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Population dynamics and whereabouts of ducks ringed in The Netherlands

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Preface

I enjoyed the many months in which I analyzed the data, because it provided me with a continuous learning experience. I learned one programming language and paradigm after another. I felt able to contribute to better global communication, because I applied international standards and open source software development in a new area. I learned about the different people and agencies involved in this research area, albeit step by step and with some bumps in the road. Hopefully I contributed something useful to their work.

I was supervised by almost ten supervisors from five organizations, each with their own style and preferences. That took a while to get used to. Adding to the complexity was my completely different background. I am a physicist working on ecology. That is a great combination, but they are still very different worlds. I hope I have been able to satisfy everyone involved.

I would like to thank the WREN and in particular Désiré Karelse and Fons Mandigers. They provided me with this opportunity and also with information about the Dutch duck decoys. In addition they organized a very successful meeting in March, where I was able to present and discuss my results with experts. I would like to thank Hans Schekkerman (Vogeltrekstation) for introducing me to the data and for his feedback along the way. Two of my friends were also of great assistance. Ben Lenarts provided technical assistance for the demonstration website. Jaco Schipper took the time to read my report from a complete outside perspective; he is an economist. Martin Wassen (Environmental Sciences, Utrecht University) provided me with very useful feedback at the start and near the end of my work. Thanks in advance to Stefan Dekker (Environmental Sciences, Utrecht University) for being the official second reader. Ariëtte Dommering of the Kennispunt Bètawetenschappen (Utrecht University) has taken care of an important part of the communication behind the screens. Marcel Klaassen (Dutch Institute for Ecology) was my direct supervisor and I would especially like to thank him for being able to deal with my slightly non standard work style. He also provided me with very detailed useful feedback on the draft versions of this report. Last but not least I met a lot of friendly, nice and interesting people at the Dutch Institute for Ecology in Nieuwersluis, where I spent most of my time this year.

Sjors Provoost
April 2008, Utrecht

Nederlandse Samenvatting

Al decennia lang worden er eenden in eendenkooien geringd en elders weer teruggevonden. Inmiddels is een uniek en omvangrijk databestand opgebouwd van jarenlange terugmeldingen uit het hele Euraziatische areaal. Hiermee zijn bijv. meer dan 250 verschillende ringers, waarvan waarschijnlijk ca. 150 kooiker, actief geweest. Deze hebben sinds 1958 ca 94.000 ringen omgedaan.

In 2006 is de Werkgroep Ringwerk Eendenkooien Nederland (voorlopige naam WREN) opgericht met het doel het ringwerk in eendenkooien aan evaluatie te onderwerpen en dit voort te zetten op basis van een actueel en wetenschappelijk verantwoord onderzoeksprogramma. In samenwerking met het Kennispunt Bètawetenschappen van de Universiteit Utrecht en het Nederlands Instituut voor Ecologie (NIOO) is er een studentenproject opgestart. Onder begeleiding van prof. dr. Marcel Klaassen (vakgroep Landschapsecologie, departement Biologie, faculteit Bètawetenschappen van de Universiteit Utrecht) en drs. Hans Schekkerman (NIOO, Vogeltrekstation) is Sjors Provoost met de afstudeeropdracht aan de slag gegaan.

Dit onderzoek analyseert, met behulp van moderne computertechnieken, de database met ringgegevens van 150.000 eenden die sinds 1911 in Nederland zijn geringd en waarvan bijna 40.000 terugmeldingen bekend zijn. De centrale vraag bij dit onderzoek is welke functie en betekenis ringdata van watervogels uit eendenkooien hebben en/of nog kunnen krijgen.

Het was overigens nog een hele puzzel om uit de data op te kunnen maken welke eenden wel en niet in een kooi geringd zijn en hier zit nog steeds een zekere mate van onderzekerheid in omdat kooivangsten nooit als aparte categorie in de databestanden zijn opgenomen. 95% van alle in Nederland gevangen smienten tussen 1958 en 2007 zijn waarschijnlijk in kooien gevangen. De smient komt tot 1945 nog nauwelijks in de database voor, maar wordt daarna steeds vaker gevangen. Na de jaren zestig neemt dit weer af om tussen 1985 en 1995 weer plotseling sterk op te leven. Zoals al bekend was, overwintert de smient graag in onze regio, maar ze overwinteren ook in het zuiden van Frankrijk, Groot Brittannië en Ierland. Wat vooral opvalt is dat een eend die de ene winter nog in Nederland een ring gekregen heeft, niet noodzakelijkerwijs hoeft terug te komen in Nederland. 32% van de smienten wordt teruggevonden in Nederland, onder de nogal gewaagde aanname dat de terugmeldkans voor alle landen hetzelfde is. In mei zijn de smienten tot aan de Jenisej rivier in Siberië en tot ver boven de poolcirkel terug te vinden.

Uit de ringgevens kan ook een indruk verkregen worden van de snelheid waarmee eenden zulke grote afstanden afleggen. Enerzijds zijn er wat anekdotische recordsnelheden van honderden kilometers per dag. Als we echter naar de gemiddelde snelheden kijken voor die eenden die binnen hetzelfde seizoen teruggevonden zijn als dat ze geringd zijn, dan worden er slechts enkele tientallen kilometers per dag afgelegd. Dit maakt duidelijk dat de snelheid van migratie niet alleen uit de vliegsnelheid bestaat maar ook uit de snelheid waarmee lichaamsreserves worden aangelegd om de vluchten te volbrengen.

Als men alleen op de database afgaat lijken uiteindelijk vrijwel alle smienten in alle landen de dood tegemoet te vliegen. Schijn bedriegt hier waarschijnlijk, omdat het nou eenmaal veel makkelijker is om een dode smient terug te melden dan een levende.

Kortom, het ringwerk in de kooien levert een interessant beeld op van wat er met de eenden gebeurt en zonder de kooien zou er nu bar weinig data zijn. Het is echter wel tijd voor een nieuwe aanpak. De huidige aanpak is nog gebaseerd op het pionierswerk van Christian Mortensen die in 1907 graag wilde weten waar vogels heen gingen (Where do ducks fly?). Overigens deed hij dat met 100 zelfgemaakte ringen en kocht vervolgens 100 talingen van de Deense kooikers om deze, tot verbazing van deze kooikers, weer los te laten. Er werden er zestien van teruggemeld o.a. uit Nederland. Inmiddels hebben we daar een redelijk beeld van en wordt het tijd om meer specifieke vragen te stellen en het ringproces daarop aan te passen. Daar is de WREN in samenwerking met diverse belanghebbenden dan ook mee aan de slag gegaan.

De eenden die geringd worden vormen een onderdeel van een groter geheel, namelijk alle eenden. Het is daarom belangrijk om deze aantallen in perspectief te kunnen zien. Daarvoor zijn bijvoorbeeld de tellingen van SOVON van belang, maar ook de totale vangsten afschotcijfers. Als men bijvoorbeeld de invloed van jacht wil bepalen op de groei van de populatie, onder andere met behulp van ringgegevens, dan is het noodzakelijk om te weten hoeveel eenden met ring, maar ook hoeveel eenden zonder ring geschoten worden. Op die manier kan zelfs een eend die nooit geringd is, van betekenis zijn en waardevolle informatie leveren.

Watervogelonderzoek in combinatie met ringwerk (o.a. populatiedynamica) zal naar verwachting van grote betekenis zijn voor onderzoek naar op de mens overdraagbare (dier-)ziektes (zoönoses), klimaatverandering (global change) en dergelijke. Hierbij valt te denken aan ringen, biometrie, nemen van monsters, swaps, verenonderzoek, zendering e.d. Spreiding van herkomst van gegevens, nauwkeurigheid en standaardisatie zijn daarbij van belang. Meer kooikers en eendenkooien zullen in de toekomst benodigd zijn om dit tot een succes te maken.

Tot slot zit er toekomst in het aan elkaar koppelen van alle internationale data en meer internationale samenwerking bij het ringwerk. Hoewel er al veel samengewerkt wordt, maken de huidige databanken en meetprogramma's nu nog een onderscheid tussen landen die de eenden zelf niet maken.

