



**A risk assessment of
Mandarin Duck (*Aix
galericulata*) in the
Netherlands**

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Sovon-report 2014/15



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Table of contents

Acknowledgements.....	3
Samenvatting	5
Summary	7
1. Introduction	9
1.1. Background and goal.....	9
Risk assessment.....	9
Riskmanagement.....	9
1.2. Methods	10
2. Short introduction to the status and biology of the Mandarin Duck.....	11
2.1. Introduction.....	11
2.2. Taxonomy and identification.....	11
2.3. Status.....	12
2.4. Biology.....	12
3. Risk assessment.....	15
3.1. Pathways of introduction	15
3.1.1. Introduction pathways in the Netherlands	15
3.1.2. Introduction pathways in other countries.....	15
3.1.3. Conclusions.....	16
3.2. Establishment of Mandarin Duck in the Netherlands and Europe.....	17
3.2.1. Establishment of Mandarin Duck populations in the Netherlands	17
3.2.2. Establishment of populations of Mandarin Duck in other countries	19
3.2.3. Conclusions.....	21
3.3. Population growth and expansion rate of Mandarin Duck in the Netherlands	21
3.3.1. Population growth rate	21
3.3.2. Expansion rate	22
3.3.3. Conclusions.....	24
3.4. Endangered areas: Habitat and potential distribution.....	24
3.4.1. Habitat requirements – literature overview.....	24
3.4.2. Potential distribution of Mandarin Duck in the Netherlands.....	25
3.4.3. Conclusions.....	26
3.5. Success of establishment and limiting factors	26
3.5.1. Success of establishment of non-native populations of Mandarin Duck	26
3.5.2. Enhancing and limiting factors for establishment and or spread of Mandarin Duck populations in the Netherlands.....	27
3.5.3. Conclusions.....	28

3.6. Impact.....	28
3.6.1. Negative ecological impact.....	29
3.6.2. Positive ecological impact	31
3.6.3. Economic impact	31
3.6.4. Social impact.....	31
3.6.5. Health impact	31
3.6.6. Status of Mandarin Duck in European alien invasive databases and lists	32
3.6.7. Risk assessment of Mandarin Duck using the ISEIA protocol	33
4. Risk management.....	35
4.1. Introduction.....	35
4.2. Prevention	35
4.3. Eradication	35
4.4. Management	36
4.5. Effectiveness, efficiency and costs	36
References	37
Appendix 1. Applying the ISEIA protocol on Mandarin Duck	40
Appendix 2. Technical details of the modelling of potential habitat of Mandarin Duck in the Netherlands...	44

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Samenvatting

De Mandarijneend is een exoot die zijn oorspronkelijke verspreidingsgebied in Oost - Azië heeft. Vanwege de kleurige verentooi is het de meest populaire soort in watervogelcollecties. Uit collecties ontsnapte (of vrijgelaten) vogels hebben zich inmiddels succesvol in het wild gevestigd. Invasieve exoten kunnen aanzienlijke ecologische, economische of sociale schade veroorzaken. Daarom zijn mogelijke schadelijke effecten van de Mandarijneend door middel van een risicoanalyse in beeld gebracht en beoordeeld volgens het ISEIA-protocol (Invasive Species Environmental Impact Assessment).

Wijze van introductie

Vanaf de 18e eeuw werden grote aantallen Mandarijneenden in het wild gevangen en naar Europa geëxporteerd als siervogel voor particuliere watervogel collecties, parken en dierentuinen. De Mandarijneenden die momenteel in het wild in Europa voorkomen, stammen af van individuen die in de 20e eeuw zijn ontsnapt of doelbewust zijn geïntroduceerd. Mandarijneenden zijn gemakkelijk in gevangenschap te houden en te fokken en zijn dan ook in grote aantallen aanwezig bij particulieren en in andere siervogelcollecties. Deze vormen zeer waarschijnlijk een constante bron van nieuwe introducties. Hoeveel individuen worden gehouden en jaarlijks ontsnappen en zo bijdragen aan de opbouw van de populatie is niet bekend. Er zijn waarnemingen van geringde vogels uit watervogelcollecties die voorkomen in vrij levende populaties in het wild.

Vestiging

De eerste broedpoging van Mandarijneend in het wild vond plaats in 1964 in de buurt van Den Haag in het duingebied Meijndel. In de periode tot 2000 vestigde de soort zich in verschillende delen van Nederland: De Noord- Veluwe, Zuid Veluwe en omgeving, Zuidoost- Achterhoek, Limburg, West -en Midden- Noord-Brabant en de duinen in Noord-Holland. Uit recente waarnemingen van Mandarijneend in het broedseizoen uit de periode (2009-2013) blijkt dat de Mandarijneend als broedvogel momenteel nog steeds aanwezig is in de Veluwe, Zuidoost- Achterhoek, Limburg en Zuid - West Noord-Brabant. Verder is de soort aanwezig in verschillende atlasblokken (5 x5 km²) in Twente (Oost- Overijssel) en rond Nijmegen. Losse waarnemingen van vogels in het broedseizoen zijn bekend van verschillende locaties verspreid over het land, vooral in Midden -en Oost- Noord-Brabant, Utrecht, Zuid-Holland en Noord-Holland. Deze losse waarnemingen hebben niet noodzakelijk betrekking op broedgevallen of gevestigde populaties. De Mandarijneend heeft een populatie gevestigd die zich meer of minder succesvol voortplant en in staat lijkt zichzelf in het wild in stand te houden. Het plaatsen van nestkasten en bijvoeren in de winter heeft op zijn minst lokaal (Noord Veluwe) bijgedragen aan vestiging van de populatie.

De populatiegroei en verdere verspreiding

De aantallen van Mandarijneend zijn snel toegenomen, althans tussen de jaren 1980 en late jaren 1990. Gegevens uit het watervogelmeetnet suggereren dat de aantallen zijn toegenomen tot begin 2000 en dat ze sindsdien fluctueren, gestabiliseerd zijn of mogelijk licht toegenomen. Hierbij dient te worden aangetekend dat een deel van de Mandarijneenden populatie niet wordt onderzocht in het Watervogelmeetnet. Gegevens uit de kerngebieden van de populaties geven een wisselends beeld: afname in twee gebieden en toename / stabilisatie in één gebied.

Parallel aan de toename van het aantal is ook de verspreiding sterk toegenomen, ten minste tot de late jaren 1990. Het is onduidelijk of daarna uitbreiding van dieren vanuit de kerngebieden plaatsvindt. Uit de vele losse waarnemingen van de soort in 2009-2013 blijkt dat op landelijke schaal de verspreiding is toegenomen, maar een recent compleet overzicht van broedterritoria ontbreekt. Mogelijk speelt ook een toegenomen waarnemingsinspanning een rol. Het is zeer waarschijnlijk dat ook nieuwe gebieden met geschikt habitat op den duur gekoloniseerd kunnen worden door middel van dispersie van vogels van nabije populaties. Uit ringgegevens blijkt verder dat sommige individuen aanzienlijke afstanden kunnen afleggen.

Habitat en potentiële verspreiding (bedreigde gebieden)

De Mandarijneend heeft een sterke voorkeur voor parken, landgoederen, tuinen van villa's met een combinatie van oude bossen en vijvers, maar ook voor meer natuurlijke habitat zoals beboste beekjes. De holtes waar de soort in nestelt komen vooral voor in oude loofbossen. In Vlaanderen zijn ook enkele waarnemingen van individuen die zich gevestigd hebben bij vijvers in open landschap wanneer er voldoende nestgelegenheid aanwezig is. Op basis van een ruimtelijke modellering is een kaart gemaakt van het potentiële verspreidingsgebied. Dit omvat met name de hoger gelegen gebieden in het oostelijk deel van Nederland en delen van het duingebied, waaronder Natura 2000-gebieden met hoge natuurwaarde en delen van de EHS. Mogelijk worden ook stedelijke gebieden (stadsparken en tuinen met oude bomen en water) gekoloniseerd, ook in de lagere delen van het land.

Succes van vestiging, stimulerende en beperkende factoren

Het succes van Mandarijneend kan worden verklaard door een aantal factoren: De soort maakt gebruik van een unieke en niet bezette ecologische niche, de hoeveelheid geschikte habitats, geschikt klimaat en het verdwijnen van trekgedrag. Geregelde ontsnappingen uit gevangenschap kunnen verder bijdragen aan toename van de populatie in het wild. Het verstrekken van nestkasten en bijvoeren heeft aanvankelijk sterk bijgedragen aan het ontstaan van de eerste Nederlandse populatie. Mogelijk speelt dit nog steeds een rol, maar in welke mate is onduidelijk. Factoren die ongunstig uitpakken voor de populatie zijn strenge winters en natte en koude weersomstandigheden in het voorjaar. Ook predatie door Boommarter kan lokaal een negatief effect hebben op de reproductie. In de omgeving van Velp is dit de vermoedelijke oorzaak van de achteruitgang van de populatie.

