo = water bird census, bmp = breeding bird census and ptt = point-transect counts). Dots represent nationwide yearly indexes; 1990-2008.

3.1.5 Regulation of numbers

In the previous paragraphs some elements in the regulation of numbers have passed by:

- mortality in relation to the severity of the winter;
- mortality in relation to food abundance and quality in summer (rainfall);
- food availability in winter in relation to number of flooding days along the rivers;
- culling mortality.

These factors have limited the population growth in the past decades. It is evitable in all datasets that since 2000 the increase in numbers has slowed down (Tabel 3.1, 3.3). This might be caused by density dependent factors limiting further growth (Newton 1998), and/or an external factor such as increasing culling pressure. The Egyptian Goose is an invasive alien species in The Netherlands, and thus is not protected by law. Since 2002, culling of the species (with a rifle) is only possible with a permit under article 67 of the Flora and Faunawet. Before 2002 shooting was possible under specific conditions. The numbers shot are registered on a local scale (by Game Management Units), and consequently put into a national database (KNJV). The number of shot birds has gradually increased in the past ten years (Fig. 3.15). In 2007/2008 nearly 20.000 geese have been shot in the Netherlands, equal to 1.5 geese per 100 ha. However, especially in the early years of the central registration, not every Game Management Unit sent their data to the national database of the KNJV. In the province Zuid-Holland the absolute numbers shot are fairly well known (Lensink *et al.* 2010). Here, culling started halfway the nineties. From 2000 onwards registration was nearly complete: the numbers shot showed a rapid increase in the early years but flattened recently (Fig. 3.15).

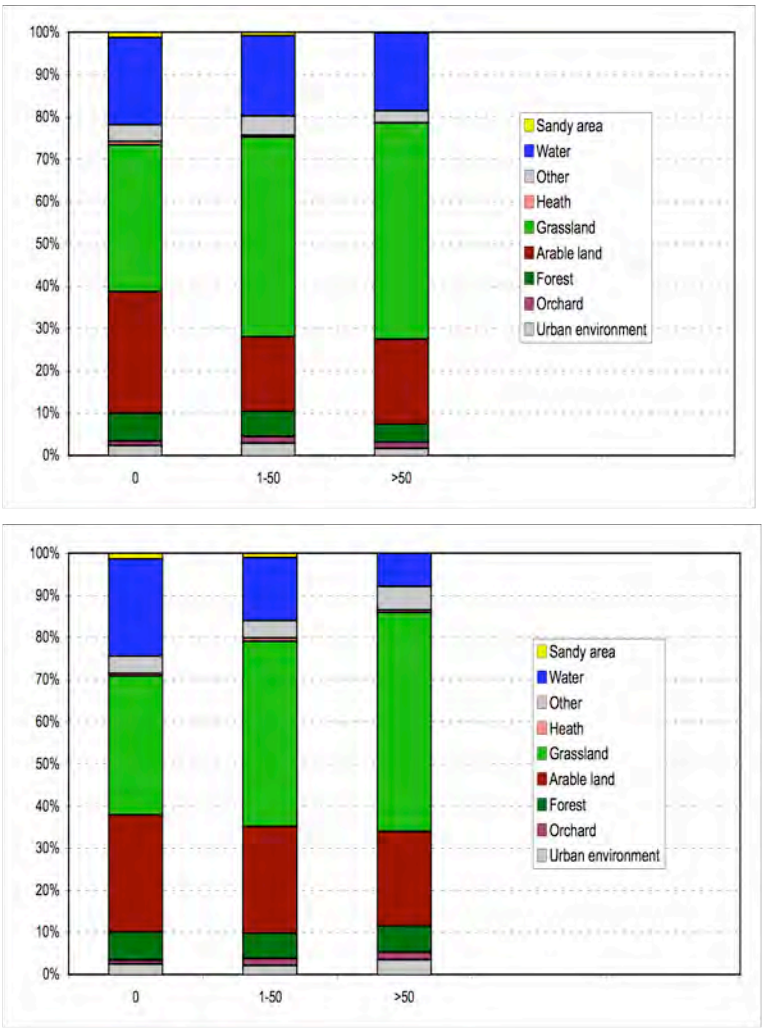


Figure 3.14 Proportion of grassland and other habitat types in waterfowl census areas where 0, 1-50 or >50 Egyptian geese were observed in January 2000 (upper panel) and January 2008 (lower panel).

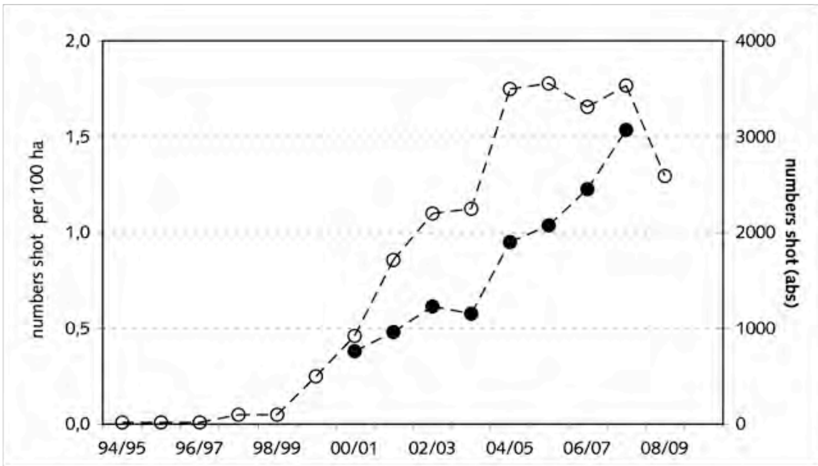


Figure 3.15 *The number of Egyptian goose shot, a relative figure for The Netherlands in 2000-2008 (filled symbols ; data KNJV) and an absolute figure for Zuid-Holland in 1994-2009 (open symbols; data from Lensink et al. 2010).*

In order to evaluate the impact of culling, a Leslie-matrix of a population was used where hunting is at a negligible level (Table 3.6). Accounting for the culling presented in fig. 3.15, the number of breeding pairs in the province of Zuid-Holland was modelled to increase between 1998 and 2009 from 950 pairs to 2.250 pairs, while the estimated total number of birds at the end of the breeding season from 6.100 to 14.400 individuals (Lensink *et al.* 2010). In reality, the estimated size of the breeding population in 1998 was 880 pairs, whereas the numbers observed in July 2007-2009 varied between 11.300 and 14.200 individuals (Fig. 3.16). Depending on the exact numbers shot, the population seems to level off or only slowly increase. According to the model results, without culling the total number of birds in Zuid-Holland would have increased since 1995 to 9.550 breeding pairs and 50.000 birds (July) in 2009 (Lensink *et al.* 2010); the latter under the assumption of continuous unlimited or exponential growth (Fig. 3.16).

Table 3.6 *Vital population parameters used to model the effect of shooting in a Leslie - matrix. See appendix 1 for further details.*

	1Y	2Y	>2Y
F	0	0,731	0,731
S 1Y	0,7	0	0
S 2Y, >2Y	0	0,85	0,85

Based on the results of Zuid-Holland, the impact of culling on a national scale was also modelled. First the population development was calculated under de condition of continuous exponential growth (Fig 3.16). Secondly, the numbers culled were extracted from the calculated population size. Since not every bird shot, would have survived until next year, culling figures were taken for 45%.

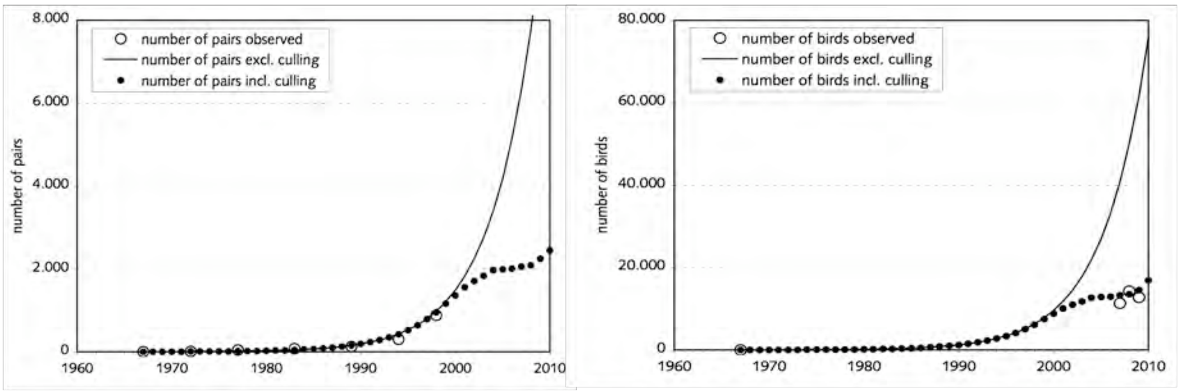


Figure 3.16 Population development in Zuid-Holland according to modelling (solid line, closed dots) and observed bird numbers (open dots). In the left panel the number of pairs is depicted, in the right panel the number of birds (after Lensink et al. *2010).*

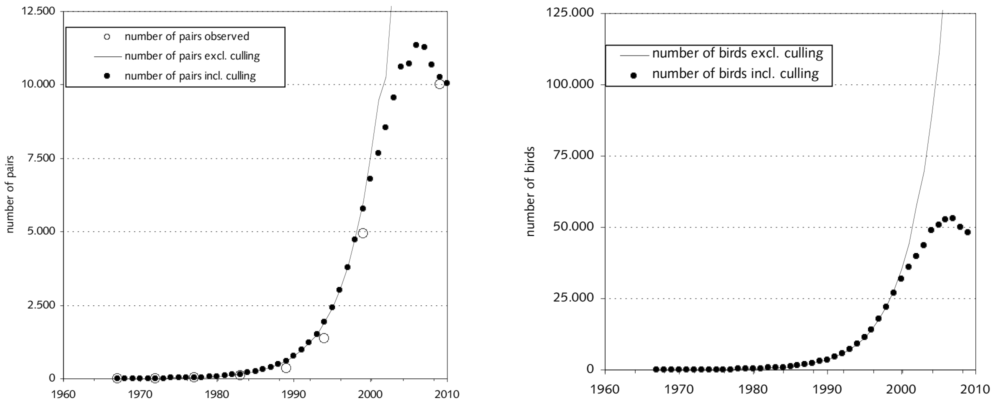


Figure 3.17 Population development in The Netherlands according to modelling (solid line, closed dots) and observed bird numbers (open dots). In the left panel the number of pairs is depicted, in the right panel the number of birds.

In 1999 the size of the breeding population in The Netherlands was estimated at 4.950 pairs. The intensity of culling increased in the subsequent years (Fig. 3.15), leading to an estimated number of breeding pairs of about 10.000 in 2009 (Table 3.1). Based on the model results, the recent size of the population on the national scale seems to be more or less stable at 10.000 breeding pairs, i.e. around 50.000 individuals in July (Fig. 3.17). In order to reach this stable population level, the culling has to be around 27% of the population size in July. Without culling since the nineties, the total numbers would have increased up to 60.000 breeding pairs, i.e. 280.000 birds in July 2009 (under ongoing exponential growth, matrix in Tab 3.6). Based on Habitat Suitability Indices (Appendix 2) the total breeding population for The Netherlands is calculated at a maximum of 28.000 pairs.

3.2 England

The first introduced population of Egyptian Geese was established in England already in the 17th century, limited to East Anglia, mainly in the county of Norfolk. After the initial growth, the population remained stable of approximately 400-500 birds (Sutherland & Allport 1991). At the end of the 1990's the population approximately doubled (Gibbons *et al.* 1993) and spread further in England (Lensink 1996). Nowadays, there is another population in Suffolk (Gibbons *et al.* 1993), with smaller numbers in other areas (Holling 2007) and a limited spread westwards (Fig. 3.16). According to the latest estimates, there are 700 birds breeding in England and at least 1.000 wintering (RSPB website 2009) but due to the patchy reporting of breeding Egyptian Geese in England these figures could be underestimates and the real size of the breeding population could be much higher (i.e. 2.500-3.000 individuals) (Banks *et al.* 2008). Since September 2009, the Egyptian Goose is on the list of species (i.e. general licence of species) that can be legally shot without a special permission (RSPB website 2009). Currently, the GB Non-Native Species Secretariat is working on a risk analysis of the Egyptian Goose (NNSS website 2010).