Chapter 1

Introduction

1.1 Background

In 1899 Christian Mortensen wanted to know where birds fly. He came up with a method to find out and began to put rings with a unique identifier on birds. He then waited for people to report them back to him. A century later there are more ways to track a bird, but ringing is still most common. Birds of many different species are ringed, including several duck species like the mallard, wigeon and teal. What distinguishes bird ringing from other, equally important, research methods available to ecologists is that a ring makes it possible to follow an *individual* animal in time and space. Because it is currently more affordable than tracking a duck with a satellite transmitter, rings can be applied to a very large number of birds. Before a bird can be ringed, it needs to be captured alive. Many bird species are caught in nets or by other means. For ducks a suitable catchment method already existed long before Mortensen ringed his first bird. In The Netherlands and Great Britain, ducks are caught and ringed in duck decoys. A duck decoy (*eendenkooi*) is a pond of water in a quiet nature area that attracts many ducks. Once in the pond, the duck is lured into a trap and captured. In the past all captured ducks were eaten, but a significant part of them is now given a ring. The decoyman (*kooiker*) puts a uniquely marked ring on a duck. He or she records data such as location, date, species, gender and age. He releases the duck and sends the data to the Dutch Center for Avian Migration and Demography *Vogeltrekstation Arnhem* (VTS), which stores it in a database. There are hundreds of thousands of ducks in The Netherlands. Hundreds, sometimes thousands, of those ducks are ringed every year and this has been going on for over 70 years now. Often a duck is seen again some time after ringing, sometimes as far away as Finland or Siberia. Hundreds of people, including hunters and volunteers, inform the VTS when they recapture or recover a duck. The result of this effort is a database that contains data on over one hundred forty thousand ducks, thirty thousand reports from dead recoveries and seven thousand live recaptures.

Recently a Dutch NGO was created with the objective to take the ringing effort in the Dutch duck decoys to the next level: The Dutch Group for Ringing in Duck Decoys *Werkgroep Ringwerk Eendenkooien Nederland (WREN*). It facilitates communication between researchers and decoy operators. First it wants to know what can be learned from the data that is collected so far. Then it wants to know how the ringing process can be improved to make the data even more valuable and how it can answer future research questions.

The Dutch duck data has not been analyzed for a while. Donker (1959) analyzed the results for wigeon and Wolff (1966) for teal. I analyzed the data of all ducks that were captured between 1936 and 2006 in The Netherlands. I focused mainly on the species that are most often caught in duck decoys. I created an overview of the main spring and winter destinations of teal, wigeon and mallard. I found out how many ducks were recovered dead and how many were recaptured alive. I analyzed how that depends on the country and time of the year. I have also compared different methods for calculating migration speed. Finally I calculated the yearly survival chance of several species. When I discuss these results, I consider what changes in the ringing process and what additional data can lead to new insights about three issues.

The first issue is the impact of hunting policy on population dynamics. Because ducks migrate, the hunting policy of one country can have an effect on the population in another country.

The second issue is the impact of global change such as climate change and population growth on population dynamics. Can long term changes be found in the population dynamics of the different duck species, such as migration routes through Europe. If so, can we link these changes to climate change or human population increase?

Finally, the third issue is the spread of zoonoses such as avian influenza. Duck species like the mallard potentially transport these zoonoses while migrating. If we understand their migratory behavior we can better predict the spread of zoonoses.

For each of these three issues duck ringing provides a unique opportunity, because it allows researchers to follow a large number of individual ducks on their journeys.

1.2 Aim and research questions

The aim of this research is to obtain from the database information about the migration of duck species that visit duck decoys and discuss possible future strategies.

I have addressed the following ecological questions.

- How many species and (re)captures are in the database?
- What is their distribution of sex and age?
- What is the specific contribution of duck decoys to this data?
- How many ducks remain in the Netherlands and to which countries do the others fly?
- What is their maximum flight speed?
- At what pace do they migrate over long distances?
- What percentage is recaptured alive and how many are shot?
- What is the probability of an individual to survive from one year to the next?

When I discuss the results, I will suggest new opportunities for research and what changes to the ringing protocol, or additional data, would be required for them.

Chapter 2

Methods

2.1 Data processing

I obtained a database with ring data from the Dutch Ringing Center. That database is over 70 years old. Hundreds of volunteers have contributed to its data. Its infrastructure started out as simple letters, was then upgraded to punch cards and later upgraded to a database on a computer. Challenges were to be expected and I encountered many. I decided to redesign the database structure and so managed to overcome many of these challenges. In the process, I built a website http://ducks.sprovoost.nl/ to make the results available to a wider audience. It shows the figures in this report and allows anyone to compare results for different species, including species that this report does not deal with.

Appendix A explains the above in greater detail. In addition, the source code of the entire analysis is available at http://code.google.com/p/ducks-on-rails/. The ring data itself must be obtained through the Dutch Ringing Center in Heteren.

2.2 Captures and recoveries, sex and age distribution

I used the database to determine the total number of captures since 1958 for teal, wigeon and mallard. The database is incomplete for the years 1936 to 1957. For that period I found the yearly number of captures in historical Limosa journals (Dutch Ornithologist Union, http://home.planet.nl/~boude112/limosa/limosa.htm). I determined the male - female ratio as well as the age distribution at the time of ringing. The database contains information about the condition of a duck upon its recapture as well as the method of recapture. For The Netherlands, France and Russia I calculated the historical monthly number of live recaptures and dead recoveries.

2.3 Contribution of decoys to duck catching

In order to assess the contribution of duck decoys to the ringing effort, I investigated which ducks in the database were ringed in decoys. Because the method of catchment was not recorded in the database, this was not trivial. For most but not all of the rings, the names and addresses of past and present ringers were stored in a table that I obtained from the Dutch Ringing Center (VTS). In that table it is sometimes recorded wether or not the ringer is a decoyman. If a ringer was a decoyman I assumed that all ducks ringed by him or her were ringed in a duck decoy. For past ringers in the period of 1984 to 1989 I used a list of ring permits and names of decoymen from the Dutch Ministry of Agriculture (Ministerie van Landbouw en Visserij (1989)). I matched the names in the list to the the names from VTS. For the remaining ringers as well as for captures without ringer information I compared the coordinates of duck decoys to the coordinates of ringing. Van der Heide and Lebert (1944) and Haverschmidt (1931) have made an inventory of decoys in the 1930s and 1940s. J.J.H.G.D. Karelse (WREN) provided me with a more recent inventory of decoys and their coordinates (2004, unpublished data). It did not contain the names of decoymen, however, but because the location of most captures was recorded, I could match them to captures by means of their coordinates. I calculated the distance between each capture and the nearest duck decoy. If this distance was less then 12 kilometers, I considered the capture to be a decoy capture. I also used criteria to determine when a ringer was *not* a decoyman: any ringer who ringed less then 20 ducks in a lifetime or only young ducks (H. Schekkerman, personal communication). Finally I compiled a list of ringers for whom, with the criteria above, I could not determine whether they were decoymen. I sent this list to two members of the WREN (J.J.H.G.D. Karelse & F. Mandigers) and they were able to identify an additional number of decoymen. I was now able to determine for each individual capture whether it likely took place in a decoy or not.

2.4 Destinations

On a map of Europe I plotted the locations of ducks that were recaptured or recovered in May and that were first captured and ringed in the Netherlands, at any time of the year. The capture and recapture / recovery did not need to have been in the same year. I repeated the procedure for ducks that were recaptured / recovered between November and February of any year. I created those maps with the Generic Mapping Tools (open source collection of tools for manipulating geographic data sets http://gmt.soest.hawaii.edu/).

2.5 Speed

I considered three different types of speed, where speed is defined as the distance (in kilometers) between a capture and a subsequent recovery divided by the time (in days) between them. *Maximum flight speed* is the maximum speed recorded in the database. I calculated the average speed at which ducks can fly for a short period of time: the *short trip speed*. For that, I considered all flights of more than 50 kilometers that took less than three days. I chose to include three days to allow for sufficient sample size. *Migration speed* is based on the work by Hilden and Saurola (1982) and Ellegren (1993) and uses the following criteria:

- Time between capture and recovery 75 days or less
- Recovery north of capture in spring, south in autumn
- Autumn flights from August until November
- Spring flights from April until June

- At least 50 kilometers
- Date known precisely
- Speed at least 10 km / day

2.6 Survival rate

I determined the number of recoveries as a function of the time since capture in order to estimate the yearly survival probability of wigeon, teal and mallard. If one captures and rings 1000 ducks in a certain year and assumes that the number of recoveries in the following year depends only on the number of ducks still alive, the survival chance between two consecutive years is given by:

$$p_{survival} = \frac{recoveries_{year=2}}{recoveries_{year=1}}$$

So if 50 birds are recovered in the first year after ringing and 25 in the second year, the annual survival chance of each individual bird is 50%. To calculate the survival chance for several consecutive years, I plotted the natural logarithm of the yearly number of recoveries and calculated the slope with linear regression. The survival chance is then given by:

$$p_{survival} = e^{slope}$$

If the uncertainty of the slope is $\delta slope$, the uncertainty in the survival chance (δp) is given by:

$$\delta p_{survival} = e^{slope + \delta slope} - e^{slope}$$

For each species in this analysis I grouped all ducks that were recovered within a year of the first capture, two years from first capture, etc. So a duck that is first captured in 1960 and then recaptured in 1962, was added to the same group as a duck that is first captured in 1988 and then recaptured in 1990. Because I considered only relative years in stead of absolute years, this adds the assumption that the survival rate is constant over all years. The quality of this estimation depends on the absolute number of birds that are recovered each year. I have only included years with at least 10 recoveries which amounts to 4 years for mallard, 8 years for wigeon and 7 years for teal.