Mogelijke negatieve effecten

De Mandarijneend neemt een unieke ecologische niche in: het betreft een in holtes nestelende eendensoort die leeft van boomzaden en van kleine ongewervelde waterdieren die van het wateroppervlak worden gegeten. De grootste overeenkomst in niche bestaat met de Brilduiker die ook holtes broedt en leeft van kleine ongewervelde waterdieren die van de bodem worden opgedoken (benthos). De Brilduiker broedt ook in lage aantallen in Nederland maar niet in hetzelfde gebied als de Mandarijneend. Op Europese schaal is deze soort vrij algemeen. Hoewel competitief gedrag is waargenomen is er geen bewijs van een negatief effect als gevolg van de concurrentie voor nestholtes of voedsel in het wild tussen de Mandarijneend en andere inheemse soorten. Hybridisatie met inheemse soorten komt zelden voor. De Mandarijneend wordt bedreigd in zijn natuurlijke verspreidingsgebied en de Europese populatie kan mogelijk van belang zijn voor instandhouding van de soort. De kans op negatieve ecologische effecten is laag. Er ook geen bewijs gevonden van negatieve economische of sociale effecten.

ISEIA score

Volgens het ISEIA protocol wordt een soort beoordeeld op basis van vier factoren : dispersievermogen of invasiviteit, kolonisatie van habitats met hoge natuurwaarde, negatieve gevolgen voor inheemse soorten en negatieve gevolgen voor de verandering van ecosysteem functies. De ISEIA score van Mandarijn eend bedraagt 8 punten en valt daarmee in de laagste risico categorie "low risk".

Aanbevelingen

Om meer inzicht te krijgen in veranderingen in aantallen is het raadzaam om een monitoring programma op te zetten in een aantal kerngebieden van de soort op de Veluwe, Limburg en Noord - Brabant.

Betere data over de huidige verspreiding van de soort en in het bijzonder de status ervan in stedelijke gebieden is gewenst. Naar verwachting zal in 2015/2016 (Nederlandse Vogelatlas Project) een vernieuwd landsdekkend verspreidingsbeeld beschikbaar komen dat beter inzicht geeft in de verandering in verspreiding sinds 1998-2000.

Uitgebreidere monitoring van broedsucces en de overleving en de factoren die daarop van invloed zijn, kunnen helpen om toekomstige populatiegroei en uitbreidingssnelheid beter te voorspellen.

Summary

The Mandarin Duck is a non-native species that has its native range in East-Asia. It is the most popular waterbird in private or public collections because of its colourful plumage. Birds that escaped, or were released, from such collections have meanwhile established a free-living population that also breeds successfully. Invasive species may have a considerable negative ecological, economic or social impact. Therefore the possible impact of the Mandarin Duck in the Netherlands has been assessed and scored according to the Invasive Species Environmental Impact Assessment (ISEIA) protocol.

Pathways of introduction

From the 18th century onwards large numbers of Mandarin Ducks were captured from the wild and imported into Europe to be kept as ornamental birds in private waterfowl collections, parks and zoos. The Mandarin Ducks currently living in the wild in Europe are considered descendants from escapes and deliberate releases in the 20th century. Mandarin Ducks are easy to keep and breed in captivity. New introductions are very likely to take place on a regular basis as the Mandarin Duck is still kept in captivity in large numbers and escaped birds from waterbird collections have been observed in free-living populations. However, precise numbers or estimates how many birds escape on a yearly basis are not available.

Establishment of populations

The first breeding attempt of Mandarin Duck in the wild was recorded in 1964 near The Hague in the dune area Meijndel. Subsequently populations established in different parts of the Netherlands: The North Veluwe, South Veluwe and surroundings, Southeast Achterhoek, Limburg, West and Central Noord-Brabant and the dunes in Noord-Holland. Available records of Mandarin Ducks in the breeding season from the period (2009-2013) show that the Mandarin Duck is nowadays still present in the Veluwe, South-east Achterhoek, Limburg and South-west Noord-Brabant. Furthermore the species is present in several atlas squares (5x5 km²) in Twente (eastern Overijssel) and around Nijmegen. Reports from birds (presence only) in the breeding season come from many locations, scattered over the country, especially in central and eastern Noord-Brabant, Utrecht, Zuid-Holland and Noord-Holland. However these observations are not necessarily associated with breeding territories or established populations. The establishment of the local population in the North Veluwe was initially stimulated by providing nesting boxes and winter food. Today, the Mandarin Duck is a species breeding successfully in the Netherlands, and at least some of the populations are likely to maintain themselves in the wild.

Population growth and expansion

Numbers of Mandarin Duck increased rapidly, at least between the 1980s and late 1990s. The results of the January counts in the national Waterbird census scheme indicate increasing numbers of Mandarin Duck until the early 2000s and more recent fluctuating numbers. However, it is noted that a part of the population of the species is not monitored in this scheme. Available data from core areas show mixed patterns: decline in two areas and increase/stabilisation in one area.

Parallel to the earlier increase in numbers a strong increase in distribution was recorded in the Netherlands at least until the late 1990s. It is unclear if this is a result of expansion of birds from the core areas. The many casual reports of the species in 2009-2013 suggest that at a national scale distribution has increased, but these reports may also relate to temporally present individuals and not permanent breeding populations or breeding territories at all, or just reflect increased observer effort. It is likely that new areas with suitable habitat can be colonized by dispersion of birds from established nearby populations. Also ring recoveries have shown that birds may fly considerable distances.

Habitat and potential distribution (endangered areas)

Detailed habitat descriptions of locations with established populations show a strong preference for parks, estates, villa gardens (combination of old woodland and ponds), but also more natural habitat

such as forested streams. Based on some reports from Flanders Mandarin Ducks are also able to settle on ponds in open landscape if nesting habitat is present.

Based on a spatial modelling analysis the potential distribution could cover habitat in the higher, eastern parts of the Netherlands and parts of the coastal dune area and possibly also urbanised areas also in the lower parts of the country. These areas include protected habitats of high conservation value.

Success of establishment, enhancing and limiting factors

The success of Mandarin Duck can be explained by a number of factors: It occupies a unique and vacant ecological niche, the availability of sufficient suitable habitats, suitable climate and the abandonment of migratory instinct. Repeated escapes or releases from captivity are probably a source for continuous new introductions and in this way contribute to maintain the population.

The first populations of Mandarin Duck were established with human assistance providing nestboxes and food. This may still contribute to the success of the Mandarin Ducks but to what extent is unclear. Factors limiting the population are unfavourable weather conditions in winter and spring; at least locally predation by Pine Marten led to reduction of a population near Velp (Gld.).

Impact

The Mandarin Duck occupies a unique ecological niche for a cavity nesting duck that lives from tree seeds and small aquatic invertebrates picked from the water surface. The biggest overlap in niche is with the Common Goldeneye which also nests in cavities and eats small benthic aquatic invertebrates and also breeds in small numbers in the Netherlands, but not in the same area.

Although some competitive behaviour has been observed, there is no evidence of a negative impact as a consequence of competition for nesting cavities or food in the wild between Mandarin Duck and other native species. The Mandarin Duck is threatened in its native range and the European population may have a conservation value in a global context. Hybridisation with native species rarely occurs and is not likely to cause any negative impact. The probability of ecological impact is low. So far no evidence was found of any negative impact on native species. Also no evidence was found of economic or social impact.

ISEIA score

The risk of a species is judged based on four factors: dispersal potential, colonization of high conservation value habitats, adverse impact on native species and adverse impact on the alteration of ecosystems functions. The ISEIA score of Mandarin Duck is 8 points resulting in a "low risk" status.

Recommendations

- In order to get more insight in changes in numbers it is recommended to set up a census scheme for Mandarin Ducks in some core areas of the species in the Veluwe, Limburg and Noord-Brabant.
- Better information on the current distribution of the species in particular its status in urban areas is desired. An updated national map of the breeding bird distribution is due in 2015/2016 (Dutch Bird Atlas project, fieldwork 2013-2015) and could be used to get better insight in the distribution changes since 1998-2000.
- More extensive monitoring of breeding success and survival rates and the factors that may affect these will help to predict future population growth rates and expansion rates.