3.3 Belgium

In the Belgium, the first successful breeding in a park in Brussels dates from 1972 (Devillers 1988). Wild populations of Egyptian Geese are registered since 1982 (Lensink 1996), which reached 50-100 pairs by 1989-91 (Anselin & Devos 1994) and 100-150 pairs by 1994 (Lensink 1999a). In 2000, the population was estimated at 300-450 pairs (pers. comm. A. Anselin, D. Vangeluwe) and reached 800-1.100 breeding pairs by 2007 (Banks *et al.* 2008) and the population is still increasing its breeding range, especially in the western and central part of the country (Fig. 3.16) where it was rather scarce before (pers. comm. A. Anselin). In Belgium all exotic species, inclusive the Egyptian Goose, are allowed to be culled without any specific permit.

3.4 Germany

In Germany breeding of free-living birds started in 1986 along the river Rhine, around Munster originating from the introduced population in The Netherlands (Lensink 1996). In 1994, there were in total 5-8 pairs recorded to breed (Lensink 1998). In 2000, breeding was recorded as far south as Karlsruhe. The latter are probably propagules of an independent group of introduced breeders near Frankfurt in the nineties. In the north successively started breeding along the rivers Eems (1992), Weser and Elbe, reaching Kiel around 2000 (Fig. 3.16). In that year, the population was estimated around 350-650 pairs (Hüppeler 2000), but reached an estimated 2.000 pairs by 2005 (Banks *et al.* 2008) and is 2.200-2.600 pairs according to the latest records (Südbeck *et al*. 2007). According to an act accepted in October 2005, it is allowed to shoot Egyptian Goose in Germany between 1 August and 15 January.

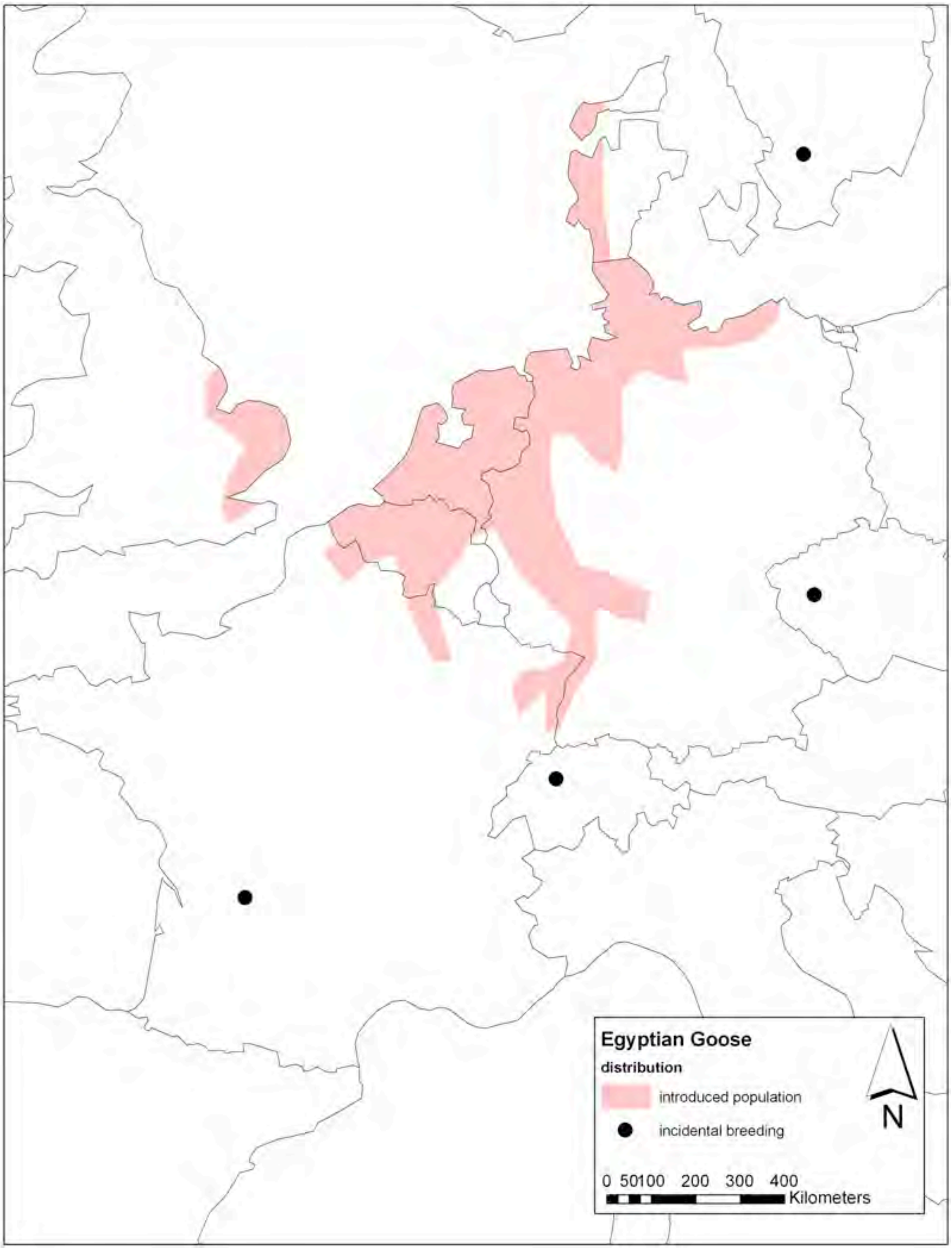


Figure 3.16 *The distribution of introduced Egyptian Goose populations in Europe (Banks* et al. *2008, this report).*

3.5 Elsewhere

3.5.1 In Europe

In France, the first breeding occurred in 1995, and by 2000 5 pairs were known to breed. In 2006, the population size was estimated at 210-235 individuals, with 23 breeding pairs (Banks *et al.* 2007). This population originates from Belgium, and mainly concentrates in the northeast, but birds are seen as far south as Lyon. In the northeast, the number of birds is strongly increasing and the species is starting to be widespread in new places elsewhere (Fig. 3.16). In 2009, a breeding pair with young was observed 80 km west of Brive (pers. obs. R. Lensink). No regulation measures are planned at the national scale but some regional applications for eradication (by culling adult birds) have been sent to the Ministry of Environment (pers. comm. C. Fouque and V. Schricke).

In Denmark, the Egyptian Goose was observed for the first time in 1987, whereas the first breeding occasion was registered in 2000. Since that year, the species has bred yearly in Denmark (pers. comm. V. Knudsen). In 2007, at least 20 pairs were breeding in Denmark (Jutland; Fig. 3.16) but the population is expected to further increase (Banks *et al.* 2008). According to the latest records of 2008, in total 320 birds were observed at 170 different locations (but mostly from areas along the Wadden Sea and at the Limfjord), spread throughout the whole year (pers. comm. V. Knudsen). Hunter associations were called in 2006 to combat the spreading of the species, but the number of observed individuals continued to increase.

A small number of birds is present in Switzerland (Fig. 3.16), and since 2003 2 pairs are annually reported to breed in an urban park (Banks *et al.* 2008). The size of the population remains low but on the verge of establishing itself, as e.g. in 2009 two new breeding sites were recorded (pers. comm. V. Keller).

In Spain, breeding occurs occasionally, but no established population is recorded.

Since 1997 some birds are seen regularly during winter in North-Italy, but not known to breed there (Banks *et al.* 2008).

Also in Sweden (1994 onwards), Poland (2000 onwards) and the Czech Republic (1996 onwards) birds are seen regularly (Fig. 3.16).

Furthermore, outside the current breeding range birds might also be of captive (primary) origin, but a further secondary spread of the Egyptian Goose from the established populations over Europe is expected.

3.5.2 Outside Europe

In Israel, the introduced breeding population is estimated at 30-50 pairs (Banks *et al.* 2008).

In the United Arab Emirates the first breeding of free-living birds occurred in 1976. There were 50 pairs reported to breed in 1991, >50 pairs in 2000 (Blair *et al.* 2000), while by 2007 the population size reached 100-200 breeding pairs (Banks *et al.* 2008).

There are also Egyptian Geese breeding in the western part of Mauritius. Although exact numbers are missing, the population is known to increase there (Banks *et al.* 2008).

There are introduced birds reported from New Zealand and Australia (Long 1981), but no permanent populations succeeded to get established (Bomford 2006; WAZA website 2009). In the United States, the species has long been kept with regular escapes occurring (Long 1981). However, the first documented nesting in wild was found only from 2002 (Braun 2004).

4 Risk analysis

4.1 Risk assessment

4.1.1 Probability of introduction

Nowadays, Egyptian Geese are breeding nearly everywhere in The Netherlands. Originally, these populations got established from a few escaped or released individuals from ornamental bird collections in parks of The Hague and Groningen since 1967. Another collection held in the Royal Garden close by Brussels, Belgium, also established fee-living populations, which extended its range towards The Netherlands. The origin of Egyptian Goose individuals in the south of The Netherlands is not clear.

The Egyptian Goose population spread to Germany in the 1980s and later on even further to other countries. Ring recoveries from birds ringed in Germany show that German birds also regularly disperse to The Netherlands: out of 393 ringed birds 21 were resighted in The Netherlands at least once (Homma & Geiter 2010). Therefore, we can conclude that these populations are regularly mixing, which is also highly possible with the Belgian populations (four known resightings of Belgium birds in The Netherlands, *information* P.W. van Horssen)..

In The Netherlands and elsewhere in Europe, the species is still held in captivity within collections, gardens and animal farms, and hence providing an existing chance of escapes. Escaped birds are capable of breeding, and thus can be the start of a new colonization kernel, although within the Netherlands the moment has passed when new escapes contributed to new colonisations or faster population growth. However, at the colonization front (i.e. Central-Europe), this can still be a risk for speeding up the spreading and the growth of the population.

4.1.2. Probability of establishment

The species has established free-living populations nearly in all regions of The Netherlands (Lensink 1996). Due to its generalist, mainly herbivorous feeding behaviour, wide range of nesting sites, it is a species that easily finds its needs in new environments. In addition, its robust built body, non-migratory behaviour, aggressive territorial defence, large clutch size, multiple broods, few predators and high chick survival all add to its high potential to establish fast growing populations (Green 1997).

Egyptian Geese forage mainly on grass in Northwest-Europe, and hence found an outstanding foraging habitat in the highly fertilized pastures of The Netherlands (van Eerden *et al.* 1996). In addition, cold winters that cause higher mortality are less frequent. As a result, the population showed an exponential increase in recent decades.

4.1.3 Probability of spreading

The original Dutch population spread further to Germany in the 1980s and recently started to breed also in Denmark (2000) and Switzerland (2003). Based on this experience, it is likely that the species will further spread, at least southwards: it is expected that the 0°C isocline will form the approximate border of the possible expansion range, as severe winters may have a negative effect on such a tropical-subtropical species as the Egyptian Goose (Lensink 1998).

The main requisites for successful breeding (i.e. freshwater and grasslands with a few trees) can be found in nearly all parts of the country, with the exemption of densely forested areas, such as the Veluwe, parts of the Achterhoek and Limburg. Therefore, the spreading of the species was in the initial period high, characterised by an average speed of 3,3 km/year (Lensink 1998). The remaining suitable sites should be colonized in the coming years but the growth of the population is expected to slow down as most of the suitable areas have been colonized already. Moreover, an increasing density of breeding pairs in a certain area has a negative effect on the reproductive success of the population.