Chapter 3

Results

3.1 Captures and recoveries, sex and age distribution

Since 1936 teal was ringed 55,851 times, wigeon 26,570 times and mallard 34,118 times. The capturing pace for all species shows great variation in time (figure 1). Although teal and mallard were already being ringed before World War II, ringing really took off in the 1950s. A sharp decline can be seen in the 1960s. At that time the ringing center had requested to stop monitoring mallards and so mallard captures do not reach significant numbers again until the late 1990s. Teal and wigeon captures recovered more quickly, although they never reached the same level as in the 1950s.

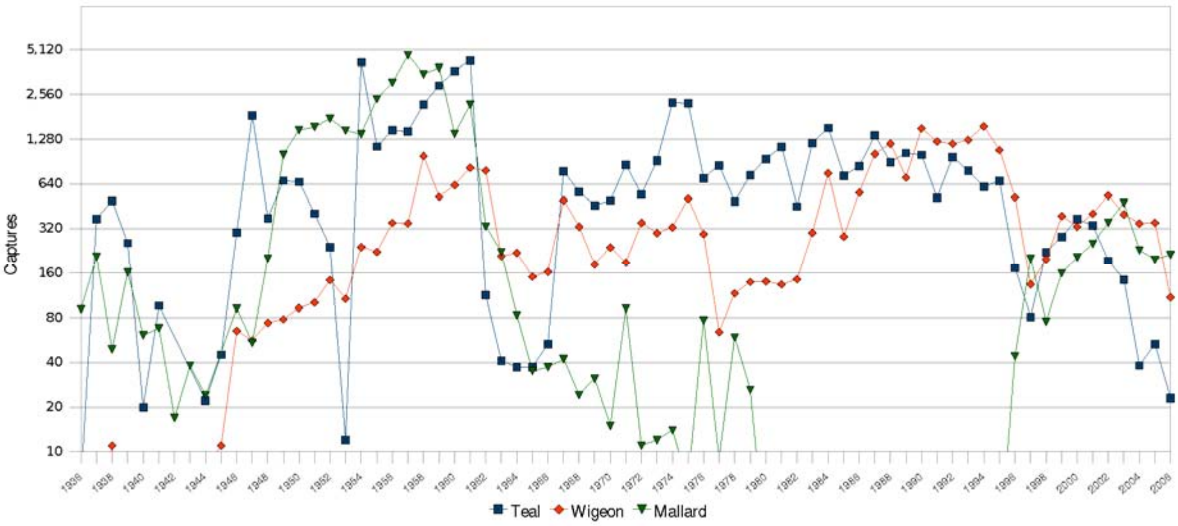

Figure 1: Number of initial captures in The Netherlands per year. Based on the Limosa journals from 1936 to 1958 and the database after 1958.

It often takes several years before a ringed duck is seen again. The average time between ringing and the first time it is recaptured or recovered is 1097 days; of those that are found, 22% are found within 100 days, 70% within three years.

More female than male teals were ringed and more male than female mallards and wigeons. For approximately 20% the sex was not determined (figure 2).

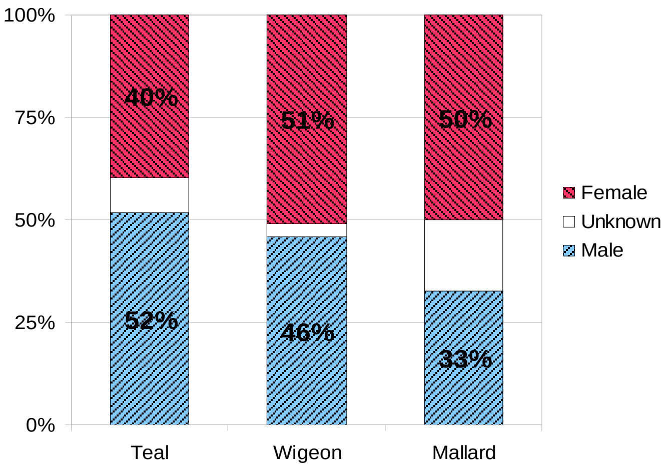

Figure 2: Sex ratio for teal, wigeon and mallard that were ringed in The Netherlands between 1958 and 2006.

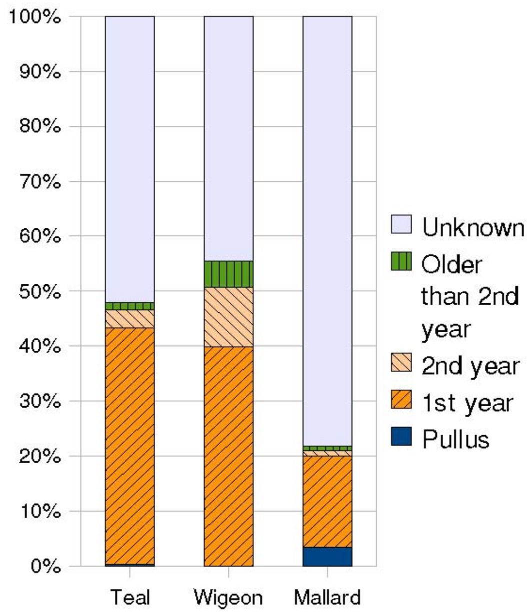

Figure 3: Age distribution for teal, wigeon and mallard that were ringed in The Netherlands between 1958 and 2006.

For 99% of all ducks, the age was noted at ringing. However in many cases it was not recorded very precisely. In such cases it was only noted that a duck was "not a pullus" or "older than first calendar year" (figure 3). The percentage of ducks for which the age was determined precisely, i.e. *pullus*, *first calendar year* or *second calendar year*, is 44% for teal, 51% for wigeon and 25% for mallard. Most ducks for which the age was determined were ringed in their first calendar year. In The Netherlands a small percentage of the ringed wigeon, teal and mallard is recaptured alive (figure 4a). In France (figure 4b) and Russia (figure 4c) however, almost none are. When ducks spent autumn and winter in The Netherlands and France the maximum number of recoveries occurred there. In spring and autumn, when they were flying to or back from their breeding grounds, they were often recovered in Russia.