1. Introduction

1.1. Background and goal

The Mandarin Duck is a non-native species that occurs in the Netherlands in low numbers. It is not clear which impact this species has at this very moment or may have in the future. Therefore Sovon Dutch Centre for Field Ornithology was asked to conduct a risk assessment for this species and report on the following questions:

Risk assessment

The risk assessment considers the situation in which no measures are taken to prevent escapes or to manage or reduce the existing population. It gives an estimate of the potential risks when the population is not hindered in its natural development in any way. In the risk assessment we try to answer the following questions:

a) Probable pathways of introduction

Describe the possible current and future pathways of introduction of Mandarin Duck in the Netherlands.

b) *Establishment of Mandarin Duck populations and the species' current distribution*

Describe where the Mandarin Duck has established permanent populations in the Netherlands and elsewhere in its non-native range and describe its current distribution.

c) *Potential habitat for future establishment of populations of Mandarin Duck*

Describe the species' habitat in the Netherlands and give insight in the potential breeding range in future, based on its habitat choice

d) *Probability of dispersion*

What is the current and expected population growth rate and expansion rate of the Mandarin Duck population in the Netherlands?

e) *Success of establishment, enhancing and limiting factors*

Which factors may account for the establishment of Mandarin Duck populations in its non-native range and which factors may enhance or limit further population growth.

f) *Impact*

Describe to what extent the Mandarin Duck may cause ecological, economical and social damage in the Netherlands. Take into consideration the damage that is already present or may take place in the future. Also consider the damage in countries outside the Netherlands, situated in the same climate zone. Quantify the damage if possible. Additionally apply the ISEIA risk protocol to Mandarin Duck. Also consider positive impacts.

Riskmanagement

a) *Elimination*

Describe concisely the available technical options to eliminate (small) populations. Discuss effectiveness, feasibility, consequences and if possible the costs of the different options.

b) *Management*

If relevant describe the available technical options to manage the established population: to prevent dispersion or to minimize the impact. Discuss effectiveness, feasibility, consequences and if possible the costs of the different options.

1.2. Methods

This document was compiled based on information from scientific literature, general web search, other (not peer-reviewed) ornithological publications, data analyses, expert judgement and consultation of experts or informal information sources. Moreover, we used data from national bird surveillance schemes in The Netherlands, carried out in the framework of the national network ecological monitoring". These include breeding bird surveys and monthly counts of non-breeding birds in winter.

Literature

The ISI Web of Knowledge was searched for relevant scientific publications by using "Mandarin Duck" as a keyword. Additional literature was found by following literature quotes in publications and by a search in the Sovon library-catalogue that contains many titles of non-peer reviewed publications such as in journals of local bird study groups.

Furthermore an internet search was carried out in databases on invasive non-native species and national reports on invasive species. For information on ecology, distribution and population establishment in different European countries national bird atlases and national or regional status reports were consulted.

Data sources en analyses

The following data sources of observations or counts of Mandarin Ducks were used in this report.

National monitoring schemes, carried out according to standardised methods and interpretation:

- Dutch Common Breeding Bird census scheme (BMP) <https://www.sovon.nl/nl/BMP>).
- Dutch Waterbird monitoring scheme (<https://www.sovon.nl/nl/watervogels>) Other data sources, collected non-systematically:
- Accidental reports of breeding territories submitted to Sovon
- Breeding territories submitted to the Bird atlas project so far <https://www.sovon.nl/nl/content/vogelatlas>.
- Other casual observations of birds present between March and August, indicating possible breeding territories, submitted to online portals <http://waarneming.nl/> and <http://www.telmeel.nl/>
- Number of individuals present in the non-breeding season, submitted to portals <http://waarneming.nl/> and <http://www.telmeel.nl/>

Details on habitat modelling are given in the sections 3.2.2. and appendix 2. A special account on Sovon's homepage gives a concise overview of occurrence of Mandarin Duck in The Netherlands (<https://www.sovon.nl/nl/soort/1780>).

2. Short introduction to the status and biology of the Mandarin Duck

2.1. Introduction

This chapter aims to give a short introduction to the status and biology of the Mandarin Duck. More detailed information about the species' status and habitat choice in its non-native range are presented in the risk assessment chapter (chapter 3). The following overview publications were frequently consulted for the compilation of this chapter: Cramp & Simmons (1977), Glutz von Blotzheim & Bauer (1990), del Hoyo *et al.* (1992),; and Lever (2013).

2.2. Taxonomy and identification

The Mandarin Duck (*Aix galericulata*) is a monotypic species in the family *Anatidae* (ducks, geese and swans). It is placed in the genus *Aix* together with the American Wood Duck (*Aix sponsa*). The Mandarin Duck is a compact duck species (41-51 cm, wingspan 68-74 cm, 444-500 g). The male is unmistakable, with white supercilium, orange whiskers and orange-green bushy crest and orange-red bill. Remarkable are the orange wing "sails". The female (and juvenile and male in eclipse plumage) has a greyish plumage (eclipse male = distinguishable by reddish bill from female, juvenile= more uniformly grey-brown and less distinct face markings). They can be distinguished from female-plumage American Wood Duck (this species is occasionally reported in the wild in the Netherlands, sometimes together with Mandarin Ducks) by a thinner white supercilium behind the eye and a thinner white markings around eyes, slightly streaked cheeks, thicker bill, with less concave base, light orange nail of bill and round spots on the flanks.



Figure 2.1. A pair of Mandarin Duck in Velp (Gld) in 2012. Photo Roy Verhoef.



Figure 2.2. American Wood Duck (*Aix sponsa*). Photo Marianne Slot.

2.3. Status

In its native breeding range, Mandarin Duck has a scattered breeding distribution in South Eastern Russia, North Eastern China (in particular Manchuria), Korea and Japan, between 120 and 140° E and 40 and 50-55° N. The species is partly migratory and winters in eastern China and Japan. Only the Japanese population is mostly sedentary. Both the breeding and non-breeding range are estimated at 1,850,000 km². The global population in its native range is estimated at c. 65,000-66,000 individuals in 2006 (Wetland International 2006, BirdLife International 2014). Currently the Mandarin Duck is considered of “Least Concern” on the Global Red List of endangered Bird Species, although it has declined as a consequence of habitat destruction (deforestation, drainage of wetlands), water pollution and (illegal) catching for export and for consumption nationally (BirdLife International 2014). Besides the native Asian population, the species has established populations in six European countries, the United States and the species has also been reported from South Africa. See for a more detailed review on the status of the species in its non-native range section 4.2.1.

2.4. Biology

Habitat

Mandarin Duck both in its native and non-native range requires fresh water pools, lakes, rivers, marshes or swamps with a dense marginal growth of deciduous woodland and shrubs, especially rhododendron. It prefers a littoral vegetation of reeds and sedges or other emergent vegetation as a shelter opportunity. The presence of old trees with cavities is important for nesting opportunities. See for a more detailed review on the habitat of the species in its non-native range section 4.2.2.

Diet and foraging

The Mandarin Duck is a dabbling duck and feeds in particular at night, but also during day. It forages both in its native and non-native range mainly on aquatic plants, tree seeds, such as acorns (*Quercus spec.*), Sweet chestnuts (*Castanea sativa*), beech-mast (*Fagus sylvatica*) and hazel nuts (*Corylus spec.*). It also feeds on corn from stubble fields. These are important food sources during the winter season. At some locations (parks, gardens) in its non-native range the species is supplied with winter food. In particular during spring and summer, the species also forages on aquatic invertebrates as land snails, insects and fishes.

Breeding biology

The Mandarin Duck is a monogamous species. Pairs are formed in winter. It breeds in single pairs. The species is both in its native and non-native range a cavity-breeder and needs 0.3 to 2.5m deep holes in trees at 3-18m above the ground, mostly deciduous trees.

In its non-native range in the Netherlands trees such as beeches (*Fagus sylvatica*), ash (*Fraxinus excelsior*, *F. ornus*), linden (*Tilia spec.*) and alder (*Alnus glutinosa*, *A. incana*) were used (Bijlsma 1994). The cavities are old nest holes of Black Woodpecker (*Dryocopus martius*) or holes caused by tree decay, mostly where a branch broke off. The holes can be used repeatedly in several years.

Mandarin Duck also accepts nesting boxes specially designed for them or for other species such as Tawny Owl (*Strix aluco*), Barn Owl (*Tyto alba*), Stock Doves (*Columba oenas*) and Kestrel (*Falco tinnunculus*).