Likely, the German population will show the largest increase in numbers in the coming years. Based on the population development since 1994, when the number of breeding pairs was only 7 pairs, the growth shows an exponential increase (Fig. 4.1). If the same trend sets forth, the German population will yearly increase by 50% new breeding pairs of Egyptian Geese, probably reaching 12.000 individuals by 2010. However, the increase could be highly dependent on the local circumstances, as the Belgian population has shown a much slower increase, by extending the breeding population by approximately 30% new pairs yearly. Based on the comparable climatic and ecological conditions between The Netherlands and Denmark, it is expected that without management this latter country will also experience an exponential increase in Egyptian Geese numbers in the coming years.

- *The species has documented breeding in The Netherlands for more than 40 years and has colonized the whole country and spread to all Northwest-European countries. Further spreading is expected, especially into Central-Europe.*

4.1.4 Vulnerable areas

Egyptian Geese are commonly found in the vicinity of freshwater habitats, which are most often protected areas (Natura 2000-sites), threatening the integrity of the protected local biodiversity (Houston & Schreiner 1995). However, the species is often occurring in smaller groups or pairs in less traditional waterfowl habitats as well, as any open landscapes with a few trees and a form of freshwater source suits its breeding requirement. Therefore, it is likely that the species will spread to most protected areas, except for the densely forested areas, such as the Veluwe.

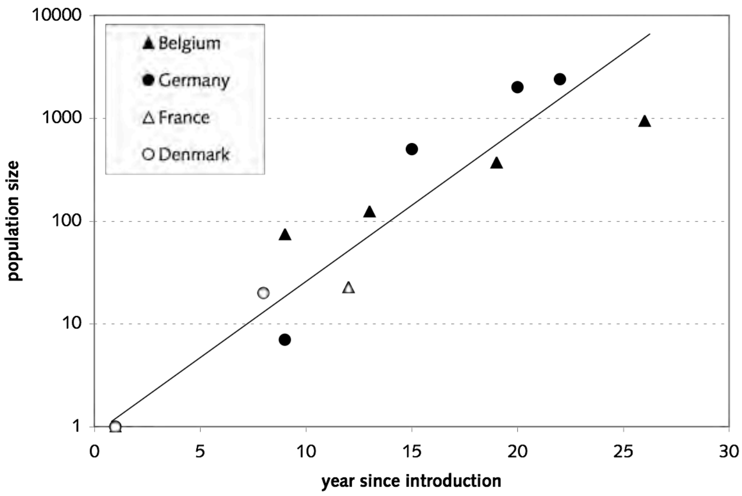


Figure 4.1 *Population development of Egyptian Geese in four countries around The Netherlands; regression line $y = 0,9072e^{0,3359x}$, $R^2 = 0,9174$*

4.1.5 Impact

Ecological impact

The negative ecological impact of waterfowl introductions on native species may occur in the form of:

1. hybridization;
2. competition for food;
3. competition for nesting sites;
4. introduction of diseases.

1. Waterfowl species are known to have a great propensity to hybridize with other species even from other subfamilies (Weller 1969). Hybridizations of Egyptian Geese mainly occur with other introduced goose and duck species (Banks *et al.* 2008). Reported occasions are with ruddy shelduck, a member of the same subfamily Tadorninae, but also with Barnacle Goose *Branta leucopsis* and Canada Goose *Branta canadensis* from the subfamily *Anserinae* (Lensink 1996; Harrop 1998). However, these hybrids are usually infertile (Homma & Geiter 2010).

2. In The Netherlands, Egyptian Geese forage mainly on grasslands, which are abundantly present. Therefore, competition for food with other species might be of minor importance. Nevertheless, the species is known for its aggression towards other birds (Teixeira 1979; Lensink 1996; Pieterse & Tamis 2005), which may cause avoidance by other species and consequently a limited availability of foraging areas. This may be of special importance during moulting (usually in the summer months), when many waterfowl species become flightless. In this period water birds are especially

vulnerable and are under physiological stress due to the moult. Most waterfowl species seek undisturbed sites, which may are in a limited number available. Therefore, several species are commonly destined to share moulting sites and the surrounding foraging sites. A large number of congregating Egyptian Geese may be experienced as threatening by other species, which may choose to switch to suboptimal sites.

3. The species often breeds in nests of Goshawks and Buzzards, which are eventually chased away by the geese themselves (van Dijk 2000). In addition, Egyptian Geese use in The Netherlands the same nesting sites as Shelducks and Mallards *Anas platyrhynchos* (Van den Bergh 1993; Lensink 1996). The breeding period of Egyptian Geese may start as early as February, and hence the geese could occupy existing nests of other species or generally the most suitable nesting sites before other species start breeding. van Dijk (2000) reported that due to this phenomenon Goshawks were forced to adapt their breeding strategy. Goshawk pairs deciding to build a new nest seemed not to be affected but another pair that reclaimed the nest and laid the own eggs next to the geese clutch failed to keep the eggs sufficiently warm. Lensink & van den Berk (1996) compared the population development of Egyptian Goose and native species (i.e. great Crested Grebe *Podiceps cristatus*, Greylag Goose *Anser anser*, Shelduck, Gadwall *Anas strepera*, Buzzard and Kestrel) in the Ooypolder (approximately 20.000 ha) over the period 1975-1995. The results could only conclude that, parallel to the increase in Egyptian Goose numbers, the population of most native species also significantly increased, whereas the number of Kestrel pairs remained stable. A similar observation was reported from the dune areas (van Ommering & Verstrael 1987). Even though no obvious effects on native species are documented in The Netherlands, the presence of Egyptian Geese may still have a negatively influence: for instance by slowing down the population growth or preventing the establishment of native species. Especially that in South-Africa a sparrowhawk species was shown to raise a lower number of chicks due to usurpation of nests by Egyptian Geese (Curtis *et al.* 2007). Moreover, probably due to its extremely fierce territorial behaviour (during pair formation and the beginning of the breeding season), there are reported cases of Egyptian Geese drowning other bird species: Common Shelducks, Magellan geese *Chloephaga picta*, Mallards, a Magpie, a Moorhen *Gallinula chloropus*, House Sparrows *Passer domesticus*, Starlings *Sturnus vulgaris* and Blackbirds *Turdus merula* (Eikhoudt 1973).

4. As discussed in § 2.2.4, the species seems can be a vector of avian influenza infections. The large moulting aggregations in the summer may give place to easy spread of such diseases. The species is not known to make long distance movements, and hence Egyptian Geese would not play a role as vectors of diseases on a large scale. Nevertheless, ring sightings and

recoveries have proved that populations of neighbouring countries do exchange, and hence a limited spread of such diseases may easily occur.

Economic impact

In South Africa the species is recognized as an agricultural pest species. In Europe concerns are increasing. The birds here are almost completely dependent on grasslands, which are commonly fertilized agricultural pastures (Beck *et al.* 2002). Grazing of a large number of geese (e.g. aggregations during moulting, reaching occasionally more than 1.000 individuals lately) causes damage to grasslands, especially that this occurs additional to the grazing of the fast-growing breeding populations of the Greylag Goose and Canada Goose *Branta canadensis*. In recent years in The Netherlands the damage recorded for Egyptian goose is increasing (Fig. 2.2, Tab. 2.1, *NB* the figures recorded here are just a small fraction of the real damage). Moreover, Egyptian Geese in England were also observed to switch to forage on grain fields in the winter (Sutherland & Allport 1991), which behaviour is also described by Beck et al. (2002) on winter grain, sugar beet and potato fields in the winter and spring in Belgium. In The Netherlands feeding on winter wheat is known from several areas in the western half of the country. Additionally to actual consumption, damage may be caused also by trampling and polluting pastures by defecation.

High concentrations of Egyptian Geese nearby poultry farms may raise concerns for the occurrence of avian influenza or other pathogenic diseases. In South Africa, an outbreak of H5N2 avian influenza at an ostrich farm was related to contact with Egyptian Geese (Thompson *et al.* 2008). In Israel, Egyptian Geese were shown to be the first species of the order Anseriformes to carry the avian paramyxovirus, serotype 3 (Shihmanter *et al.* 1998)

Finally, moulting aggregations may locally intensify eutrophication processes by defecating in smaller standing waters. This may shift the nutrient balance towards a high P/N ratio. This ratio at values above 6 can lead to a higher chance on the development of *blue algae* and bacterial loads.

Social impact

A large number of geese can cause annoyance due to defecating on public roads. For the same reason, aggregations on freshwater areas also used as human recreational swimming waters may also be experienced as unwanted.

In addition, the species is well known for its aggression. Although no records are available of Egyptian Geese attacking humans, during breeding they may eventually behave fiercely to protect their nests.

- *Despite indications of a negative effect on local ecosystems, scientific evidence is scarce, mainly due to the lack of long-term and experimental studies. Examples of crop damage in South Africa may be warning signs for a* *serious economic impact; in Europa damage is increasing and possible already serious in size and amount.*

4.2 Risk-assessment score by the Bomford and the ISEIA method

Two methods have been used to calculate a risk assessment score.

The Bomford method (Bomford 2003, 2006, 2008) is a numerical system developed and widely applied in Australia to assess the risks of invasive vertebrates. The score incorporates the potential distribution of a certain species, based on climate models and further attributes relevant to the species biology, potential economic, environmental and social damage as well management possibilities.

The Invasive Species Environmental Impact Assessment (ISEIA) score is an initiative of the Belgian Forum on Invasive Species (Branquart 2007). It refers to a protocol that allocates invasive species to a category based on a two dimensional ordination of invasion stage and environmental hazard.

The first method is strong in detail and in assessing risk of entries (establishment risk score, category B). The second method is strong in assessing risks of ecological effects, but refers only to species that already have established populations in the wild. The Bomford method includes an assessment of social and economic impact, which the ISEIA-method lacks.

Due to its open landscape-character, the risks of establishment are always relatively high in The Netherlands. This implies that the establishment risk score in the Bomford method will inevitably give a high sore.

In this report, the Bomford and ISEIA methods were used in their original form. Smits *et al.* (2010), however, proposed to update the detailed Bomford method into a "continental" classification with a focus on a so-called "Pest risk score". In fact, the risk categories: Match to areas with susceptible native species or communities (C6), Primary production pest status (C7), Spread disease (C9) have to be upgraded with subsequent categories from the ISEIA method: Impact to native species, competition, hybridisation, impact on ecosystems, predation and disturbance of food web. This procedure needs gauging into the score system and two or three test species (e.g. invertebrate, bird, mammal) as a pilot. A combination as such would strengthen both methods.

4.2.1 Bomford method

The method developed by Bomford (2003, 2006, 2008) is more comprehensive than the method of the ISEIA but focuses largely on the risk of introductions. Due to the extensive character of the analysis, the outcome is reported in Appendix 3 and in table 4.1 only an overview of the outcome is presented. The Vertebrate Pest Committee

(VPC) Threat Category is determined from a combination of three calculated risk scores: risk to public safety, the risk to establish a wild population and the risk to become a pest.

According to our analysis, the VPC-threat category is "extreme" for the Egyptian Goose. The Australian Vertebrate Pest Committee recommends that such species should not be allowed to enter, nor be kept in anywhere in the country. If, however, once escaped, specimens should be immediately re-exported, subjected to humane destruction or, in exceptional circumstances, transfer to an established and approved collection of the species. As the Egyptian Goose has already colonized The Netherlands, prevention is not appropriate any more. However, a further spread of the species in Europe may be prevented if required.

Table 4.1 Overview of the risk assessment conform the Bomford method, see appendix 3 for details.

Category	Explanation	Score	Outcome
A. Public safety Risk Score	0 = not dangerous 1 = moderately dangerous 2 = highly dangerous	0	not dangerous
B. Establishment Risk Score	≤6 = low 7-11 = moderate 12-13 = high ≥14 = extreme	12	high risk
C. Pest Risk Score	<9 = low 9-14 = moderate 15-19 = high >19 = extreme	19	high risk
VPC threat category	A+B+C		Extreme risk

4.2.2 ISEIA method

The outcome of the ISEIA method (described in detail in App. 4) is summarized in table 4.2, with the following reasoning:

- *Dispersal potential*: Egyptian Geese are highly fecund and proved to disperse at distances above 1 km/year (i.c. 3 km/year). All bird species fall into this category.
- *Colonization of natural habitats*: Egyptian Geese are usually found on freshwater habitats, frequently of high conservational value.
- *Impact on native species*: There is at least one documented case of Egyptian Geese (in its native area) causing a decline in the productivity of another native species. Furthermore, in Western Europe it may form a moderate source of competition for nesting sites and food. However, well-designed and long-term studies are lacking.