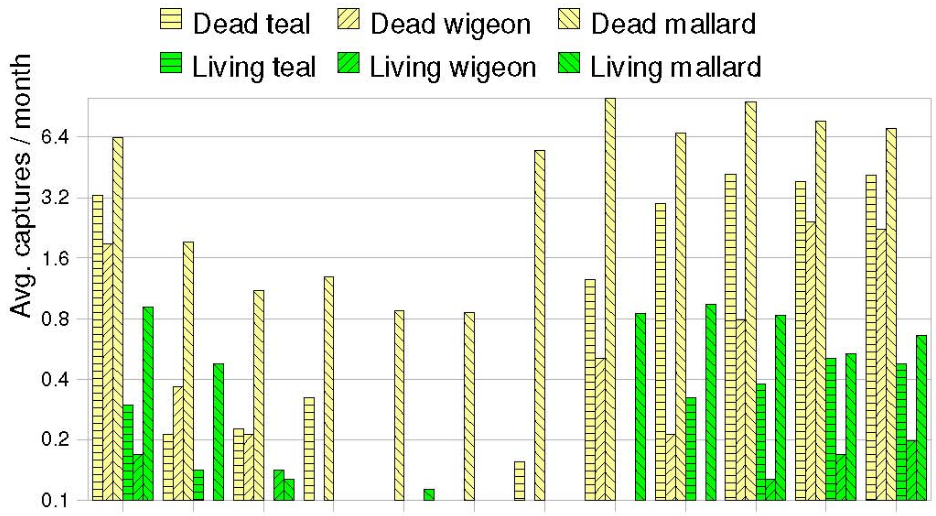

Figure 4a: The Netherlands

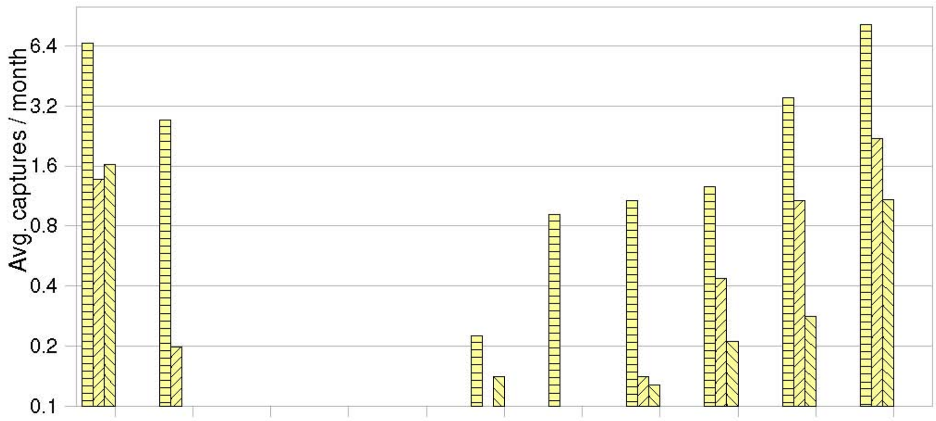

Figure 4b: France

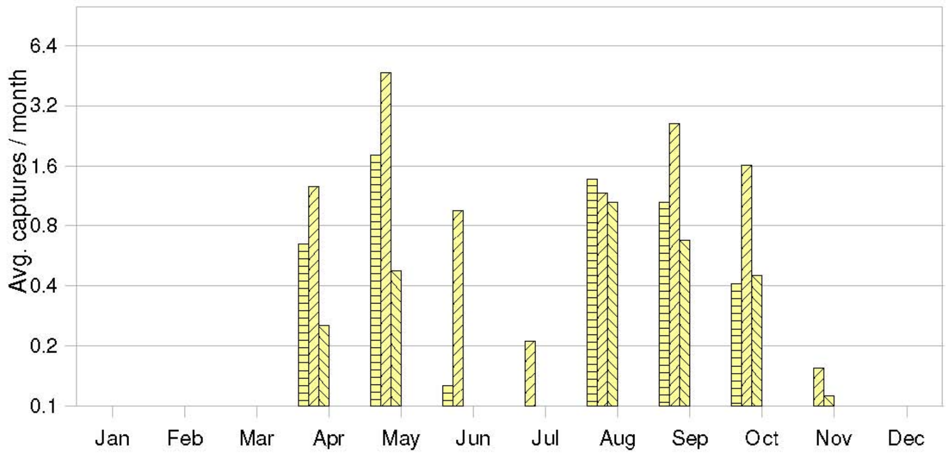

Figure 4c: Russia

Figure 4a, 4b, 4c: Recaptures and recoveries of ducks that were initially captured in The Netherlands. For The Netherlands, France and Russia they show the average number of captures per month between 1936 and 2006.

3.2 Contribution of decoys to duck catching

Pintail, northern shovelers, wigeon and garganey are almost exclusively caught in duck decoys (figure 5). Also the majority of teal and mallards are caught in decoys. Tufted duck and common eider were usually caught by other means.

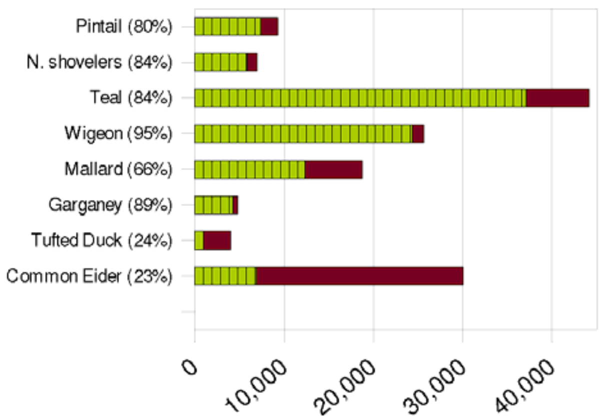

Figure 5: Estimated number of captures after 1958 in a duck decoy (dashed) and by other means (solid)

Teal is mostly caught in decoys near the main Dutch rivers and on Texel, but caught by other means east of Lake IJssel (figure 6). Wigeon is almost exclusively caught in duck decoys and most captures take place near the three major rivers. Mallard is caught all over the country except in the far south. There are many places where it is not captured in decoys.

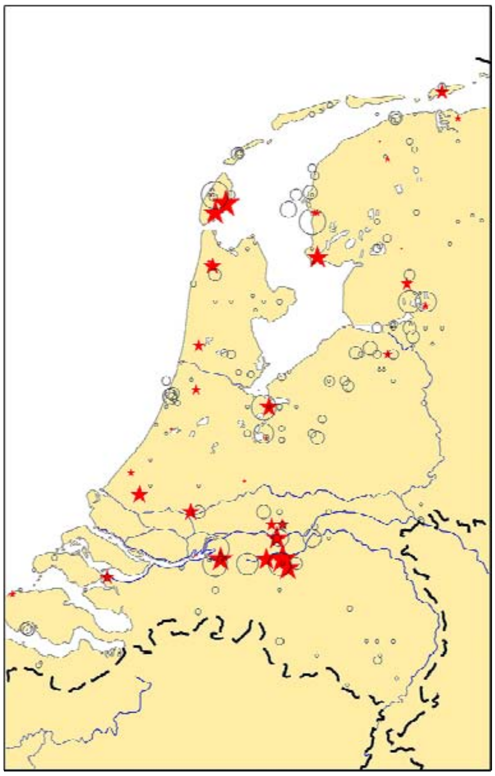

Figure 6a: Teal

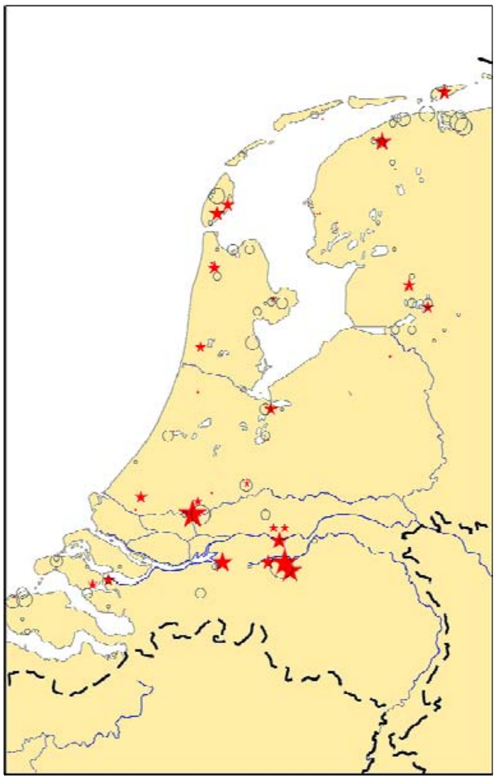

Figure 6b: Wigeon

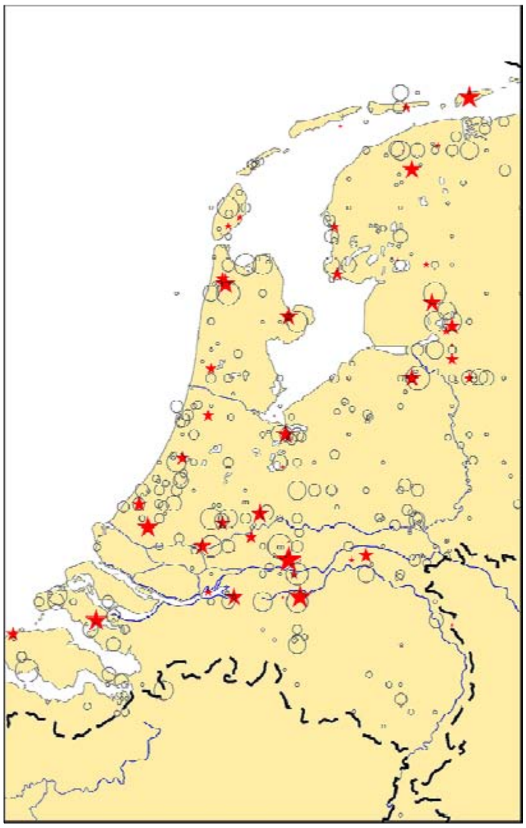

Figure 6c: Mallard

Figure 6: Duck captures in decoys are shown as (red) asterisks. Captures by other means as (black) circles. The size of asterisks and circles increases with the base 10 logarithm of the number caught.

The three most active decoys of the last decade are the Bakkerswaal in Lekkerkerk, Rhoon and the Nieuwe Kooi in Vught. Together they account for 68% of all teal, wigeon and mallard captures between 2000 and 2006. They captured ducks mostly in autumn and winter (figure 7, see next page) and hardly in spring and summer.

3.3 Destinations

Recaptures and recoveries occur both in the same year as ringing as well as in later ones. In winter most teal ringed in the Netherlands are reported back from the United Kingdom, Ireland, The Netherlands, western and southern France (figure 8a). Recaptures from Finland and North West Russia are mostly from May when the birds are en route to their breeding destination. In wigeon a largely similar pattern can be observed (figure 8b), but in May it travels further east than teal; large numbers are found as far north east as the Jenisej river in Siberia. In contrast to teal and wigeon, the majority of mallard recaptures takes place in the Netherlands (figures 8c and 9).