Both in its native and non-native range breeding starts in April. The average start of laying of the non-native population near Renkum in the Netherlands in 1987-1991, 1993 was 20 April (3 April – 1 May, N=11) (Bijlsma 1994). At a study site in England eggs were found from the third week of March till late June with a peak between mid-April and the beginning of June (Davies & Baggott 1989).

The clutch size is 9-12 eggs in the species' native range. In its non-native range in the Netherlands four complete clutches near Renkum counted 10, 10, 11 and 12 eggs (Bijlsma 1994). Davis & Baggott (1998a) found at their study site in England highly variable clutch sizes with a mean of 16,9 eggs. This is larger than the 9-12 usually reported. They relate this to intra-specific nest-parasitism: nest-dumping.

The eggs are incubated by the female and hatch after 28-33 days (at least in the native range). The ducklings leave the nest c. 24 h after hatching, they drop themselves to the ground and move to nearby water bodies. The female takes care of chicks and they fledge after 40-45 days.

Mandarin Ducks reach sexual maturity after a year.

Non-breeding biology

The females start moulting after the breeding season in small pools near the breeding area. At least in its non-native range in the Netherlands the males start already moulting from mid-May onward.

The population near Renkum, the Netherlands, stayed near the nesting location (<1500 m) until August (Bijlsma 1994). In autumn and winter Mandarin Ducks remain near breeding areas on fresh water pools, canals etc. mostly in small groups, at least in their non-native range. In its native range the species is partly migratory. Although the European population is considered sedentary several ringing recoveries show that the species is able to cover large distances (section 3.3.3.).



Figure 2.3. Nesting space of mandarin Duck in Groningen, 2010. Photo Ana Buren.



Figure 2.4. Typical habitat of Mandarin Duck in a park near Velp (Gld.). Photo Frank Majoor.

3. Risk assessment

3.1. Pathways of introduction

The Mandarin Duck has established non-native populations in several countries including the Netherlands (section 2.2). In this section the pathways of introduction for the existing populations are described and possible pathways for introduction of Mandarin Ducks in the wild in the future are discussed.

3.1.1. Introduction pathways in the Netherlands

In general it is assumed that the Dutch populations originate (from descendants) from escaped or deliberately released birds. The species is very popular in waterbird aviaries (Lensink 2002).

The origin and development of the population in the North Veluwe and IJssel valley is described in Gerritsen & van den Bergh (1995). It had its origin in Heerde, where a breeding record was reported in a nesting box near a garden pond in 1967. These birds presumably originated from an aviary on a nearby estate. More nest boxes were placed on the location in Heerde by the owner and the species increased and it dispersed to other nearby villa gardens where nesting boxes had been placed.

Moreover birds were supplied with food (corn) in winter.

In the South Veluwe the species was released in Park Sonsbeek, in Arnhem in the 1970s. According to Lensink (2002), this population did not reproduce and he assumes that the population in the South Veluwe originates from the population in the North Veluwe and IJssel valley.

In western Noord-Brabant most breeding territories were recorded nearby waterbird collections, in parks and private gardens. Sometimes free-living birds were seen together with birds with pinioned wings¹ (Samenwerkingsverband Westbrabantse Vogelwerkgroepen 2007).

The origin of the other populations has not been described in detail. The birds outside the Veluwe area probably originate from separate escapes (Lensink 1996). In Limburg the three core areas for Mandarin Duck are all close to waterbird collections, the presumed sources (Hustings *et al.* 2006).

In the Netherlands, Mandarin Duck is by far the most popular duck kept in private collections. It is easy to keep and to breed. The numbers are estimated as “considerable” but no exact figure can be given (pers. com. P. Eyma Aviornis International Nederland). Private owners in the Netherlands and Belgium usually pinion adult birds and breed young ducks indoors under heating lamps, because they are sensitive to cold and wet conditions. Ducklings easily die from undercooling when raised outdoors in captivity due to hazardous weather conditions in spring. The captive population in private collections in the Netherlands and Belgium is considered to be large enough to maintain itself. Surplus young ducks are mainly sold through private channels mostly to other countries in Europe (pers. com. P. Eyma). Since 1 July 2007, the import of wild birds into the European community has been prohibited. From 1 Januari 2018 onwards the pinioning of birds will be prohibited by law which may lead to more escapes (P. Eyma, pers. com.). The extent to what Mandarin Ducks from waterbird collections have contributed to free-living populations is not clear, but Mandarin Ducks with rings from waterbird collections have been observed among free-living birds in the Netherlands (F. Majoor, unpublished).

3.1.2. Introduction pathways in other countries

Belgium

In Belgium the species was introduced in Flanders in parks in the provinces of Antwerp and Limburg in the 1950s. These birds had clipped wings from waterbird collections (De Smet 2002 *in*: Vermeersch *et al.* 2004). According to Vermeersch *et al.* (2004) the Mandarin Duck is kept in many

¹ In this report we use the expression “to pinion” for the Dutch term “leewieken” i.e. the operative removal of the pinion joint in bird’s wings and we use the expression “to clip wings” for the Dutch term “kortwieken” i.e. the temporarily removal of wing primaries which needs to be repeated every year after moulting.

waterbird collections all over Flanders and it is likely that this were the sources of birds reported in the wild there. Colonisation of new areas from source-areas may also have taken place, for instance in the Brussels-area. De presence of the Mandarin Duck east of Antwerp in some private ponds may originate from a local source, but also from the nearby population in western Noord-Brabant in the Netherlands.

Germany

The introduction and spread of the population in Berlin and surroundings is described in Witt (2003). Mandarin Ducks were released in the 1920s in the Großer Tiergarten Berlin, presumably as a decorative species. Surrounding areas as far as Potsdam have been colonised by dispersal from this population. The species is still kept as ornamental bird and in captivity bred juvenile are still being released in the wild and could integrate with existing populations of the species in the wild (Grüneberg *et al.* 2013).

Great Britain

The Mandarin Duck was introduced in Great Britain in Southern England as an ornamental bird, in gardens and parks, first in the 18th century, but in particular in the early 20th century; birds were imported from the native area. Since 1981 it has been illegal to release or permit the species to escape into the wild. However this may still happen. The current large population is mainly the result of the expansion of the descendants of birds escaped or deliberately released in England in the 20th century (Lever 2013).

Switzerland

In Switzerland the small sedentary population Mandarin Ducks in Basel originates from escapes from a zoo (Kestenholz 1997).

France

In France the species has established three small isolated populations in Vallée de l'Erdre near Nantes, and two at Île de France, on a castle pond and a lake. No information was found on the origin of these populations. Dubois (2007) suggests that (some) individuals of the French population of Mandarin Ducks may originate from the large British population, based on a ringing recovery in Les Landes (SW-France) of a bird from the Channel Island of Guernsey.

USA

In the USA a free-flying colony Mandarin Ducks became established in California in 1972, originating from a collection nearby. Another population was reported from North Carolina. This may originate from a nearby avicultural collection (Lever 2013).

3.1.3. Conclusions

The Mandarin Duck has been a popular bird in waterbird collections (already since the 18th century in England), because of its attractive appearance. Birds from the native area in East-Asia were imported to Europe and kept in villa gardens, parks, zoos etc., sometimes as free-living populations. Mandarin Ducks living in the wild in Europe are considered descendants from escapes and deliberate releases in the 20th century. It is very likely that new introductions still take place as the Mandarin Duck is kept in captivity in large numbers and escaped birds from waterbird collections have been observed in free-living populations. Moreover, an increase in escaped birds is likely when in 2018 pining of wings will be prohibited by law within the EU. *The probability of new introductions of Mandarin Ducks from waterbird collections into the wild is high.*

3.2. Establishment of Mandarin Duck in the Netherlands and Europe

In this section the establishment of Mandarin Duck is set out in detail for the Netherlands (section 3.2.1) and for other countries in its non-native range (section 3.2.2.).

3.2.1. Establishment of Mandarin Duck populations in the Netherlands

In the Netherlands the Mandarin Duck has established populations in several parts of the country:

The Hague and surroundings

The first breeding attempt of Mandarin Duck in the wild in the Netherlands was recorded in 1964 near The Hague in Meijendel, a dune area with ponds. The species regularly bred in the area in very low numbers until 1975 when the nesting trees were cut. In the late 1970s the species occurred in low numbers in city parks in The Hague (Bijlsma *et al.* 2001) and it still did so in 1992-1994 (Lensink 1996). However the species was not reported there anymore in 1998-2000 (SOVON 2002).