- *Impact on ecosystems*: Aggregations of Egyptian Geese may cause local eutrophication of standing waters. In addition, their grazing effects could eventually cause a disruption in food webs.

The outcome of this method is a score of 10 putting the species into category B: Watch list. The watch list contain species that have a moderate impact. According to its invasion stage in The Netherlands, Egyptian Geese can be considered widespread, and hence the final categorization of the species is B3, the highest category of the watch list. This result suggests that no immediate management actions are necessary but further developments should be followed carefully. Actions that imply the watch list are legislation and restrictions for keeping the species.

Table 4.2 ISEIA of the Egyptian Goose. Abbreviations indicate: L=low, M=moderate, H= high (score 1-3).

Category	estimate	score
1. Dispersal potential	H	3
2. Colonization of natural habitats	H	3
3. Impact on native species	M	2
4. Impact on ecosystems	M	2
Total score		10
List	B	

- *According to the Australian Bomford method, the species does not form a risk to the public safety, has a high risk to establish after entering a new area and has an extreme risk to become a pest species after establishment. The combination of these three outcomes ranks the Egyptian Geese in the category of extreme risk, which implies management action.*
- *According to the ISEIA method, the species has a high dispersal and colonization potential, but the impact on native species and ecosystems is moderate, placing the species on the watch list. Such species require no immediate action but developments should be carefully monitored.*

4.3 Risk management

4.3.1 Prevention

Preventing the introduction of non-native species is considered to be the most cost-effective and most ecologically sound strategy (Duncan *et al.* 2003; Banks *et al.* 2008). Regarding the Egyptian Goose in The Netherlands, however, prevention is not applicable any more: the species has colonized nearly the whole country.

In case an eradication campaign would be successful, prevention of new introductions should clearly be considered. In order to achieve a successful prevention strategy, the main steps should include 1) a standardized registration of captive Egyptian Geese in ornamental collections and prevention of escapes; 2) the formulation of a suited legislation to prevent introductions from abroad and the enforcement of such legislation. Considering the first step, several standard procedures exist that describe the necessary measures to prevent escapes (see Blair *et al.* 2000; Owen *et al.* 2006). Considering the second step, a recently published report is intended to provide guidelines to improve the legislation of introductions (Shaw 2006). Such legislation should include the prohibiting of deliberate release of individuals and regulating the keeping of non-native species in captivity to prevent escapes.

4.3.2 Eradication

The prevention of new introductions in The Netherlands is close to impossible, due to the large populations of Egyptian Geese in the surrounding countries. However, as the estimated maximum number of individuals has passed 64.000, eradication would also be a difficult task: eradication has the highest chance to succeed when the target population is still small (Duncan *et al.* 2003; Banks *et al.* 2008). Eradication programmes in continental countries are commonly ineffective due to the numerous potential sources of new introductions (Bomford & O"Brien 1995). Only large scale, harmonized actions may be successful, such as the recent eradication campaign of Ruddy Ducks *Oxyura jamaicensis*, which managed to considerably reduce the numbers of this invasive species in several European countries (Banks *et al.* 2008)

Considering the large population size of Egyptian Geese in The Netherlands and their large breeding territories, visiting individual nests for egg destruction seems not to be cost-effective.

In Belgium, capture of individuals during the moulting period was also considered as an effective measure (Beck *et al.* 2002). Although this might be generally applicable for waterfowl species, Egyptian Geese do not become completely flightless in July and August (Gerritsen 2001), and hence might be more difficult to capture.

Hunting of Egyptian Geese, was reported to have little impact in Africa (Clancey 1967), but seemed to be effective in slowing down the rate of increase from 25%/year to 0%/year in Zuid-Holland (Lensink *et al.* 2010). For this purpose, about 19% of the population had to be culled annually. The indications that the population growth in The Netherlands has slowed down in the last decennium (see Chapter 3.1) might also be a result of increasing culling efforts, in combination with density-dependent and drought effects.

Egyptian Geese are distinctive animals, both visually and vocally, which may support culling efforts. On the other hand, individuals may be spread over large areas in small family groups or in pairs even in the winter period, limiting the efficiency of culling. In addition, the willingness of game management units to cull Egyptian Geese may be influenced by the low consumption value of the meat (Clancey 1967).

Generally, due to the large colonization capability of the species, such local initiatives would likely only result in a short-term success. If elsewhere the populations remain to increase, such initiatives would result in a continuous effort (Bomford & O"Brien 1995). A nationally synchronized eradication could have a higher chance to lead to long-term results, but due to the extensive and still growing introduced populations in the surrounding countries, it would be preferable to strive for international cooperation.

Moreover, culling might be ineffective if limited exclusively to the winter period, due to the high compensatory potential of the species during the breeding season (see compensation for winter mortality in Chapter 2.2.4). However, the possibilities to carry out such measures in the breeding season might also be strongly limited by restrictions on the use of fire arms in nature reserves but also outside, due to possible effects on breeding native species.

Last but not least, a preceding task before the start of any eradication measures would be the raising of public awareness of risks introduced non-native species pose (Weller 1969). The media may raise the sympathy of the general public to such ornamental species, eventually leading to protests by animal rights and welfare organizations (Temple 1990). This can be avoided by an adequate publicity on the necessity of such measures.

4.3.3. Management

Whether such rigorous measures as eradication are needed in the specific case of the Egyptian Goose should have valid arguments (Coblentz 1990). This calls for more research on the ecological and economic effects of the species, as Egyptian Geese are generally recognized as aggressive birds but well-documented effects on native species are scarce (see Chapter 4.1.5):

- hybrids with native species are usually infertile;
- competition for food is unlikely due to the large amount of available grasslands;
- a negative effect on the breeding success of a sparrowhawk species is documented in South-Africa, but not known in The Netherlands;
- the species may be a vector to e.g. avian influenza but no such records are available from Western-Europe.

The economic threat might be more present already, due to the exponentially increasing numbers. However, while extensive research has been conducted on the foraging ecology of wintering geese species in The Netherlands, the actual effects of Egyptian Geese have not yet been systematically studied.

The two risk analysis methods also suggest that the Egyptian Goose can be considered as a serious invasive species. Especially the results of the Bomford method point towards the necessity of immediate action. Considering the efficiency of the different measures described in the previous section, the local success of culling efforts in Zuid-Holland suggests that this could be a plausible management option, at least in preventing further exponential increase of the species.

Considering the large current population size, applying additional measures (e.g. prevention of escapes and introductions, new legislation) may be less cost-effective, as the free-living population is already self-supportive and individuals in captivity form only a small fragment of the population in the wild: worldwide there are only 604 birds known to be kept in zoos (WAZA website 2009). Although this latter figure does not include populations in urban parks, the free-living population has reached such numbers in Western Europe and increase with such a speed that new escapes form no considerable contributions any more. Additional measures, however, might be considered after evaluating a preliminary period of culling efforts. Such evaluation may rely on the well-established water bird monitoring schemes of SOVON.

- *Prevention of introduction or spread is not feasible in the case of Egyptian Geese.*
- *Complete eradication has a low chance of success due to the large population size in The Netherlands and the surrounding countries.*
- *Further research is needed to specify the impact on biodiversity, economy and safety.*
- *The risk assessment suggests that management actions are needed to prevent further exponential increase. Culling schemes should preferably be co-ordinated internationally to be cost-effective.*

5 Conclusion, discussion and recommendations

The spread of the Egyptian Goose in The Netherlands in the past 40 years is without precedent. Besides colonizing all regions of the country, it established vital and exponentially growing populations also in the surrounding countries. Nevertheless, the species in not necessarily a good invader everywhere. In England, for instance, the population hardly grew in the past two centuries. The English and Dutch environmental factors that affect population size (i.e. winter mortality, summer rainfall) do not differ very much. Likely, the reason for its success in The Netherlands is the combination of abundant fertilized grasslands, freshwater and suitable nesting sites. The great quantity of high quality grass may be responsible for the larger number of fledged chicks in The Netherlands, compared with its original home range or England.

Once the Egyptian Goose population in The Netherlands reached a substantial level, spreading of the species to surrounding countries was inevitable. Meanwhile, the Belgian and German populations are themselves sources of further dispersion to even more countries in Europe. It is expected that within a few years, the breeding range of Egyptian Geese will reach Central-Eastern Europe. Although occasional observations report the occurrence of individuals even in Scandinavian countries, Denmark might be its northern distribution limit, due to the severity of winters. Based on its success in the Netherlands, it seems that the species can easily cope with other climatic conditions. This latter is also revealed by the large natural geographical home range in Africa: from coastal lagoons in Somalia through altitudes of up to 3.000 m in Kenya to offshore islands in South Africa. It seems that being a generalist in its habitat, nesting sites and diet, the species finds its needs anywhere where freshwater is in the vicinity. Moreover, except for nest predation by crows and small mammals (Havekes & Hoogkamer 2008), the Egyptian Goose has currently only a few natural enemies in Europe that would regulate the growth of the population (Lensink 1998).

Although Egyptian Geese are generally known as aggressive birds, there are only occasional reports of negative effects on native species. Hybrids seem to be infertile, and competition for food is currently not intensive, considering the availability of grasslands in The Netherlands. Competition for nesting sites has been studied, but no clear effects on the population level were found, at least in The Netherlands. On the other hand, as it may compete for nesting sites with less common birds, such as the White Stork, or even with red list species, such as the Peregrine Falcon, future developments should be followed with care.

As the species shows here resident behaviour, it cannot be considered a serious vector for diseases either. Nevertheless, further targeted research would be required to get a more detailed insight in the risks the species poses here. Especially, regarding the economic damage it may bring about at agricultural areas, e.g. grasslands and crops. There are reports of more than 1.000 individuals being temporally concentrated during the moulting period. Such aggregations cause damage to grasslands and yield losses in croplands, but systematic studies are lacking.

Based on the two risk analyses carried out, the Egyptian Goose should at least be labelled as an invasive species with a high potential to become a pest species, either in ecological, economic or social sense. Regarding the Australian Bomford method, which weights the invasion and dispersion potential heavier, the Egyptian Goose should be viewed as an invasive species of extreme risk. Considering the velocity of spreading of the species in The Netherlands and the surrounding regions, this is already confirmed in Northwest Europe. Although according to the categorization Egyptian Geese have the potential to become a serious pest once established, this has to be proven for the present case. Despite many indications, no clear conclusions can yet be drawn.

Since the estimated maximum number of Egyptian Geese is around 50.000 individuals in The Netherlands, and will likely almost reach 12.000 birds in Germany and 4.000 in Belgium this year, the Northwest-European population only in these three countries will be above the 65.000 animals. Eradication of such a number of birds seems to be very difficult. Management actions to limit further rapid growth can be considered. An internationally co-ordinated management programme (including culling) may be an effective option.

This risk analysis was based on little information on crop damage and very little information on ecological and social damage. To build a strong and consistent future policy more facts and economic, ecological and social damage is necessary.

6 Literature

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APPENDIX 1 Structure and size of the population Egyptian Goose in The Netherlands (*in Dutch*)

Structuur en omvang van de populatie nijlganzen in Nederland

Omtrent het aantal broedparen nijlganzen in Nederland zijn in het verleden op basis van veel verschillende bronnen schattingen gedaan. Voor de eerste decennia na de vestiging in 1967 geeft Lensink (1996) een samenvatting voor verschillende tijdvakken. De gegevens uit de broedvogelatlas zijn het materiaal voor een schatting voor het jaar 2000 (Lensink 2002). In de risicoanalyse nijlgans (dit rapport) wordt op basis van de schatting uit 2000, een schatting voor 2009 gegeven. Hierbij is zowel de in het veld geregistreerde toename onder broedvogels (gegevens BMP) als onder niet broedvogels (gegevens Watervogeltellingen) behulpzaam geweest. De omvang van de broedpopulatie wordt in 2009 geschat op 9.500-10.500 paar (zie tabel 3.1).