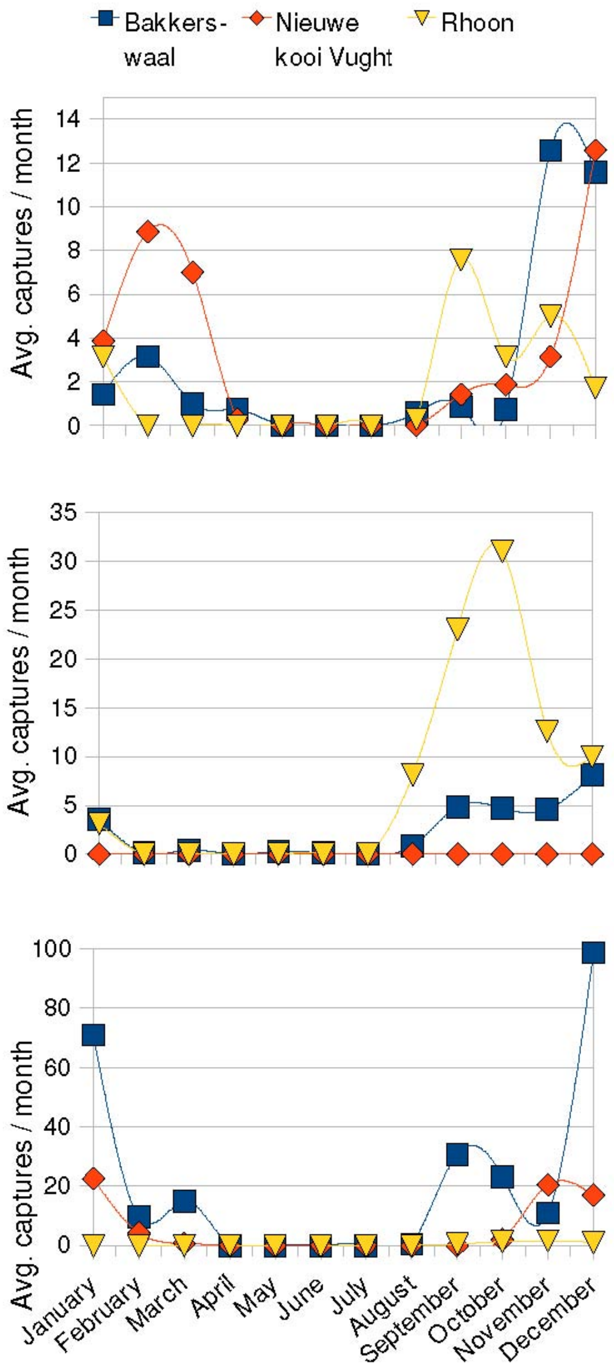

Figure 7: Average number of monthly captures of teal, wigeon and mallard in the three most active decoys between 2000 and 2006.