The North Veluwe and IJssel valley

In 1967 a breeding record was reported in a nesting box near a garden pond in Heerde in the North-Veluwe. The species dispersed to other nearby villa gardens where nesting boxes were provided. Since the 1980s numbers have increased considerably in the North Veluwe, coinciding with a range expansion. In November 1993 213 individuals were counted there (Gerritsen & van den Bergh 1995). Lensink (1996) estimated the breeding population in the North Veluwe and adjacent IJssel valley (Heerde-Hattem) at more than 50 breeding pairs. In 1998-2002 it was estimated at 30-40 breeding pairs (Lensink 2002).

The South Veluwe and adjacent areas

Mandarin Ducks were released in Park Sonsbeek, in Arnhem in the 1970s, but these birds were not capable of reproducing according to Lensink (2002). Birds were also reported from the nearby estates Warnsborn, Rozendaal and Beekhuizen, from the Arnhem Openluchtmuseum and from Doorwerth. Further west, the Mandarin Duck was reported from a forested stream valley near Renkum in 1974. Numbers started to increase from 1979 onwards and the first breeding record was reported there in 1987. In 1987-1994 1, 3, 5, 9, 7, 6, 7 and 6 pairs respectively were recorded, all along a 1800 m long stream-transect (Bijlsma 1994). The population probably reached the local carrying capacity (availability of nesting sites) in the 1990s and it expanded its distribution to the south, to the Betuwe between Heteren, Hemmen and Zetten (>10 pairs in 1995-1999) (Bijlsma *et al.* 2001). In 1998-2000 the species was also reported from some estates in south-eastern Utrecht (province), where it had not been reported in the 1980s (van den Bijtel 1990). The population in the South-Veluwe, adjacent parts of the Betuwe and Utrecht was estimated at 50-70 breeding pairs in 1998-2000 (Lensink 2002). The species has declined sharply around Arnhem since 2005; breeding success is presumed to be low, probably as a consequence of increased predation by Pine Marten (F. Majoor, *unpublished*).

Southeast-Achterhoek

The first breeding territories were reported in 1994 along natural streams in this area in eastern Gelderland. The numbers increased to 26 pairs in 2006 and since 2006 the population has fluctuated between 11 and 19 breeding pairs (Kwak 2005, R. Kwak *unpublished*).

Limburg

The first observations of Mandarin Duck in Limburg date back to 1977. Three core areas (more than 25 ind.) were distinguished by Schaafstra & Boonstra (1999): Venlo-Tegelen-Baarlo-Blerick, near the river Meuse, Kerkrade and a park pond in Brunssum. Hustings *et al.* (2006) distinguished, besides the core area Venlo-Tegelen, Baarlo (c. 10 pairs in 1992-2004) a population near Swalmen with at least 5 pairs. Furthermore they defined a slightly larger core area in south-eastern Limburg, near Brunssum, Heerlen, Hoensbroek and Kerkrade: 10-15 pairs in 1992-2004. These core-areas are situated close to waterbird collections, the presumed sources. They estimated the population in Limburg at 35-50 pairs in 1992-2004 and in 2002-2004 at 50-75 pairs.

Noord-Holland

In the dune-area in Noord-Holland the species has been present at Elshout-estate since the early 1980s and has spread from there to nearby estates and the dune area (Lensink 1996). This population peaked in the late nineties, with more than 50 individuals and has declined sharply since to c. 10 individuals in 2006 (van Deursen 2009). The author related the decline to the increase of the Egyptian Goose (*Alopochen aegyptiacus*), that may take over nesting sites from Mandarin Duck, and to the establishment of Pine Marten in the area, a potential predator. Lensink (1996 & 2002) estimated this population at minimal 10 breeding pairs in 1992-1994 and at 10-15 breeding pairs in 1998-2002. More to the north, in the dune area between Castricum and Schoorl the species has been recorded in low numbers since 1985; the population was estimated at 1-5 breeding pairs in 1992-1994 (Lensink 1996).

South-western and central Noord-Brabant

In south-western Noord-Brabant the species has been reported annually since the late 1980s, most records originate from area Rucphen-Breda (Lensink 1996). The population was estimated at 3-6 breeding pairs in 1992-1994 (Lensink 1996), 12-16 in 1994-1996 (Samenwerkingsverband Westbrabantse Vogelwerkgroepen 2007) and in 1998-2002 at 20-25 and in central Noord-Brabant at 10-15 breeding pairs (Lensink 2002). Although most breeding pairs were recorded near waterbird collections, the number of records from natural habitat has increased. (Samenwerkingsverband Westbrabantse Vogelwerkgroepen 2007).

Other areas

The species has been reported from several other locations in the Netherlands. According to Lensink (1996) Vosbergen near Groningen and Hardenberg (Overijssel) concerned permanent establishments. However the species was not reported from these locations in 1998-2000 (Sovon 2002).

Current breeding distribution

Although the establishment of the populations of the Mandarin Duck in the Netherlands has been described well until around 2000, little information is available on the current status of the species in the Netherlands. In order to give an indication from which areas the species has been reported recently a map has been produced showing the 5x5 km squares from which breeding territories (SOvOn) were reported in the period 1999-2013 and casual observations of Mandarin Ducks were reported in the breeding season (March-August; Waarneming.nl and Telmee.nl) (figure 3.1).

Breeding territories were reported from 115 atlas squares. The map shows clusters of occupied squares in the known core-areas Veluwe, Southeast Achterhoek, Limburg and South-west Noord-Brabant. Furthermore the species is present in several squares in Twente (eastern Overijssel) and around Nijmegen. Reports from present birds in the breeding season come from no fewer than 445 additional squares, scattered over the country, and especially reveals many occupied squares in central and eastern Noord-Brabant, Utrecht, Zuid-Holland and Noord-Holland.

As stated earlier this map only shows the reported records of breeding territories. As the species is poorly studied in breeding bird census schemes it is likely that this underestimates the real distribution. Although the observations of the species in the breeding season suggest that the species is present over large parts of the countries. This may be an overestimation of the breeding distribution, as not all observation may consider breeding territories.

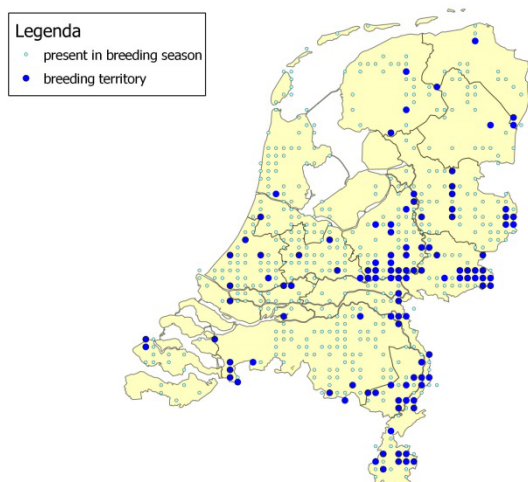


Figure 3.1. Distribution of Mandarin Duck in 2009-2013 in the Netherlands (5x5 km squares), based on submitted breeding territories (BMP, LSB, atlas) represented by dark blue dots and completed by other observations during the breeding season, only submitted to *Waarneming.nl* and *Telmee.nl* represented by light blue dots.

3.2.2. Establishment of populations of Mandarin Duck in other countries

Mandarin Duck has established populations in Belgium, Germany, Great-Britain, France, Switzerland and Austria and the species has been reported, more occasionally from several other European countries (Banks *et al.* 2008). Outside Europe the Mandarin Duck has established two populations in the United States and the species has also been reported from South Africa (Lever 2013). In the following the establishment of the populations in countries mentioned above will be described in more detail.

Belgium

The Mandarin Duck has occurred in the wild in Flanders since 1950s. It was introduced in parks in the provinces of Antwerp and Limburg. The first breeding case was recorded in 1987 in Park van Boecheut, Meise. In 2000-2002 the Flemish population was estimated at 80-95 breeding pairs (Vermeersch *et al.* 2004). The species was recorded as probable or confirmed breeding bird in 58 atlas squares scattered over Flanders in 2000-2002, with concentrations east of Antwerp, around Brussels and along the middle reaches of the river Demer. More recent estimates are not available. According to Vermeersch & Anselin (2009) the species has increased on the long term (1994-2007), but the short term trend 2000-2007 is stable.

The Mandarin Duck was reported from the wild in Wallonia in 1939, the first breeding record was recorded in 1985 and number have increased since the late 1990s. The breeding population was estimated at 53-71 pairs in 2001-2007 (Jakob *et al.* 2012). It occurs in particular in the north of Wallonia, Hainaut, Brabant, Meuse and Vesdre valleys.