Vervolgens is de vraag hoe het aantal broedparen zich verhoudt tot de omvang van de totale populatie nijlganzen in ons land (aantal exemplaren). Indien zowel de structuur van de populatie bekend is als informatie over reproductie en overleving, kunnen aantallen broedparen worden vertaald naar aantallen vogels. De verkregen schatting van het aantal vogels zou vervolgens in lijn moeten zijn met de aantallen nijlganzen zoals die bijvoorbeeld uit de resultaten van watervogeltellingen naar voren komen.

De volgende informatie over structuur en life-history parameters is beschikbaar:
Leeftijd first time breeding: waarschijnlijk na 1 winter (Cramp & Simmons 1978);
Geslachtsverhouding: geen feiten; 1:1 is aannemelijk;
Reproductie: variërend tussen 1,57 en 2,19 juveniel/paar (Lensink 1998). Deze gegevens stammen uit de eerste helft van de jaren negentig. In de jaren daarna zijn tot 2003 langs de rivieren vergelijkbare waarden gevonden tot een maximum van 2,2 juveniel/paar/jaar (gegevens RLe). Cijfers zijn inclusief paren zonder jongen. Verschillende waarnemers in het westen van het land melden dat sommige paren tot twee broedsels in een jaar groot brengen. In welke mate dit gebeurt is onbekend.
Overleving: in 2010 is door Van der Jeugd & Majoor een analyse van een gekleurringde groep nijlganzen uit de stadsparken van Arnhem gepubliceerd. Hieruit rollen cijfers voor de overleving: Y1 0,41, Y2 0,718 en >Y2 0,81.

De verschillende gegevens kunnen worden gebruikt om een matrix (*cf.* Caswell 2000) te vullen (uitgaande van reproductie 1,9 juv/paar, na eerste winter eerste maal broeden).

Matrix 1

	1Y	2Y	>2Y
F	0	0,68	0,78
S 1Y	0,41	0	0
S 2Y, >2Y	0	0,718	0,83

Uit de matrix kan worden afgeleid dat de toename van de populatie 8,5% per jaar is. Wanneer de eerste maal broeden voor de helft na de eerste winter en voor de helft na de tweede winter plaatsvindt, neemt de jaarlijkse toename af tot 6,2% per jaar.

Matrix 2

	1Y	2Y	>2Y
F	0	0,341	0,78
S 1Y	0,41	0	0
S 2Y, >2Y	0	0,718	0,83

Na de eerste vestiging van de soort in 1967 bedroeg de jaarlijkse toename onder broedvogels tot in de jaren negentig 28,2% per jaar (tabel 3.3), om nadien af te vlakken door een toenemend afschot en mogelijk ook dichtheidsafhankelijke factoren. Een matrix die gebruik maakt van de beschikbare bronnen (matrix 1 en 2) beschrijft de populatieontwikkeling onvoldoende adequaat.

In 1998 is door Lensink een range van matrices doorgerekend waarbij de beschikbare gegevens over reproductie en de populatieontwikkeling tot dat moment uitgangspunt waren. Uit deze analyse volgde dat de populatieontwikkeling goed kon worden nagerekend met matrices waarin de overleving voor eerstejaars vogels rond 0,7 lag en voor oudere vogels rond 0,85. Deze waarden lagen ook binnen de range van waarden zoals die voor andere soorten watervogels met een vergelijkbaar gewicht, en zonder veel jachtdruk, bekend zijn (*cf*. Ebbinge 1996, Cramp & Simmons 1978, BWP-update diverse afleveringen, BTO.birdfacts.org).

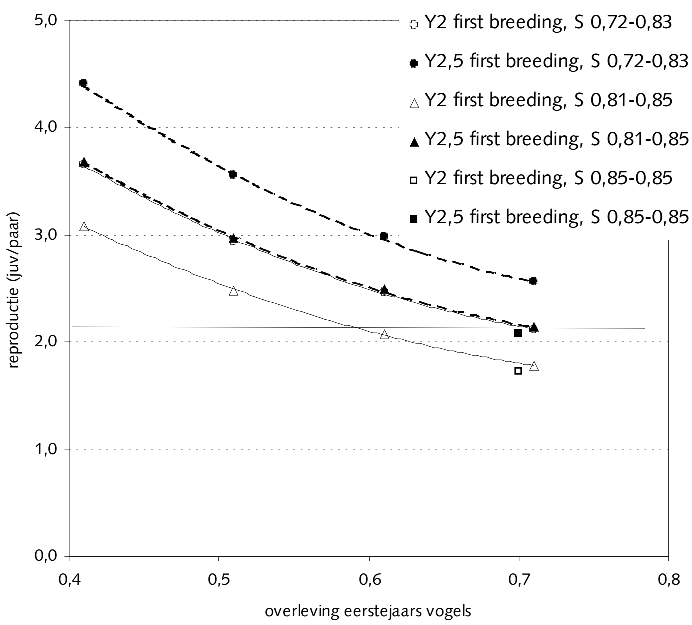
Matrix 3

	1Y	2Y	>2Y
F	0	0,731	0,731
S 1Y	0,7	0	0
S 2Y, >2Y	0	0,85	0,85

Matrix 1 en 2 kennen een overleving zoals gemeten in het veld en een reproductie die hoger ligt dan in het veld is gemeten. Matrix 3 kent een reproductie zoals die in veld voorkomt en een overleving die hoger is dan uit de analyse van een gekleurringde populatie volgt (Van der Jeugd & Majoor 2010).

De gekleurringde populatie nijlganzen in Arnhem leeft in stadsparken die op pleistoceen zand zijn aangelegd. De vogels foerageren daar overwegend op gazons en grasvelden langs vijverpartijen. Deze grasvelden drogen in de zomermaanden vrij snel uit waarbij de kwaliteit van de vegetatie (als voedsel) achteruit gaat. Dit is mogelijk een van de verklaringen waarom tussen overleving van jongen en neerslag in de zomermaanden een positief verband is vastgesteld (Van der Jeugd & Majoor 2010). Daarnaast is het aannemelijk dat de overleving van jongen in de Arnhemse Parken lager is dan in bijvoorbeeld het rivierengebied en de Hollandse veenweiden. Deze graslanden blijven bij droogte langer vochtig met navenant meer en ook beter gras. Voor modellering op nationaal niveau zijn de overlevingsgetallen van Van der Jeugd & Majoor (2010) vermoedelijk te laag.

Naar aanleiding van de vorige alinea's zijn een aantal matrices opgesteld met verschillende combinaties van reproductie, overleving eerstejaars vogels, overleving oudere vogels en leeftijd *first time breeding* (na 1 winter of na 1,5 winter). De matrices voldoen aan de voorwaarde dat ze de vastgestelde populatieontwikkeling redelijk beschrijven en in 2009 op ongeveer 10.000 broedparen uitkomen, waarbij het afschot van de afgelopen 15 jaar is verdisconteerd (figuur A1.1). Daarnaast geven zij een jaarlijkse toename van 26% (zonder verdiscontering van afschot).



Figuur A1.1 *Verband tussen overleving van eerstejaars vogels en reproductie, waarbij de populatie toeneemt tot ongeveer 10.000 paar in 2009. De bovenste twee lijnen kennen een lagere overleving voor oudere vogels (0,72 en 0,83) dan de onderste twee lijnen (0,81 en 0,85). De twee middelste lijnen vallen vrijwel samen! Voor beide matrices het verband bij a) first time breeding na 1 winter (Y2) en b) de helft na een winter en de helft na twee winters (Y2,5), horizontale lijn in het veld gemeten maximale jaarlijkse reproductie (2,2 juv/paar/jaar). Links onder de lijn de uitkomst van matrix 3 (vierkantjes) voor beide opties van 'first time breeding'.*

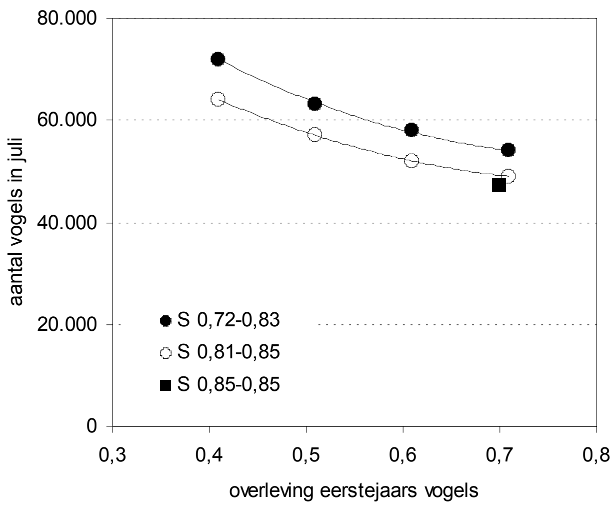
Wanneer reële waarden voor de reproductie als uitgangspunt worden genomen, dan wijzen de gegevens erop dat de overleving groter moet zijn dan in Arnhem is vastgesteld. Daarnaast ligt een *first time breeding* na 1 winter meer voor de hand dan na gemiddeld 1,5 of 2 winters. Daarmee is matrix 3 een reële weergave van de werkelijkheid (reproductie 1,72 juv/paar/jaar) alsook matrix 4 (reproductie 2,12 juv/paar/jaar).

Matrix 4

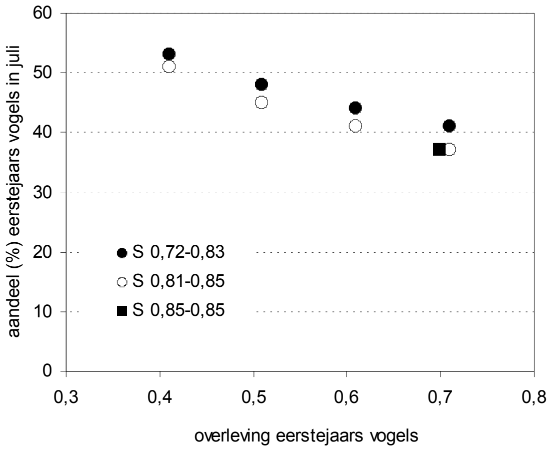
	1Y	2Y	>2Y
F	0	0,759	0,877
S 1Y	0,71	0	0
S 2Y, >2Y	0	0,718	0,83

Voor iedere combinatie van reproductie en overleving kan de populatieomvang in juli (na het broedseizoen) worden uitgerekend, gebaseerd op een aantal broedparen van 10.000. Varianten met een geringe overleving van eerstejaars vogels (en een hoge reproductie) leveren een populatie van rond de 70.000 ex in juli. Varianten met een hoge overleving van eerstejaars vogels (en adulten) komen op een aantal vogels van rond de 50.000 ex in juli (figuur A1.2).

Reproductie en overleving zijn ook van invloed op de structuur van de populatie. Bij een lage overleving en een hoge reproductie is het aandeel juvenielen in juli hoger dan bij een hoge overleving en een lagere reproductie: Binnen de doorgerekende varianten loopt het aandeel juvenielen uiteen van 53 tot 37%.



Figuur A1.2 Aantal vogels in juli bij verschillende combinaties van reproductie en overleving.



Figuur A1.3 Aandeel juvenielen in juli bij verschillende combinaties van reproductie en overleving.

Conclusie

Het aantal broedparen van de nijlgans wordt anno 2009 geschat op ongeveer 10.000 paar. Op grond van de populatieontwikkeling in de voorgaande decennia (inclusief afschot) en de in het veld vastgestelde reproductie wordt aangenomen dat de overleving van eerstejaars vogels rond de 0,7 ligt en die van ouderejaars vogels tussen 0,8 en 0,85. Dit is in lijn met een eerdere schatting uit de jaren negentig (Lensink 1998). De matrices 3 en 4 vormen hiervan een afspiegeling. De bijbehorende omvang van de populatie in de nazomer is rond 50.000 ex waarvan minder dan 40% juvenielen.