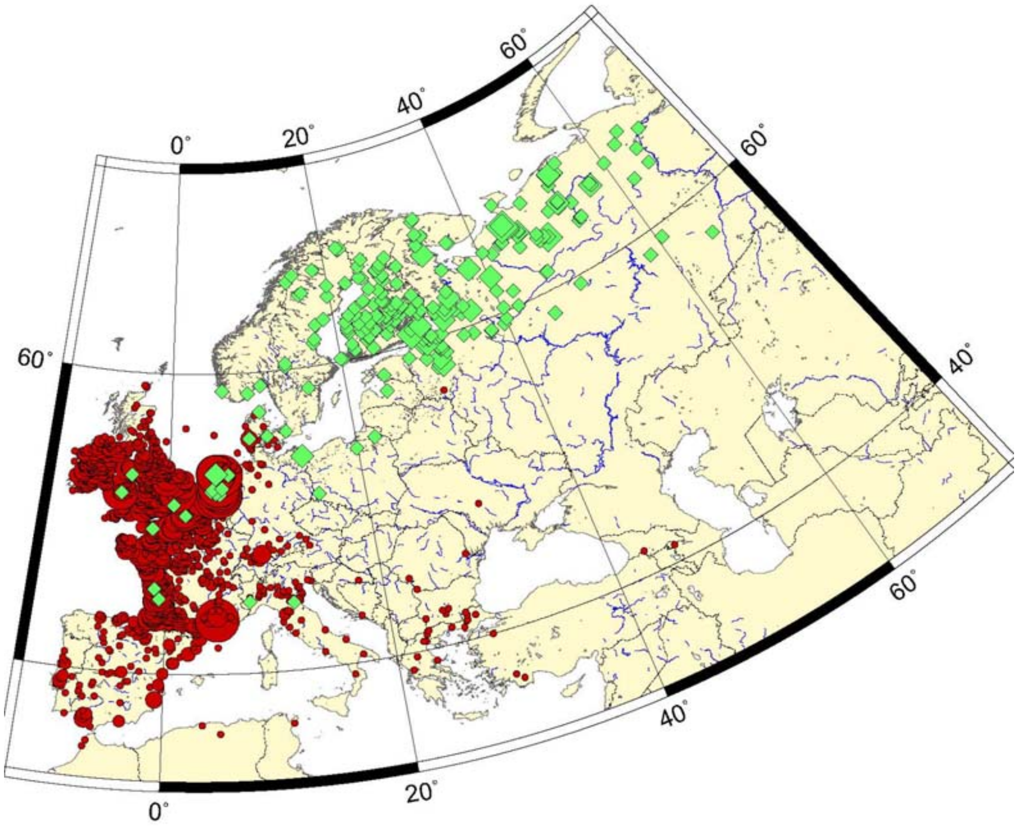

Figure 8a: Teal

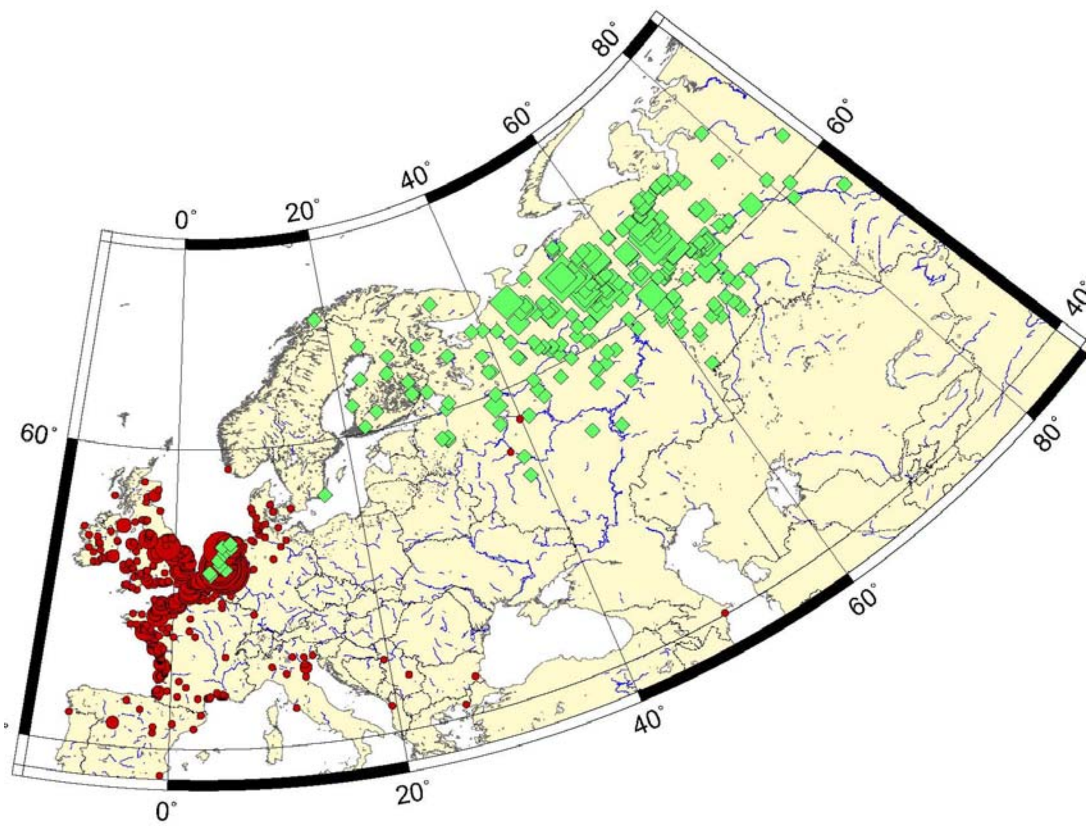

Figure 8b: Wigeon

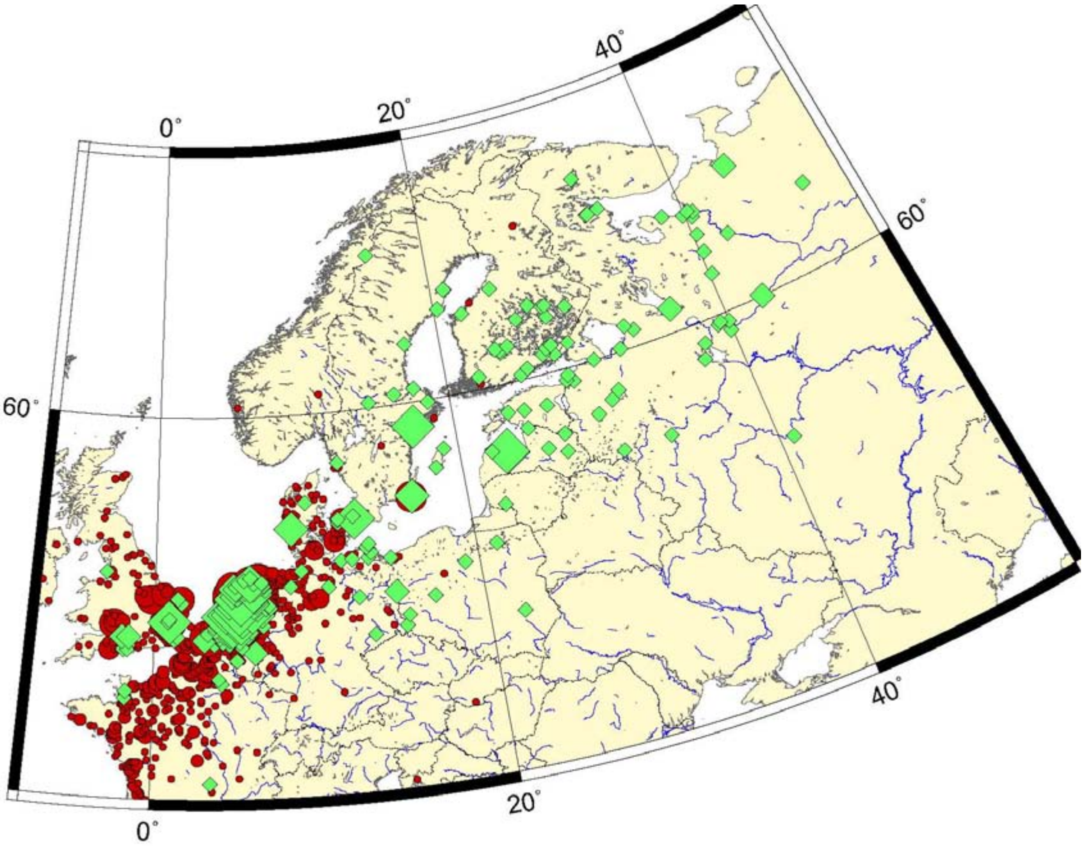

Figure 8c: Mallard

Figure 8: Recaptures and recoveries of three common ducks species in Europe since 1911. Ducks were captured in The Netherlands in any part of the year. The dark (red) circles represent ducks reported back from November until February. The light (green) diamonds represent recaptures and recoveries in May. The size of the symbols increases with the base 10 logarithm of the number caught. The diameter of the diamonds is twice that of the circles for the same number of captures, to improve visibility. May captures are put on top of the winter captures.

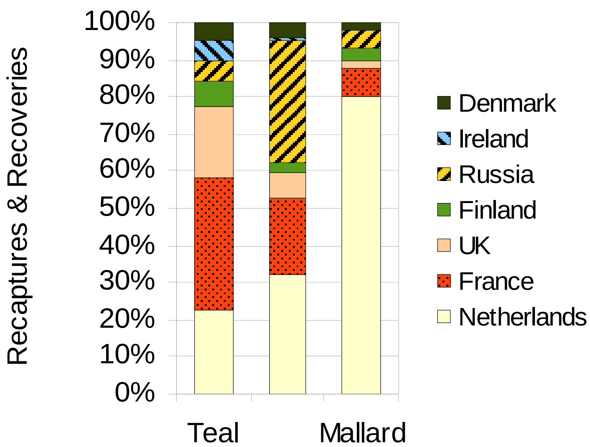

Figure 9: The most common countries where these species are recaptured and recovered.

3.4 Speed

Of the seven duck species considered, northern shovelers, pintail and teal are the fastest; at least one individual duck of these species has travelled 400 kilometers in a single day (figure 10a). The fastest gadwall, mallard and wigeon have travelled at half this speed. When all flights of more than 50 kilometers that took less than three days are considered (*Short trip speed*, figure 10b), a similar pattern emerges, but at lower speeds. Northern shovelers, pintail and teal are the fastest. Gadwall and garganey have almost closed the gap, but mallard and wigeon are still relatively slow. The northern shovelers autumn *migration speed* is clearly much higher than that of the other species. The distribution of maximum and short trip speeds does not apply here (figure 10d). The speed distribution for spring migration is unclear because of the lower sample size (figure 10c).

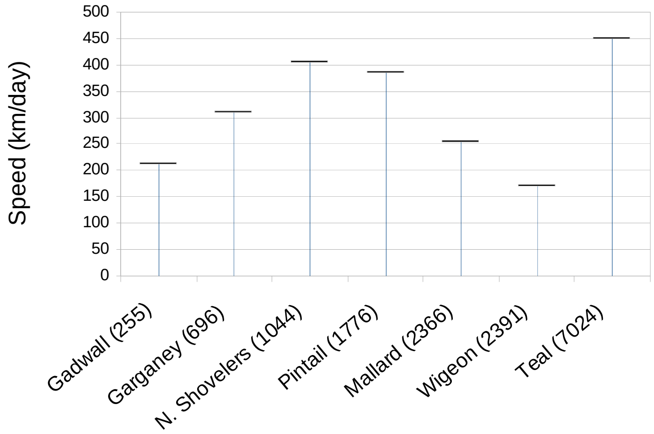

Figure 10a: Maximum speed

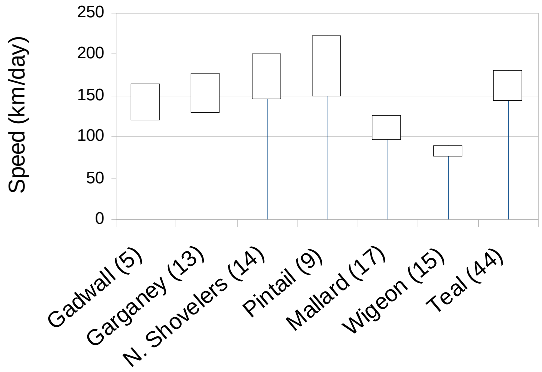

Figure 10b: Short distance

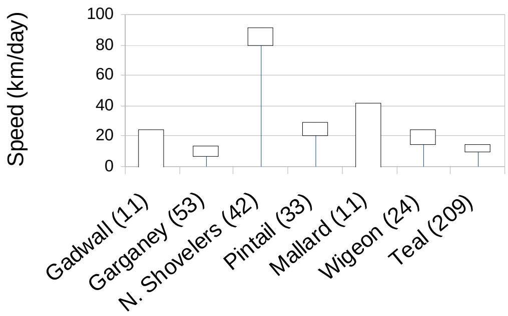

Figure 10c: Autumn migration

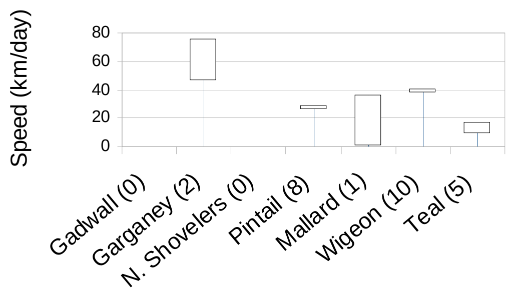

Figure 10d: Spring migration

Figure 10a shows the maximum speed recorded in the database for each species. The number in brackets is the total number of recaptures of the species. Figure10b shows the average speed of all flights that took three days or less. The number of flights is given in brackets. Figures 10d (spring) and 10c (autumn) show the average speed of all flights that meet the criteria set by Hilden and Saurola (1982). The number of flights that met the criteria are given in brackets. All figures consider flights that departed from The Netherlands between 1936 and 2006.

3.5 Survival

The yearly survival chance estimates were based on the slope in figure 11. They are 0.54 ± 0.015 for teal (first 7 years had more than 10 recoveries each, 1354 total), 0.64 ± 0.02 for wigeon (first 8 years, 1870 recoveries) and 0.53 ± 0.1 for mallard (first 4 years, 115 recoveries).

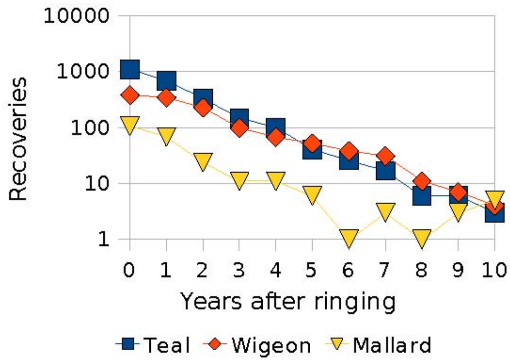

Figure 11: For all teal, wigeon and mallard that were ringed in The Netherlands between 1936 and 1996 this figure shows the number of ducks that were recovered in the year of ringing, the first year after ringing, etc., up to ten years.