Germany

In the forthcoming atlas of Breeding Birds in Germany the German population is estimated in at 430-600 pairs. It is not clear if the species has increased (in Banks *et al.* (2008) the breeding population in 1996-2002 was estimated at 100-200 pairs), or if the data provide a more comprehensive overview. Witt (2003) distinguished a core area around Berlin with 80-120 breeding pairs around 2000 and some smaller populations of tens of breeding pairs occurred scattered over Germany e.g. about 15 in Niedersachsen and 5 in Schleswig-Holstein.

In Nordrhein-Westfalen the first breeding record was reported in 1960. In 2005-2009 the population was estimated at 70-90 pairs. The only self-sustaining population in Nordrhein-Westfalen occurs in the Swalm-Nette area near Viersen (c. 20-30 pairs), about 20 km from the Dutch border in Limburg (Grüneberg *et al.* 2013).

Great Britain

The Mandarin Duck was first introduced in Southern England before 1745 as ornamental bird in gardens and parks. The first breeding attempt in captivity was reported in 1834 and the first report of a Mandarin Duck in the wild dates from 1866. More free-living birds were reported from the 20th century (Lever 2013). In 1972 the population was estimated at 300-400 pairs (Sharrock 1977). Around 1988 the population had increased to c. 3500 breeding pairs. The bulk of the population was recorded in Surrey, Berkshire and Buckinghamshire, but also north at River Tay in Scotland (Davis 1988). Between 1988-1991 and 2008-2011 the species' range had expanded with 123% to the Midlands, of northern England and parts of Scotland (Balmer *et al.* 2013). A recent population estimate has not been made.

Switzerland

First breeding of Mandarin Duck was recorded in 1958 in Basel. There is a small sedentary population, originating from escapes from a zoo. The largest stock lives near Solothurn, since 1974. Since 1981 breeding was recorded elsewhere in the Swiss lowlands, almost exclusively below 500m altitude. The Swiss population was estimated at 200 individuals in mid-1990s, among them 10-15 breeding pairs, but this may not be an accurate number. Banks *et al.* (2008) estimated the Swiss breeding population at less than 10 pairs in 2004-2007.

Austria

Escaped Mandarin Duck have been recorded since the early 1900s, mainly along the Danube. Breeding was first recorded in the 1980s in Vienna. Between 1996-2002 and 2004-2007 the species has increased from 10-20 to 40-60 breeding pairs (Banks *et al.* 2008).

France

In France the species first bred in the wild in 1977. In the 2000s the population was estimated at 28-34 pairs (Dubois 2007). Three isolated populations are distinguished: Vallée de l'Erdre near Nantes, and two at Île de France, on a castle pond and a lake.

USA

In 1972 Mandarin Ducks settled on an impoundment in California. In 1987 it was estimated at c 550 birds and around 2010 at 100-200 pairs. Eggs are bred in captivity and young reared in captivity and subsequently released upon fledging. Another population of c. 6 breeding pairs was reported from a man-made lake in North Carolina (Lever 2013).

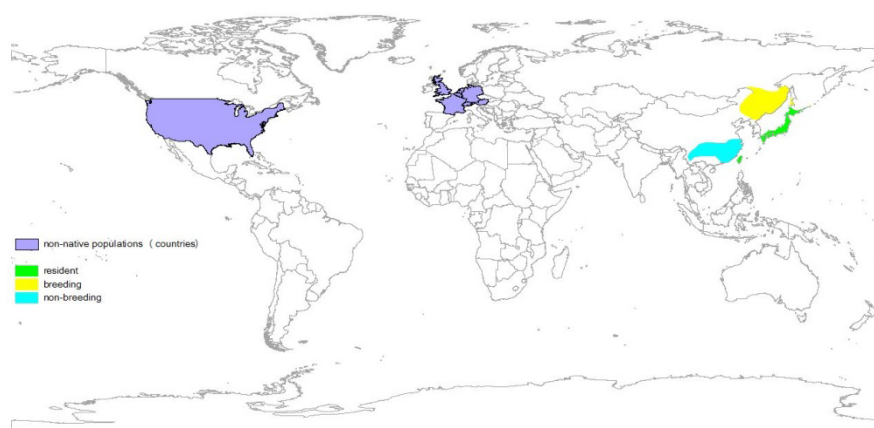


Figure 3.2. Global distribution of Mandarin Duck. Non-native distributions: just countries indicated with established populations. Source native distribution: BirdLife International.

3.2.3. Conclusions

The first breeding attempt of Mandarin Duck in the wild was recorded in 1964 near The Hague in the dune area Meijndel. Subsequently populations established in different parts of the Netherlands: The North Veluwe, South Veluwe and surroundings, Southeast Achterhoek, Limburg, West and Central Noord-Brabant and the dunes in Noord-Holland. Available records of Mandarin Ducks in the breeding season from the period 2009-2013 show that Mandarin Duck is nowadays still present in the Veluwe, South-east Achterhoek, Limburg and South-west Noord-Brabant. Furthermore the species is present in several atlas squares in Twente (eastern Overijssel) and around Nijmegen. Reports from birds (presence only, no confirmed breeding) in the breeding season come from many sites, scattered over the country, especially in central and eastern Noord-Brabant, Utrecht, Zuid-Holland and Noord-Holland. However these observations are not necessarily associated with breeding territories or established populations. The establishment of the local population in the North Veluwe was initially stimulated by providing nesting boxes and winter food.

In the Netherlands the Mandarin Duck has successfully established a population which is more or less successfully reproducing and likely to maintain itself in the wild. It is not clear, however, to what extent population trends are explained only by reproduction of these free-living birds, and to what extent escapes and releases support the population.

3.3. Population growth and expansion rate of Mandarin Duck in the Netherlands

3.3.1. Population growth rate

The Netherlands

In most core areas of the Mandarin Duck in the Netherlands (section 3.2.1) the species increased at least until *c.* 1999, with the exception of the population in The Hague, that may have become extinct. Recent population estimates are not available, except for the Southeast-Achterhoek, the Dune area near Haarlem and around Arnhem in the South Veluwe. In the South-east Achterhoek the species increased with *c.* 10% per year between 1999 and 2013, but the numbers have stabilised since 2006 (Kwak 2005, Kwak *unpublished*). Near Haarlem the species declined with *c.* 20% per year, based on counted individuals between 1999-2006. Van Deursen (2009) relate this decline to the increase of the Egyptian Goose (*Alopochen aegyptiacus*), that may take over nesting places from Mandarin Duck and the establishment of Pine Marten (a potential predator) in the area. The species has declined around Velp, Arnhem since 2005 due to low breeding success (F. Majoor, *unpublished*).

Breeding numbers of Mandarin Duck have not been monitored in the Breeding bird monitoring scheme in the Netherlands (Boele *et al.* 2013). Hence, proper trends of the breeding population are not available. However some population estimates are available based on atlas surveys and on reconstructions of the population size by Lensink (1996). A comparison of the estimates shows a strong increase in breeding numbers of *c.* 27-29% per year in 1988-1999. Reliable recent estimates are not available. Lensink *et al.* (2013) conclude that the breeding numbers have stabilised between 1998-2000 and 2008-2010 at 250-300 pairs, based on waterbird census data.

The results of the January counts in the national Waterbird census scheme indicate increasing numbers of Mandarin Duck until the early 2000s and more recent fluctuating numbers (figure 3.3). The real numbers are probably higher because a part of the population concentrates on small water bodies that are often not monitored and individuals may be overlooked because of their secretive behaviour.

Figure 3.3 shows the numbers counted during the January-census, representing the waterbird counts with highest coverage, including many potential waterbodies where Mandarin Duck may be found. This figure shows rather fluctuating numbers and the recent numbers are lower than around 2009. The numbers in 2008-2010 are 7% higher than in 1998-2000.

Surrounding countries

Most recent data from neighbouring countries indicate a stabilisation of the breeding numbers in Flanders (2000-2007; Vermeersch & Anselin 2009) and an increase in Germany, at least in Nordrhein-Westfalen, with 39% between 1989-1990 and 2005-2009; Grüneberg *et al.* 2013).

Table 3.1. Overview of national estimates of the breeding population of Mandarin Duck in the Netherlands and its distribution, expressed as number of occupied atlas squares (5x5km).

The yearly growth rate of the breeding population is indicative, based on the median value of the range of years and the population estimate.