APPENDIX 2 Population estimates based on Habitat Suitability Indices (*in Dutch*)

Habitatgeschiktheid in een model (door P. Wiersma, SOVON Vogelonderzoek Nederland)

Inleiding

De populaties uitheemse ganzen in Nederland groeien snel of hebben de potentie om snel te groeien. Omdat de huidige verspreiding waarschijnlijk een voortvloeisel is uit de locatie(s) van introductie is het onwaarschijnlijk dat hun verspreidingsgebied zich in de toekomst zal blijven beperken tot hun huidige verspreidingsgebied. Als we aannemen dat de ganzen nog niet alle mogelijke geschikte habitats in Nederland hebben bezet kunnen we een voorspelling doen van de toekomstige verspreiding gebaseerd op habitatkenmerken van de huidige verspreiding. We hebben dit onderzocht met behulp van een statistische classificatie- en regressietechniek om te bepalen welke habitatkenmerken de huidige verspreiding het best verklaren. Vervolgens hebben we de uitkomsten van de analyses gebruikt om te voorspellen welke gebieden in Nederland over de geschikte habitats beschikken. Dit resulteert in kaarten van heel Nederland waar per gebied een voorspelling is gedaan van het aantal per soort.

Aanpak

Voor het opstellen van habitatgeschiktheids-modellen (HSI of *habitat suitability indices*) zijn habitatkenmerken gekozen die volgens onze inzichten (*i.c.* SOVON) bepalend zijn voor het voorkomen van de verschillende ganzensoorten (

Tabel A2.1). Informatie over habitatkenmerken van broed- en foerageergebieden van deze ganzensoorten is verkregen uit het Zomerganzenrapport (Van der Jeugd *et al.* 2006), Conover & Kania (1991), Dieter & Anderson (2009), Hupp *et al.* (2008), Kleefstra (2009), Laing & Raveling (2003), Randler (2007), Schmutz (2001), Summers & Grieve (1982). Informatie over habitatgebruik van uitheemse ganzen is helaas schaars en in veel gevallen gaan we er van uit dat het habitatgebruik van de meeste ganzensoorten overeenkomst vertoont met dat van grauwe ganzen en uitheemse Canadese ganzen; soorten waarvan de meeste informatie beschikbaar is. Relatieve broedvogeldichtheden zijn berekend uit geïnterpoleerde telgegevens uit 250-m-gridcellen afkomstig uit de broedvogelatlas (SOVON 2002).

Analyse
Voor de analyses is gebruik gemaakt van aantallen per gebied. Door gebiedsoppervlakte als verklarende variabele mee te nemen wordt gecorrigeerd voor de grootte van het telgebied. Hiervoor is gekozen omdat op deze wijze statistische modellen kunnen worden gebruikt uitgaande van een Poisson-kansverdeling. Als wordt uitgegaan van dichtheden (aantallen delen door oppervlakte) is de kansverdeling continu maar niet normaal verdeeld. Een log-transformatie kan in een dergelijk geval soms een oplossing bieden maar met onze data is dat niet het geval, omdat lage aantallen sterk zijn oververtegenwoordigd.

Tabel A2.1 Variabelen gebruikt in analyses van habitatgeschiktheid.

Variabele	Omschrijving	Bron
X, Y	Coördinaten centrum telgebied/kmhok	Topografische kaart 1:10000
Oppervlakte	Oppervlakte telgebied (ha)	Topografische kaart 1:10000
Landoppervlakte	Oppervlakte land in telgebied (ha)	Topografische kaart 1:10000
Groot eiland	Telplot wel/niet op groot eiland (Waddeneiland, Tiengemeten)	Topografische kaart 1:10000
Oppervlakte eiland	Oppervlakte eiland(en) in telplot (ha) (exclusief Groot Eiland)	Topografische kaart 1:10000
Landbouwgewassen		
Aardappels	Oppervlakte aardappelteelt (ha)	Basisregistratie Percelen 2007
Fruitbomen	Oppervlakte fruitbomen (ha)	Basisregistratie Percelen 2007
Graszaad	Oppervlakte graszaad (ha)	Basisregistratie Percelen 2007
Permanent gras	Oppervlakte permanent grasland (ha)	Basisregistratie Percelen 2007
Tijdelijk gras	Oppervlakte tijdelijke grasland (ha)	Basisregistratie Percelen 2007
Groenten	Oppervlakte groenteteelt (ha)	Basisregistratie Percelen 2007
Maïs	Oppervlakte maïs (ha)	Basisregistratie Percelen 2007
Natuurlijk	Oppervlakte natuurlijk terrein (ha)	Basisregistratie Percelen 2007
Wintergranen	Oppervlakte wintergraan (ha)	Basisregistratie Percelen 2007
Zomergranen	Oppervlakte zomergraan (ha)	Basisregistratie Percelen 2007
Overig	Oppervlakte overige gewassen (ha)	Basisregistratie Percelen 2007
Habitat hoofdcategorieën		
Groen	Oppervlakte groen (ha)	Topografische kaart 1:10000
Blauw	Oppervlakte zoet water (ha)	Topografische kaart 1:10000
Grijs	Oppervlakte bebouwing, infrastructuur (ha)	Topografische kaart 1:10000
Afstand zoet water	Kleinste afstand tot zoet water (>= 0.2 ha; m)	Topografische kaart 1:10000
Moerasbos	Oppervlakte loofbos en griend in moerasgebied (ha)	Topografische kaart 1:10000
Moeras	Oppervlakte moerasgebied (ha)	
Opgroeigebied	Oppervlakte jongen-opgroeigebied (ha)	Project zomerganzen 2006
Afstand tot opgroeigebied	Kortste afstand tot opgroeigebied (>0.2 ha)	
Ruigte	Oppervlakte overig open begroeid natuurgebied (ha)	Ecotopenkaart
Riet	Oppervlakte rietvegetatie (ha)	Vogelbescherming Rietkaart 2006
Gras	Oppervlakte grasland (ha)	Topografische kaart 1:10000
Weg en spoor	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Vliegveld	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Bebouwing	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Park en plantsoen	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Recreatie	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Glastuinbouw	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Overig agrarisch gebruik	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Bos	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Droog natuurlijk terrein	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Nat natuurlijk terrein	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Binnenwater (incl. IJsselmeer/Markermeer	Oppervlakte (ha)	Basiskaart
Bodemgebruik 2000		
Vloei- en/of slibveld	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Zee, Scheldes, Eems, Dollard	Oppervlakte (ha)	Basiskaart Bodemgebruik 2000
Dichtheid Knobbelzwaan	Dichtheid broedparen Knobbel¬zwaan	Broedvogelatlas 2002

Vervolgens is geanalyseerd hoe habitatvariabelen zijn gerelateerd met de aantallen ganzen. Omdat een groot aantal verklarende variabelen in de analyse is opgenomen zijn regressie-analyses (of meer algemeen, *generalized linear models*) minder geschikt en hebben we gebruik gemaakt van *Regression* of *Decision Trees* oftewel Classificatiebomen. Een van de krachten van Classificatiebomen is dat deze een zeer groot aantal onafhankelijke variabelen aankunnen, ook als variabelen onderling zijn gecorreleerd. Voor de analyses hebben we gebruik gemaakt van het *general boosting models* pakket "gbm" (v. 1.6-3.1; Ridgeway 2010) in de statistiek programmeeromgeving R, v. 2.11 (R Development Core Team 2010) en de R-functies samengesteld en vrijgegeven door Elith *et al.* (2008).

Een Classificatieboomanalyse construeert een zeer groot aantal bifurcatie- of beslisregels. Elke regel bestaat uit een classificatieboom die op basis van een subset van onafhankelijke variabelen de responsevariabele in twee zo homogeen mogelijke groepen verdeelt. De best functionerende habitatvariabelen worden uiteindelijk gebruikt om de gegevens op te delen. Modellen worden geschat met 70% van de data en de voorspellende kwaliteit van de schatting wordt geschat op grond van de resterende 30% van de data.

Variabelenselectie

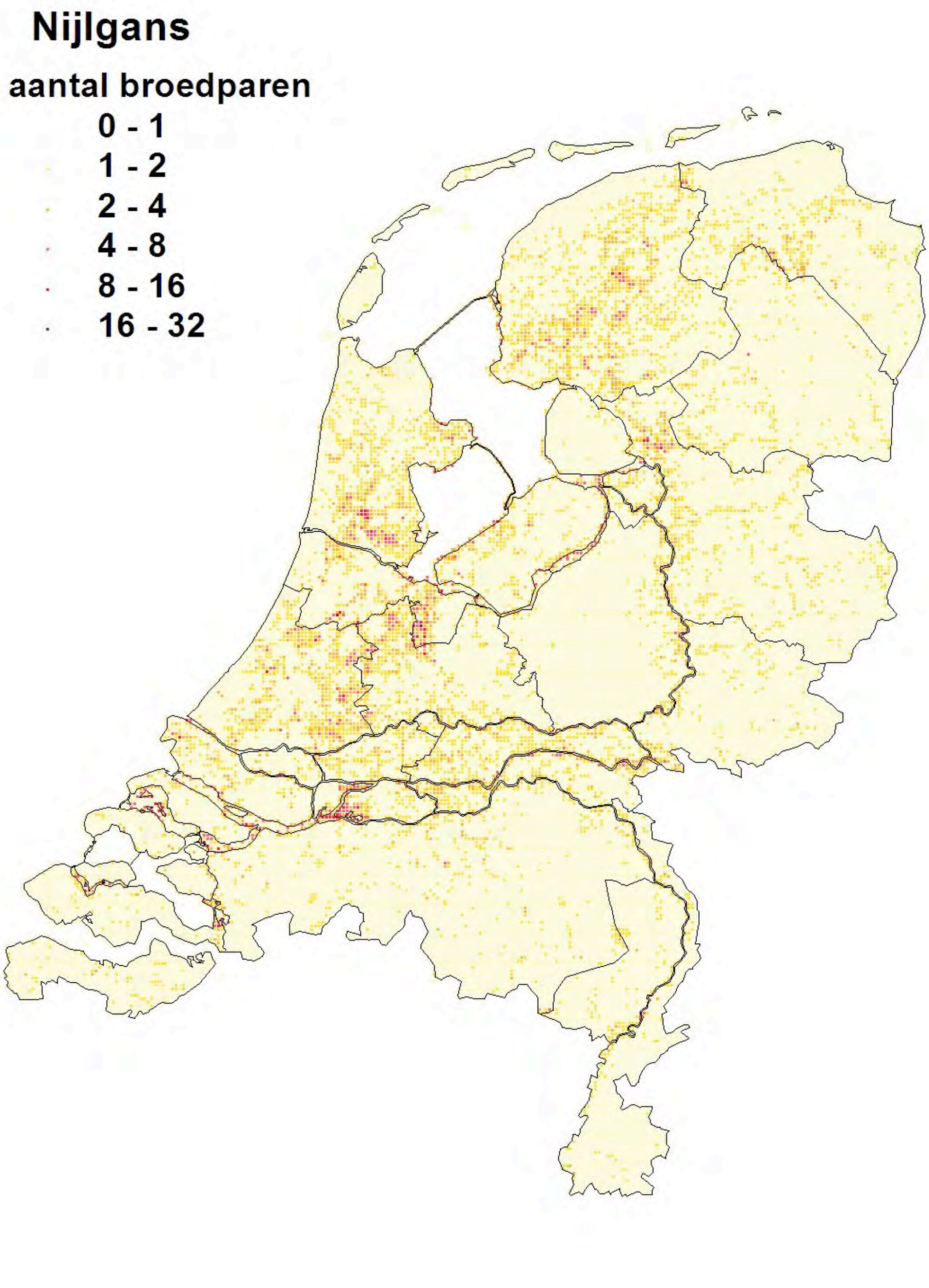
Als soorten niet geografisch gelijkmatig zijn verdeeld over Nederland en een bepaalde regio is oververtegenwoordigd dan kan dat ongewenste gevolgen hebben voor de uitkomsten van analyses. Dit gebeurt als sommige variabelen op een zelfde manier geografisch zijn verdeeld over Nederland als de ganzen. Stel dat een soort door toeval is geassocieerd met rivieren omdat zij daar is geïntroduceerd, dan zal aanwezigheid van rivieren een invloedrijke voorspeller zijn voor de aanwezigheid van deze soort. Voor gebieden waar geen rivieren in de nabijheid zijn zal een model geen of lage aantallen ganzen voorspellen. Als de associatie tussen rivieren en ganzen echter niet causaal is zal deze voorspelling waarschijnlijk fout zijn. Dit geldt bijvoorbeeld voor de fysisch-geografische regio's (FGR) die mogelijk toevallig gecorreleerd zijn met de verspreiding van sommige ganzen. We hebben analyses daarom gedaan zonder de variabele FGR. Om dit effect verder uit te sluiten hebben we analyses uitgevoerd van data afkomstig uit dat deel van Nederland dat het belangrijkste verspreidingsgebied omvat, omdat binnen die begrenzing aan- en afwezigheid met grotere waarschijnlijk berust op habitatkenmerken en niet op locatie van introductie. De selectie van data is gebaseerd op een *kernel* dichtheidsbereking per km^2 met een invloedsfeer van 5 km. Vervolgens is visueel een dichtheidsgrens bepaald die de belangrijkste verspreidingsgebieden begrenst.