Chapter 4

Discussion

Now that I have answered the ecological questions introduced in chapter 1.2, I will discuss how these results can contribute to research on hunting policy, zoonoses and global change.

4.1 Future research on the impact of hunting policy

The hunting policy of one country can have an effect on the population in another country. Hunting could have no effect, it might be a threat to the survival of a species or it might be necessary to maintain a desired population size. Ring research can contribute to the investigation of this effect, even more so when data from all countries is combined. Simply put the impact of hunting on population size follows from the equation below and ring research can contribute to its last two terms:

pop. inc. = births - natural death - hunt

The total number of killed ducks in a country (*hunt*) can be estimated from the number of recoveries in that country (figure 4). For this we need to know what fraction of the total duck population has a ring and where the ducks are from (figures 8 and 9). A calculation based on this data can then be compared to other hunting statistics. The *natural death* term can not be calculated directly from the ring data, but the sum of the natural death and hunt term can. This sum is related to the yearly survival chance of individual ducks (figure 11).

4.2 Future research on zoonoses

If some duck species transport zoonoses such as H5N1, we need to know *where* ducks fly, how *fast* they move and if they are *loyal* to one particular site. Donker (1959) also plotted the recoveries of Dutch wigeons in Europe. He found concentrations of recoveries in the same areas as I did (figure 8), for both winter and spring. We can safely conclude that many ducks visit the places that show a high concentration of recoveries. To obtain more quantitative information about the whereabouts of ducks, we need to study factors that determine the probability of a capture, such as the local duck population density, human population density and hunting policy.

The calculation of the maximum flight speed of the species (figure 10a) is quite error prone, because there is no information on the accuracy of coordinates. Satelite tracking and radar measurements are more suitable to measure this maximum performance. However, ringing makes it possible to follow a larger number of ducks and for a longer period of time (figures 10b, 10c and 10d).

I suggest that the calculation of autumn migration speed (figure 10c) is repeated on data from ducks that are ringed in Scandinavia, the Baltic states and Russia. In those countries less ducks need to be ringed for the same number of recaptures. This is because these countries have larger territories and a lower population density than western European countries. As a result a duck ringed in Russia stands a much greater chance of being recaptured in The Netherlands than vice verse. To determine whether a duck is loyal to a particular site, we need to recapture it more than once. Currently most ducks are recovered dead (figure 4b and 4c), but decoys can capture ducks alive (figure 4a).

4.3 Future research on global change

Research on global change can involve studying of past data as well as collecting new data for future monitoring. I will focus on the latter. Several variables such as survival (figure 11) or migration speed (figures 10c and 10d) can be chosen and - once defined very precisely - be monitored. I will use *survival* as an example. To get the most reliable estimate of survival in a certain time period, ringing should take place in as little time as possible. This would ensure that starting time and conditions are the same for all individuals. The recapture period should also be kept as short as possible, to keep conditions similar for the entire period. On the other hand, if one waits longer then less rings are needed for the same accuracy. In the following example the survival index is calculated every ten years. At first sight the data for teal (figure 11) seem excellent for this analysis, whereas the data data for wigeon and mallard are still very useful but less so. This suggests that about 2.500 recoveries within 8 years are needed to estimate a survival chance with confidence. The historical chance of a recovery within 8 years is 4.4%. It would therefore take 25.000 rings per year, for two years. That is about ten times the ringing effort of the late 1950s. To distinguish between country specific effects and global change, the same methodology can be used in multiple countries.

4.4 General conclusion and recommendations

Without the contribution of ducks decoys, there would be very little ring data of ducks. Despite uncertainties it is safe to assume that virtually all wigeon and teal and most mallards are ringed in duck decoys. This is consistent with Donker (1959), who claims that practically all wigeon were ringed in duck decoys, although he did not explain how he reached that conclusion. Much can be learned from this dataset and there are interesting possibilities for future reseach. For the three areas of research that I discussed international cooperation and exchange of data is very important. Building on successful efforts such as the international standard for ring data (EURING), much can be achieved here. It strikes me that there is a constant factor for the papers on duck ringing that I have considered for this research: each author only uses data from his or her own country. Guillemain et al. (2005) studied French teal, Donker (1959) and Wolff (1966) studied Dutch wigeon and teal, Hilden and Saurola (1982) studied Finish ducks and Ellegren (1993) studied Swedish ducks. I studied Dutch ducks. It would be very interesting to perform these analysis on data from all countries were ducks have been ringed.

To achieve that, I recommend that the software for data entry, processing and visualization is developed in cooperation. The end result of that effort could be one central website that can be used to report any recaptured duck from any country. This will save time because only one system needs to be further developed and maintained. It will also speed up the international synchronization of the data. Finally it could visualize new captures and recaptures more quickly which will further increase the enthusiasm of their reporters.

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van der Heide, G.D. and Lebert, T. (1944) *Een boek over eendekooien.* Heiloo, Kinheim

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Appendices

Appendix A

Data processing

I received two tables from the Dutch Ringing Center in Heteren, one for the initial captures and one for the dead recoveries and live recaptures.

The table with 146,593 initial captures does not contain all the rings. The Limosa journals since 1936 (Dutch Ornithologist Union, http://home.planet.nl/~boude112/limosa/limosa.htm) do contain the number of ringed ducks per year. From 1958 onwards the table is complete.

The second table is complete and contains a record of each ring that has been reported back. 42,058 times a ring was reported back from 38,004 individual ducks.

The tables from the Dutch Ringing Center use the internationally agreed EURING standard (Speek et al., 2007).

Table 1: Three example first captures of teal as they appear in the original data. They are described in the text. Several columns omitted for simplicity.

sch	ringnr	rspec	rx	rdate	rar	rca	rcb	rq	rid
NLA	.3235154	01840	1	1975-09-16	NL00	115	569	N	151
NLA	.3235154	01840	1	1975-09-16	NL00	115	569	N	151
NLA	.3235154	01840	0	1975-09-16	NL00	5306	0448	E	NULL

Table 2: One example recovery of the teal as it appeared in the original data. It is described in the text. Several columns omitted for simplicity.

sch	ringnr	rspec	rx	rdate	fx	fdate	far	c	ci
NLA	.3235156	01840	0	1975-09-16	1	1978-01-07	GB22	2	10

Three initial captures are shown in table 1 as an example. The first two columns (*sch* and *ringnr*) represent the ringing scheme (in this case the standard Dutch ringing scheme) and the number of the ring within that scheme. The column *rspec* holds the species, where 01840 refers to the teal. The column *rx* holds the sex, where 0 means unknown (third example), 1 means male (first two) and 2 means female. The next column shows the date of the capture.

The column *rar* is the ringing area, where NL00 refers to the island of Texel (in the province of Noord Holland). The next three columns represent the coordinates of the capture. When *rq* is N they are given in Amersfoort coordinates and when *rq* is E geographical coordinates are used that are assumed to be in the north east quadrant.

Finally *rid* identifies the ringer. In the third example this ringer is not known so the field has a *NULL* value (not the same as 0).

A full overview of the different columns and their possible values, including the columns that I did not discuss, can be found in the EURING Exchange Code (Speek et al., 2007). [1]

The EURING code was originally designed with punch card machines in mind in stead of today's database systems. Punch cards needed to store as much data on as little space as possible and allow mechanical devices to sort and search through them.

For example there are only two letters available for a country designation, so it makes sense to use the first letter to refer to the general region and the second to the specific country. A punch card sorter can then obtain all records for an entire region in one operation and then three countries from the new set in three operations. Because for the second part of the operation only the European part of the data needs to be searched, this saves time.

To save space there were only 5 characters available for coordinates. To obtain a high spatial resolution, it then made sense to use a country specific coordinate system, such as the Amersfoort Rijksdriehoek coordinates for small countries. The geographic coordinate system of latitude and longitude made more sense for large areas such as Siberia. Another way to save space was to represent each species with a number in stead of the full Latin name.

Nowadays storage space, sort and search time are less of an issue with a database of this size, that only contains duck species. Because the size of the database is too large to process and verify manually, two issues are nowadays of most importance: the format must be consistent and the data must be completely reliable.

There is need for consistency when dealing with geographical information. The different coordinate formats need to be understood by map making applications. Old countries have been replaced by new countries in the course of the century. The International Organization for Standardization (ISO) keeps track of this, but in order to use their data one needs to manually program the relation between the EURING country designations and the ISO 3166 standard.