Years	N breeding pairs	Yearly growth rate (%) (indicative)	Distribution (N occupied atlas squares)	Source
1973-1977	3-8		9	Teixeira (1979)
1979-1985	15-22	19		SOVON (1987)
1987-1989	12-18	-3		Lensink (1996)
1992-1994	48-61	29	55	Lensink (1996)
1998-2000	200-260	23	143	SOVON (2002)
2008-2010	230-300			Lensink <i>et al.</i> (2013)

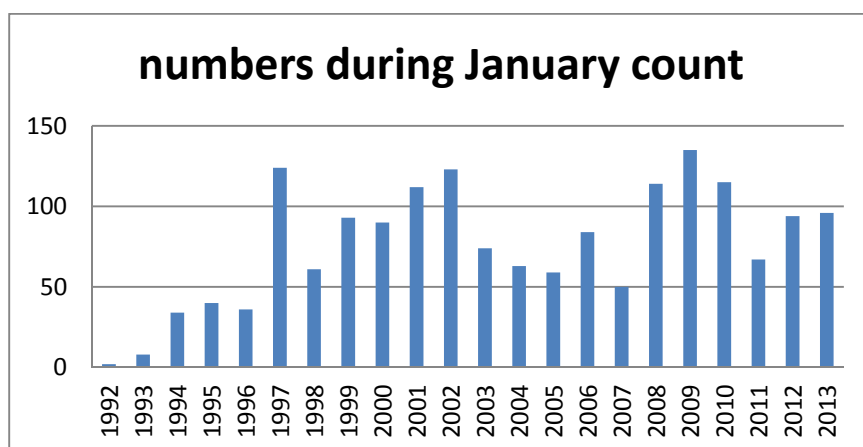


Figure 3.3. Numbers of Mandarin Duck counted during the January count in the Netherlands between 1992 and 2013. The real numbers are probably higher because a part of the water bodies is not monitored and the species may be overlooked because of its secretive behaviour.

3.3.2. Expansion rate

The Netherlands

On a national level, Mandarin Duck expanded its distribution with 511% between 1973-1977 and 1992-1994 and with 1914% between 1973-1977 and 1998-2000 (SOVON 2002). The increase is probably caused by expansion from core-areas and reports scattered over the country may indicate new introductions as well. Lensink *et al.* (2013) mentioned an expansion rate in the core areas in central Limburg of 1 km/year and in the Veluwe of almost 2 km/year. Because of a lack of good recent distribution data it is not possible to estimate the recent expansion of the species in this areas. Comparing the recent presence data (figure 3.7) to the distribution map for 1998-2000 (figure 3.8) it seems unlikely that the species has contracted its range. In 1998-2000 the species was recorded in 188 atlas squares (and in an additional 45 as possible breeding bird; SOVON 2002) and in 2009-2013 it was recorded in 115 squares and in an additional 445 birds were at least present during the breeding season. The many casual reports of the species in the breeding season may suggest further increase of its distribution, but as stated earlier some of these reports may relate to temporally present

individuals. Furthermore the number of observers and submitted observations to web-portals has increased.

Surrounding countries

From surrounding countries expansion rate for Mandarin Duck in England of 0,8-0,9 km/yr. was reported in Lensink *et al.* (2013). Between 1988-1991 and 2008-2011 the distribution increased with 123% in Great Britain (Balmer *et al.* 2013). In Nordrhein Westfalen a small increase in distribution of 23% was recorded between 1989-2000 and 2005-2009 (Grüneberg *et al.* 2013).

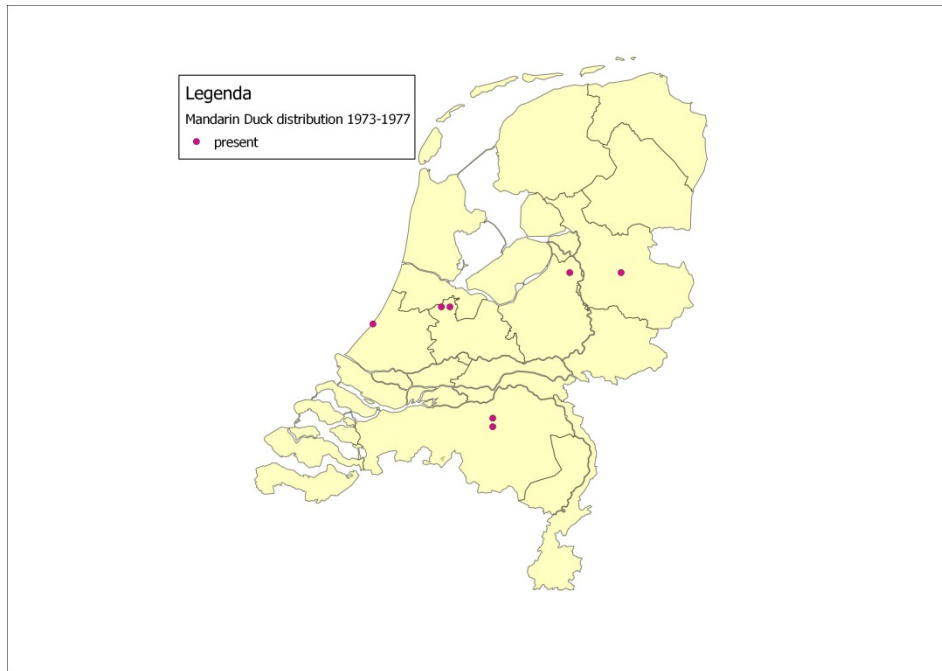


Figure 3.4. Breeding distribution of Mandarin Duck in the Netherlands in 1973-1977 (Teixeira 1979).

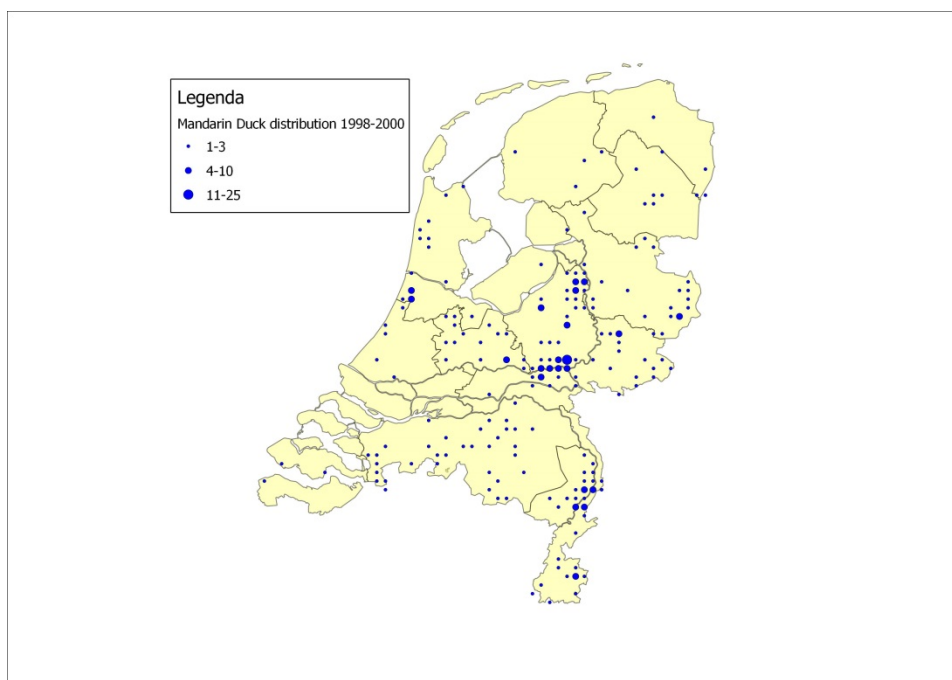


Figure 3.5. Breeding distribution (probable and confirmed breeding) and abundance (*n* breeding pairs) of Mandarin Duck in the Netherlands in 1998-2000 (SOVON 2002).

3.3.3. Conclusions

Numbers of Mandarin Duck increased rapidly, at least between the 1980s and late 1990s. Waterbird counts indicate that the numbers have fluctuated since the early 2000s. Available data from core areas show mixed patterns: decline in two areas and increase/stabilisation in one area.

Parallel to the increase in numbers a strong increase in distribution was recorded in the Netherlands at least until the late 1990s. It is unclear if there is expansion of birds from the core areas. The many casual reports of the species in 2009-2013 suggest that at the national scale, distribution has increased, but these reports may also relate to temporally present individuals and not permanent breeding populations or breeding territories at all. Moreover, they may to some extent reflect increased observer effort. An updated national breeding-distribution map is expected in 2015/2016 (Dutch Bird Atlas project) and will give a better insight in the distribution changes since 1998-2000.