Resultaten

Voor de ganzensoorten waar voldoende gegevens beschikbaar waren zijn habitatgeschiktheidskaarten geconstrueerd: grote Canadese gans, kolgans, Indische gans en nijlgans. Analyses zijn gedaan voor broedparen en voor individuele vogels. Gegevens van het aantal broedparen zijn afkomstig uit het BMP- en LSB-project en uit lokale (provinciale) telprogramma's. De habitatgeschiktheidskaarten zijn gebaseerd op een groot aantal habitatkenmerken waarmee een voorspelling wordt gedaan van het aantal te verwachten ganzen(paren) per vierkante kilometer. Door alle voorspelde waarden van de kilometerhokken te sommeren wordt een schatting verkregen van het totaal aantal te verwachten nijlgans-paren in Nederland.

Voorspelde maximum aantal broedparen op basis van habitatgeschiktheidsindices: 28.213 paar nijlganzen (figuur A2.1). Op basis van de berekeningen ligt het zwaartepunt van de maximale verspreiding in de veenweiden van Holland en Friesland en enkele waterrijke systemen in het zuidwesten van Nederland. De berekende maximale dichtheden in het rivierengebied zijn veel lager, terwijl deze dichtheden in landschappen zonder veel open water nog lager zijn.

Literatuur
Zie hoofdstuk 6



Figuur A2.1 Maximale toekomstige verspreiding van de nijlgans op basis van HSI-modellen.

APPENDIX 3 Risk analysis *cf.* Bomford

	Factor	Score	Information	Reasoning and conclusion
	Stage A: Risks posed by captive or released individuals			
A1	Risk to people from individual escapes (0-2)	0	Do not make unprovoked attacks	Low risk
A2	Risk to public safety from individual captive animals (0-2)	0	No products obtained from the species	Nil risk
	A. Public Safety Risk Score	0		**Not dangerous**
	Stage B: Probability escaped or released individuals will establish a free-living population			
B1	Climate match score (1-6)	5	The match of the natural geographic region and the region of assessment, based on 16 climate parameters of temperature and rainfall. The climate match score is 1 (low) up to 6 (extreme)	The species is rapidly spreading in Europe, and hence climate is likely not a restriction. However, severe winters cause a higher mortality. Therefore, the climate match score is set to very high (5).
B2	Established exotic populations score (0-4)	4	0 = none, 2 = on island <50.000 square km, 4 = established on large islands or anywhere on a continent	Already established
B3	Taxonomic class score (0-1)	0	0 = bird, 1 = mammal, reptile or amphibian	Birds have a lower establishment success than mammals
B4	Migratory score (0-1)	1	0 = migratory 1 = non-migratory	Non-migratory birds are more successful
B5	Diet score (0-1)	1	0 = specialist, 1 = generalist	Generalist with a broad diet
B6	Habitat score (0-1)	1	0 = undisturbed habitat, 1 = including human disturbed habitats	Including agricultural lands
B7	Range size score (0-2)	1	0 = 0-1, 1 = 2-69, 2 = 70 million km^2	Natural distribution is around 17,5 million km^2
	B. Establishment Risk Score	**13**	**Low = 6; moderate = 7-11; high = 12-13; Extreme 14**	**High risk**
	Stage C: Probability of an established species to become a pest			
C1	Taxonomic group (0-4)	3	0 = none, 1 = known to hybridize, 2 = within the group that cause agricultural damage	Causes agricultural damage and may hybridize with native species
C2	Range (0-2)	1	0 = <10, 1 = 10-30, 2 = >30 million km^2	Natural distribution is around 17,5 million km^2
C3	Diet and feeding (0-3)	0	0 = not a mammal, 1 = non strict carnivorous mammal, 2 = carnivorous mammal, 3 = grazer or browser mammal	Grazing mammals cause the largest habitat change
C4	Competition with	2	0 = no competition, 1 = minor	Nests in tree hollows

	native fauna for nesting space (0-2)		competition, 2 = strong competition (e.g. breeding in tree hollows)	
C5	Environmental pest status (0-3)	1	1 = minor pest, 2 = moderate pest, 3 = major pest (including species with unknown pest status)	Has been reported to cause decline in productivity of a native species
C6	Climate match to areas with susceptible native species or communities (0-5)	2	Identify any native animal or plant species or communities that could be susceptible to harm by the species. Compare the geographic distribution of this susceptible species with the possible distribution of the Egyptian goose. From 0 (no overlap) to 5 (complete overlap with vulnerable species or community)	Overlap with the natural distribution of several native birds, but competition is not proven. Limitations in spreading due to higher mortality in cold winters. Due to these uncertainties score set to 2.
C7	Primary production pest status (0-3)	2	0 = no damage, 1 = minor, 2 = moderate, 3 = major damage to crops	Is reported to cause 65% yield loss to crops in South Africa
C8	Match with susceptible primary production (0-5)	4	Assess potential commodity impact score for each primary production commodity	The species can be found nearly anywhere with an open landscape and hence largely matches the distribution of cereal grain (wheat, barley etc) production
C9	Spread disease (1-2)	2	1 = amphibians and reptiles, 2 = all birds and mammals	All birds and mammals can play a role as a vector of diseases/parasites
C10	Harm to property (0-3)	1	Damage to e.g. buildings, vehicles, fences, roads, ornamental gardens. 0 = $0, 1 = $1 - $10 million, 2 = $11-$50 million, 3 = > $50 million	Polluting by droppings
C11	Harm to people	1	0 = nill risk, 1 = low risk, 2 = injuries (minor), 3 = moderate, 4 = severe/fatal, 5 = extreme risk (many fatalities)	Very low risk of annoyance to people
	C. Pest Risk Score = Sum C1-C11 (1-37)	**20**	**< 9 Low, 9-14 Moderate, 15-19 Serious, >19 Extreme**	**Extreme**
	A. Risk to Public Safety Rank	**0**	**0 = not dangerous, 1 = moderately dangerous, 2 = highly dangerous**	**Not dangerous**
	B. Establishment Risk Rank	**13**	**6 = low, 7-11 = moderate, 12- 13 = high, 14 = extreme**	**Serious risk to establishing a wild population**
	C. Pest Risk Rank	**20**	**<9 = low, 9-14 moderate, 15-19 = serious, >19 = extreme**	**Extreme risk to become a pest**
	Vertebrate Pests Committee (VPC) Threat Category			**Extreme**

APPENDIX 4 Risk analysis *cf.* ISEIA method

Guidelines for environmental impact assessment and list classification of non-native organisms in Belgium.

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Version 2.5 (18/10/2007)

1. Introduction

Harmonia is an information system on non-native invasive species in Belgium, which is developed at the initiative of scientists gathered within the Belgian Forum on Invasive Species (http://ias.biodiversity.be). This system aims at collecting standardised information on exotic species which are assumed to be detrimental to native biodiversity in Belgium. It aims to include a high diversity of taxonomic groups from terrestrial, freshwater and marine environments.

Species included in the system are allocated to different list categories based on a simplified environmental impact assessment protocol (ISEIA), and geographic distribution in Belgium (species invasion stage). Such categorisation offers a scientific background to prioritise actions to prevent introduction and mitigate the impact of invasive species, including the improvement of the legislative framework at the federal and the regional levels. This standard provides detailed instructions about the methodology used for this categorisation.

2. Data source

Information is provided to the system by scientists involved in the Belgian Forum on Invasive Species. As much as possible, data entered in the database refers to the available published literature, which include peer-reviewed journals, books, grey sources (reports, etc.) and on-line databases dedicated to invasive species in Europe. Data from field surveys are also used as they provide important information about the naturalisation of new exotic species in Belgium and their habitat preferences.

Scientific nomenclature refers either to national (e.g. Flora of Belgium and neighbour areas) or international standards (e.g. Fishbase).

3. Species classification in the BFIS list system

A list system designed as a two dimensional ordination (environmental impact x invasion stage) is used to categorise non-native alien species found in Belgium and in neighbour areas, based on the guidelines proposed by the CBD decision VI/7 and the European strategy on Invasive Alien Species (figure 1).

Environmental impact and invasion stage are assessed for each species by different scientists, based on the methodology described hereafter. Results are discussed afterwards within the group to find a consensus before being published on the internet.

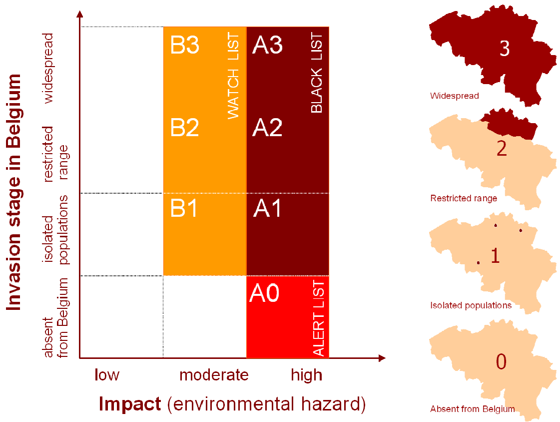

Figure 1 - List system proposed by the Belgian Forum on Invasive Species to identify organisms of most concern for preventive and mitigation actions.

4. Species screening

Not all non-native species are considered to be integrated in the *Harmonia* information system. Only organisms that are already established in Belgium or in neighbour areas characterised by similar eco-climatic conditions (Germany, Ireland, Luxembourg, Netherlands, Northern France, Switzerland and UK; hereafter Western Europe) are taken in consideration[1]. A species is considered as established or naturalised as soon as it is able to reproduce consistently in the wild and sustain populations over several life-cycles through sexual or asexual modes without direct intervention by man (= self-perpetuating populations).

Among the non-native species established in Western Europe, a special attention is given to:

(i) Non-native species that are known to cause adverse impacts on biodiversity and/or ecosystem functioning, including those that already colonised most of their potential habitats;

(ii) Species that recently expanded their geographic range, for which an adverse impact on biodiversity and/or ecosystem functioning is likely.

[1] Non-native species for which there is no evidence of establishment in Western Europe should be evaluated through a specific protocol to assess invasion likelihood. This protocol has to take into account both introduction pathways and potential for establishment in our eco-climatic conditions (see e.g. Baker et al. 2005 and EPPO 2006).

5. Methodology for environmental hazard assessment

A simplified hazard assessment methodology referred to as the Invasive Species Environmental Impact Assessment (ISEIA) was developed to classify non-native species into the BFIS list system and to identify those of most concern for preventive and mitigation actions.