Reliability of data is crucial. There are coordinates in the database such as (0,0) or (123,456), which to a human map maker clearly refer to an unknown coordinate. It is also clear to a human data processor that a wigeon from the northern hemisphere captured in January is not in his first calendar year. A computer needs to be programmed to explicitly deal with each of these situations.

It is also difficult to integrate the ring data with external data, both because of its single-table structure and because it uses its own standards in stead of internationally agreed standards.

[1] *It should be born in mind that the data that I received conforms to the EURING standard of 1979 and at that time had not been upgraded to the latest standard of 2000.*

I therefore designed and implemented a new structure. I used the open source MySQL database (http://www.mysql.com/) to store the data. To process the data I created a collection of scripts.

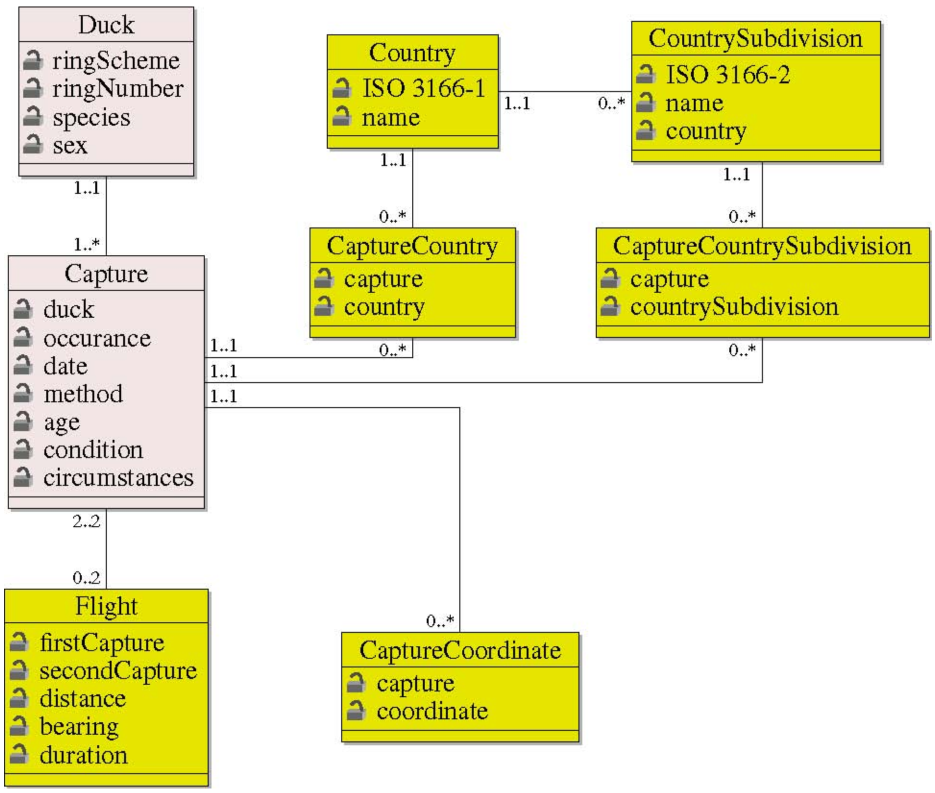

Figure 12: Core of the new database structure. Each shaded rectangle represents a table in the database. Each line represents a connection between two tables. The numbers next to these lines describe the type of connection. ``1..1'' below the duck table means that for each capture there can only be one duck. ``1..'' above the capture table means that for each duck there is at least one capture. The tables are described in the text.*

The table *Ducks* (figure 12, top left) lists all the individual ducks, their identifying ring scheme and number, their species (Latin name) and sex. From the initial captures table (table 1) I copied the columns *sch*, *ringnr*, *rspec* and *rx* (identification of the ring, species and sex) into the table *Ducks* (figure 12, top left). In this new table species are identified by their Latin name, in this case *Anas crecca* in stead of the EURING-specific code 01840.

The table *Captures* (below *Ducks* in figure 12) lists all the captures of this duck, including the first one. The captures can be uniquely identified by the combination of ring scheme, number and a unique number for each capture (occurrence).

It should be noted that the table *Captures* contains all initial captures, dead recaptures and live recoveries. I will refer to an initial capture as "initial capture", to a subsequent live recapture as "recapture" and to a subsequent dead recovery as "recovery". When I do not wish to distinguish between initial captures, recaptures and recoveries, I use the word "capture".

I copied all ducks (*sch* and *ringnr*) from the *Ducks* table into the table *Captures*. To each of these I added *occurrence* 1, as these captures represent the first capture of each duck. I also added the date of capture. The *Captures* table also contains the date of capture, which method was used to capture the duck, the estimated age at the time of capture, wether it was dead (a recovery) or alive (a recapture) and if it was recovered, under what circumstances (e.g. shot, hit by a car).

I then proceeded to process the second table of the Dutch Ringing Center, that held the recaptures. Table 2 shows the structure of this table. Only the third bird in this example was recovered. Each row begins with the information of the first capture, the same data as in the first table. In the example I show the identification of the ring, the species, sex and date of the initial capture. This is appended by information about the recovery. *fx* denotes the sex as it was determined at the time of recovery. Where the sex was unknown at the first capture, it is now known to be a male teal. Next the finding date *fdate* and area *far* are shown. GB22 refers to Buckingham in England. Column *c* refers to the condition of the bird at recovery, where 2 means the bird was freshly dead. *ci* refers to the circumstances where 10 means it was shot.

Next I copied all ducks (*sch* and *ringnr*) from the EURING recapture / recovery table into the *Captures* table. If the duck occurred only once, I gave it *occurrence* number 2, as that refers to the second capture (i.e. the first *re*capture). If a duck was released and captured again, the next capture was given *occurrence* 3, etc. I also copied the date of the capture, the condition and circumstances.

Next I processed the geographical information of the captures. The table *Countries* (figure 12, center right) contains a list of countries, based on the ISO-3166-1 standard: an international standard for country codes (http://www.iso.org/iso/country_codes). In the example in table 2 *GB* refers to the United Kingdom. The ISO 3166-1 code for the United Kingdom is *GB*, which is in this case and in many cases just like in the EURING code. Below *Countries* and connected to *Captures* is the table *CaptureCountries*. For each capture I put the country in which it took place in that table. Do do that, I converted the country information in *rar* to the ISO 3166-1 format where this was possible and removed country information where this was not possible.

The ISO-3166-2 (http://www.iso.org/iso/country_codes/background_on_iso_3166/iso_3166-2.htm) is an international standard for country subdivisions. In the example the *rar* code *GB22* refers to Buckingham in England, United Kingdom. Buckinghamshire county in ISO 3166-2 is *GB-BKM*. I stored this information in the tables *CountrySubdivisions* and *CaptureCountrySubdivsions*.

There were some problems with this. For example, Texel (table 1) is not part of the ISO 3166-2 standard. It is part of the province of Noord Holland and so I referred to the location of this recovery on Texel as *NL-NH*. The original dataset also contained former countries. For a former country like West Germany, all captures were stored under the current country Germany. Captures in the former Soviet Union could not be treated in the same way without additional information. I applied reverse geocoding to these cases. I used Geonames (http://www.geonames.org/), a free online database that contains over eight million geographical names and their coordinates, to match those coordinates to the current countries such as Estonia, Russia and Ukraine. I converted the area information (*rar* and *far*, table 1 and 2) to the ISO-3166 standard.

I put the coordinates of each capture were put in the table *CaptureCoordinates*. The original dataset contained coordinates in two different formats (geographical coordinates and Dutch Rijksdriehoekcoordinates). I converted them to decimal degrees of longitude and latitude and stored them with high precision in the table *CaptureCoordinates* (bottom center in figure 12). I removed erroneous coordinates.

I used Geonames (a free database that contains over eight million geographical names, (http://www.geonames.org/) to check for consistency between *CaptureCountries* and *CaptureCoordinates*. For coordinates near a border I allowed for 10 kilometers of inaccuracy.

I added each two consecutive captures (table *Captures*) of the same duck to the table *Flight* (bottom left, figure 12), for which I calculated the distance, initial bearing and duration. The distance between the two captures was calculated as a great-circle distance between the coordinates in *CaptureCoordinates*. A capture was only put in the flights table when its coordinates were consistent with the country of capture.

There are an additional 33 tables in the database. 13 of those are related to distinction between ducks captured in a decoy and those captured outside a decoy, as described in the next section. Others are used as temporary tables, to store additional derived data and to support a demonstration website (see below).

I used the web development framework Ruby On Rails (http://www.rubyonrails.org/) to build a web interface around the results. With it anyone can perform the analysis in this paper on the other duck species in the database. It is available at http://ducks.sprovoost.nl/.

The source code of the entire analysis as well as the website is available through Google code at http://code.google.com/p/ducks-on-rails/. The ring data itself must be obtained through the Dutch Ringing Center in Heteren.