This protocol is intended to allocate non-native species within the different hazard categories of the *Harmonia* information system, as an attempt to minimise the use of subjective opinions and to warrant the transparency and the repeatability of the assessment process (Daehler et al. 2004). The ISEIA protocol consists of four sections matching the last steps of the invasion process, i.e. potential for spread, colonisation of natural habitats and adverse ecological impacts on native species and ecosystems. It has to be noted that this protocol aims to assess environmental risks only and that direct impacts of non-native species on human interests (public health, plant protection, etc.) are not explicitly taken in consideration in the *Harmonia* system, even if adverse ecological impacts frequently induce economic damages in the long term.

Contrary to predictive pest risk assessment protocols mainly based on species' intrinsic attributes for evaluating invasion likelihood (e.g. EPA, EPPO and IPCC standards), the ISEIA approach favours the use of documented invasion histories in previously invaded areas to assess properly their potential to cause adverse ecological effects on the Belgian territory (non native species are likely to cause significant impacts on native species and ecosystems in Belgium if they have already done so in neighbour areas).

The ISEIA protocol allows to allocate species in one of the three following risk categories:

- Category A (black list): includes species with a high environmental risk;
- Category B (watch list): includes species with a moderate environmental risk on the basis of current knowledge;
- Category C: includes other non-native species, that are not considered as a threat for native biodiversity and ecosystems (low environmental risk).

Scoring system

A three point scale is selected for the assessment as it is felt to provide an adequate balance between resolution and simplicity. Providing that information exists and is well documented in the literature (low level of uncertainty), the following scores are used as much as possible for the different parameters,:

- L = low, score = 1
- M = medium, score = 2
- H = high, score = 3

When the parameter is only poorly documented, leading assessment to be based only on expert judgement and field observations, the scoring system is adapted as follows:

- Unlikely, score = 1
- Likely, score = 2

At last, when nothing can be said about the parameter (no information):

- DD = deficient data, no score.

5.1 Dispersion potential or invasiveness

This section addresses the potential of an organism (individuals, seeds, propagules, etc.) to spread in the environment by natural means and/or by human assistance, as a function of dispersal mode, reproduction potential and human commensalism.

The three following situations are recognised:

Low risk. The species doesn't spread in the environment because of poor dispersal capacities and a low reproduction potential. Examples: *Aesculus hippocastanum*, *Zea mays*.

Medium risk. Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. The species can however become locally invasive because of a strong reproduction potential. Examples: *Ameiurus nebulosus, Arion lusitanicus, Robinia pseudacacia, Tamias sibiricus*.

High risk. The species is highly fecund, can easily disperse through active or passive means over distances > 1 km/year and initiate new populations. Are to be considered here plant species that take advantage of anemochory (*Senecio inaequidens*), hydrochory (*Ludwigia grandiflora*) and zoochory (*Prunus serotina*), insects like *Harmonia axyridis* or *Cameraria ohridella* and all the bird species.

5.2 Colonisation of high conservation value habitats

This addresses the potential for an exotic species to colonise habitats with a high conservation value (irrespective of its dispersal capacities), based on habitat preference information from native and invaded areas. This potential is mainly limited by the ability of the new species to establish in habitats with specific abiotic conditions and to outcompete native species that are already present ('biotic resistance').

Habitats with a high conservation value are those where disturbance by man is minimal, thus allowing specific natural communities and threatened native species to occur. Natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers and ponds provided with natural banks and estuaries (see e.g. the list of natural habitats in the Annex 1 of the 92/43/EEC Directive) are considered as habitats with a high conservation value. Parks, orchards, planted forests, fallow lands, road embankments are habitats with an intermediate value. At last, man-made habitats like channels, farmlands or urban areas are classified as sites with a low conservation value.

Scoring system (adapted from the invasive categories of Cronk & Fuller 1995):

Low risk. Populations of the non-native species are restricted to man-made habitats (low conservation value). Examples: *Linepithema humile*, *Setaria verticillata*;

Medium risk. Populations of the non-native species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation value habitats. Examples: *Lepomis gibbosus, Sander lucioperca, Solidago gigantea*;

High risk. The non-native species often colonises high conservation value habitats (i.e. most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species. Examples: *Ludwigia grandiflora*, *Lysichiton americanus*, *Procyon lotor*, *Spartina townsendii*, *Umbra pygmaea*.

5.3 Adverse impacts on native species

This section addresses the potential of exotic species to cause species replacement through different mechanisms. Impacts may include (i) predation/herbivory, (ii) interference and exploitation competition (including competition for plant pollinators), (iii) transmission of diseases to native species (parasites, pest organisms or pathogens) and (iv) genetic effects such as hybridisation or introgression with native species. Such interactions may lead to change in native population abundance or in local extinction. They should be documented from invasion histories within Belgium or other regions characterised by similar eco-climatic conditions.

Exotic species that act as generalist predators or those which have native congeners showing similar eco-morphological traits are especially on target. The different types of interactions are considered separately for each non-native species. Their severity is scored as follows:

Low risk. Data from invasion histories suggest that the negative impact on native populations is negligible;

Medium risk. The non-native species is known to cause local changes (< 80%) in population abundance, growth or distribution of one or several native species, especially among common and ruderal species. This effect is usually considered as reversible. Examples: transmission of sublethal diseases to native species (*Crassostrea gigas, Mustela vison, Sander lucioperca*), predation/herbivory pressure leading to abundance decrease of native species (*Branta canadensis, Nysius huttoni*), moderate competition with native species (*Alopochen aegyptiacus, Pimephales promelas, Senecio inaequidens*);

High risk. The development of the non-native species often cause local severe (> 80%) population declines and the reduction of local species richness[2]. At a regional scale, it and can be considered as a factor precipitating (rare) species decline. Those non-native species form long-standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals (*Fallopia japonica, Prunus serotina, Solidago spp*., etc.), intraguild predation leading to local extinction of native species (*Dikerogammarus spp., Harmonia axyridis, Neogobius melanostomus, Rana catesbeiana*), transmission of new lethal diseases to native species (*Pacifastacus leniusculus, Pseudorasbora parva, Rana catesbeiana, Sciurus carolinensis*).

Species impact score = maximal score recorded for predation/herbivory, competition, disease and genetic interaction sections.

5.4 Alteration of ecosystem functions

This section addresses the potential of an exotic species to alter native ecosystem processes and structures in ways that significantly decrease native species ability to survive and reproduce. Ecosystem impacts may include (i) modifications of nutrient cycling or resources pools (e.g. eutrophication), (ii) physical modifications of the habitat (changes or hydrologic regimes, increase of water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications of natural successions and (iv) disruption of food webs, i.e. a modification of lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

[2] Exotic plants that are known to often form large and dense monospecific stands are considered as a high risk for native plant communities when the potential for species replacement is poorly documented.

Scoring system:

Low risk. The impact on ecosystem processes and structures is considered as negligible.

Medium risk. The impact on ecosystem processes and structures is moderate and considered as easily reversible. Examples: temporary modification of soil or water properties (*Lemna spp*.), decrease or increase of the rate of colonisation of open habitats by shrubs and trees (*Pinus nigra*);

High risk. The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alteration of physico-chemical properties of water by invasive aquatic plants (*Hydrocotyle randunculoides, Ludwigia spp., Myriophyllum aquaticum*), facilitation of river bank erosion (*Impatiens glandulifera*), prevention of natural regeneration of trees (*Lonicera japonica, Prunus serotina, Rhododendron ponticum*), destruction of river banks, reed beds and/or fish nursery areas (*Eriocheir sinensis, Myocastor coypus, Ondatra zibethicus*), food web disruption (*Crassostrea gigas*, *Lates niloticus*).

Ecosystem impact score = maximal score recorded for nutrient cycling, physical alteration, natural successions and food web sections.

Note: When impact is strongly dependent on the type of ecosystem, one should consider the worst case scenario, with a special focus on vulnerable ecosystems.

5.5 Global environmental risk

Consistent with other risk assessment standards, equal weight is assigned to each of the four sections, i.e. dispersion potential, colonisation of natural habitats, species and ecosystem impacts. The global ISEIA score is the sum of risk rating scores from the four previous sections (global score is between 4 and 12). It is used to allocate species to the different risk categories (see table).

ISEIA score	List category
11-12	A (black list)
9-10	B (watch list)
4-8	C

6. Invasion stage in Belgium

In addition to species classification in risk categories, invasion stage is also taken in consideration in the list system as it provides important information to prioritise actions in the field, especially for invasive species which are highly detrimental.

As illustrated in figure 1, a distinction is made between:

(i) Alert list species: species that are not yet naturalised in Belgium but are invasive in neighbour areas. Note that only species with a high environmental impact among non established species are taken in consideration, e.g. organisms from the list of worst invasive alien species threatening biodiversity in Europe (SEBI 2010) or from the priority list of invasive alien plants to be managed in EPPO member countries. Importation and trade regulation are the adequate tools to avoid intentional introduction of alert list species in our country;

(ii) Species under naturalisation (isolated populations): species that are at the prime stage of the invasion process in Belgium, that only form recent and small isolated populations located in the immediate vicinity of their introduction points, resulting in a non contagious or random distribution of the observations. These species only colonised few of their potential habitats in the country and can still be eradicated at a national scale at a very low cost corresponding to the damage they can cause in the future if no action is undertaken;

(iii) Naturalised species with a restricted range: species whose populations are in strong expansion in the wild and form new populations far away from their introduction points after an active dispersion phase, but whose distribution is still limited to some biogeographic areas in Belgium. Those species are likely to be contained in some regions of the country providing that active control measures are undertaken;

(iv) Widespread naturalised species: species that are widely distributed in the country and that already colonised most of suitable sites for their establishment.

7. List of contributors

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Contributors: Sonia Vanderhoeven, Wouter Van Landuyt, Fabienne Van Rossum, Filip Verloove (vascular plants); Nancy Fockedey; Francis Kerckhof (marine organisms), Tim Adriaens, Patrick De Clercq, Wouter Dekoninck, Jean-Claude Grégoire (insects); Dieter Anseeuw, François Lieffrig, Jean-Claude Micha, Denis Parkinson, Jean-Claude Philippart, Hugo Verreycken (fishes), Anny Anselin, Diederik Strubbe, Anne Weiserbs (birds), Margo D'aes, Benoît Manet, Grégory Motte, Vinciane Schockert, Jan Stuyck (mammals).

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Appendix – List allocation of some non native species through the ISEIA protocol

	5.1	**5.2**	**5.3 – Impact on native species**				**5.4 – Impact on ecosystems**				**ISEIA**	**LIST**
	Spread	Natural habitats	Predation	Competition	Disease transm.	Hybridisation	Nutrient cycling	Physical alter.	Successions	Food webs	**SCORE**	
Aix galericulata	high	high	low	likely	DD	low	low	low	low	low	**9**	**B**
Cameraria ohridella	high	medium	low	low	low	low	low	low	low	DD	**7**	**C**
Carassius gibelio	high	high	low	high	low	high	medium	high	low	high	**12**	**A**
Crassostrea gigas	high	high	low	high	medium	likely	likely	high	low	high	**12**	**A**
Epilobium ciliatum	high	high	low	unlikely	low	medium	DD	low	low	low	**9**	**B**
Eriocheir sinensis	high	high	high	likely	DD	low	DD	high	low	likely	**12**	**A**
Harmonia axyridis	high	high	high	high	low	low	low	low	low	likely	**11**	**A**
Ludwigia grandiflora	high	high	low	high	low	low	high	high	high	low	**11**	**A**
Ondatra zibethicus	high	high	high	DD	DD	low	medium	high	high	likely	**12**	**A**
Pacifastacus leniusculus	high	high	medium	high	high	low	low	low	low	likely	**11**	**A**
Procyon lotor	high	high	likely	DD	DD	low	low	low	low	low	**9**	**B**
Robinia pseudacacia	medium	medium	low	high	low	low	high	high	high	low	**10**	**B**
Sciurus carolinensis	high	high	medium	high	high	low	low	medium	low	likely	**11**	**A**
Tamias sibiricus	medium	high	medium	likely	DD	low	low	low	low	likely	**9**	**B**
Umbra pygmaea	medium	high	low	medium	DD	low	low	low	low	low	**8**	**C**

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