It is likely that new areas with suitable habitat can be colonized by dispersion of birds from established nearby populations.

3.4. Endangered areas: Habitat and potential distribution

This section focuses on the areas in the Netherlands that may be occupied based on the species' habitat choice. Therefore an overview was made of the species' habitat requirement based on literature (section 3.3.1). Besides the species' potential distribution in the Netherlands based on habitat is mapped using a spatial modelling approach (section 3.3.2).

3.4.1. Habitat requirements - literature overview

The Mandarin Duck both in its native and non-native range requires fresh water pools, lakes, fens, (small) rivers, canals, streams, ditches, marshes or swamps with a dense marginal growth of deciduous woodland and shrubs (branches hanging over the water), especially rhododendron. It prefers a littoral vegetation of reeds and sedges or other emergent vegetation as a shelter opportunity. Regarding the surrounding woodland it prefers tree species such as such as beeches (*Fagus sylvatica*), oaks (*Quercus spec.*), sweet chestnut trees (*Castanea sativa*) and hazel trees (*Corylus spec.*), because of its preference for feeding on beech mast, acorns, chestnuts and hazelnuts. In parks it can also benefit from winter feeding. The presence of old trees with cavities is important for nesting opportunities. Alternatively the species breeds in nest boxes designed for this species (entrance diameter 15 cm, Lever 2013) or for other species, such as Tawny Owl (*Asio otus*), Barn Owl (*Tyto alba*), Little Owl (*Athene noctua*), Common Kestrel (*Falco tinnunculus*), Goosander (*Mergus merganser*), Stock Dove (*Columba oenas*). Mandarin Ducks can be rather opportunistic in their choice of their nesting location; even breeding in buildings and in a nest of Common Buzzard (*Buteo buteo*) have been reported.

Detailed information on habitat requirements in terms of needed surfaces of woodland and water bodies are not available in literature. The species generally nests near water, but breeding records up to one kilometre from waterbodies were reported from Switzerland (Kestenholz 1997).

Although the species prefers waterbodies in or nearby woodland, the species may also occur as a breeding bird on exposed lakes/pools, situated in more open landscape as is the case in Flanders (Vermeersch *et al.* 2004).

In particular during hard winters the species concentrates on ice-free water preferably nearby the breeding locations.

Table 3.2. Reported habitat choice and nesting locations of Mandarin Ducks in the Netherlands and other European countries.

Population	Habitat description	Reported nesting locations	Sources
The Hague	dune ponds, city parks	tree cavities	Bijlsma (2001)
North Veluwe and IJssel valley	ponds in wooded villa gardens, estates and (artificial) streams	nest boxes placed for this species	Gerritsen & van den Bergh (1995), Lensink (2002)
South Veluwe and adjacent areas	city parks, wooded estates with ponds, streams in deciduous woodland with old trees e.g. beeches >2000yr.	tree cavities made by Black Woodpeckers, or as a consequence of decay (in Beech, alder, ash, linden), also in pollard willows, in nest box (for Tawny owl) and possibly in chimney	Bijlsma (1994), Lensink (2002)
Southeast Achterhoek	streams in woodland	nest boxes (for Barn Owl) (amongst others)	Kwak (2005)
Limburg	park pond and, forested streams	tree cavities and nest boxes (for Stock Dove)	Schaafstra & Boonstra (1999), Lensink (2002)
Noord-Holland	estates, infiltration channels and wooded ponds in the dunes	tree cavities and nesting boxes	Lensink (1996), van Deursen (2009)
Southwest and central Noord-Brabant	ponds, fens, streams or ditches in deciduous woodland	natural tree cavities, possibly chimneys	Samenwerkingsverband Westbrabantse Vogelwerkgroepen (2007)
Flanders	park and forest ponds, but also ponds in open landscape	pollard-willows, cavities in oaks and in nest of Common Buzzard (<i>Buteo buteo</i>) and nest boxes	Vermeersch <i>et al.</i> (2004)
Wallonia	parks, near rivers, little lakes bordered with woodland	tree cavities made by Black Woodpecker, nest boxes and buildings (spire, attic)	Jakob <i>et al.</i> (2010)
Germany	park ponds, fish ponds, reservoirs, running waters etc. with surrounding old woodland	tree cavities and nest boxes	Grüneberg <i>et al.</i> (2013)
Great Britain	park ponds, fish ponds, reservoirs etc. with surrounding old woodland	tree cavities(e.g. in oak, <i>Quercus spec.</i>) and nest boxes (also for Tawny Owl (<i>Asio otus</i>) and Goosander (<i>Mergus merganser</i>)	Lever (2013)
Switzerland	city parks, forest lakes, rivers and reservoirs. Old deciduous woodland <500m altitude near water bodies, but can breed up to 1 km from waterbodies	tree cavities, nest boxes, indications that the species also breeds in buildings near ponds	Kestenholz (1997)

3.4.2. Potential distribution of Mandarin Duck in the Netherlands

The potential distribution of the Mandarin Duck in the Netherlands was mapped, based on the environmental characteristics of sites where Mandarin Ducks were observed in 2009-2013. Two scenario's were worked out: an analysis including breeding territories and an analyses including all observations of Mandarin Ducks during the breeding season (March-August). The technical details of this analysis are described in Appendix 2.

The analysis based on breeding territory data shows a strong preference of the species for the presence of forest, in particular Beech forest (*Fagus sylvatica*) and the presence of water bodies. It also shows a preference for higher altitude-locations (sandy soils) and landscapes with little open terrain (Appendix 2). Based on this model most potential habitat can be found in the higher, eastern parts of the Netherlands and in parts of the coastal dune area (figure 3.3).

If casual records of Mandarin Ducks in the breeding season are also included to the model, built-up areas become an important habitat feature of the species (Appendix 2). The area of potential habitat as

is shown in figure 3.4 is extended considerably compared to figure 3.3. in particular in the urbanised lower parts of the Netherlands.

The much larger area of potential habitat, shown in map 3.4 can be explained by the many casual reports of Mandarin Ducks in urbanised areas (section 3.2.1). These do not necessarily concern breeding territories and may refer to temporally present birds. However it is an indication that the species may be able to settle in urbanised areas besides forested, water habitats in the countryside.

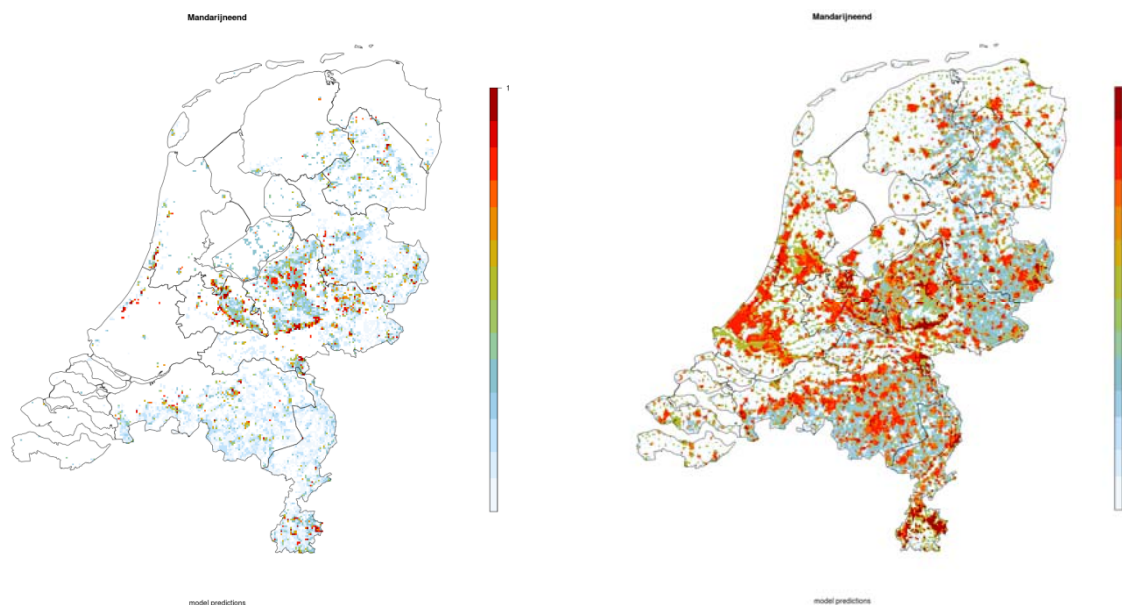


Figure 3.3 (left). Potential distribution of Mandarin Duck in the Netherlands - based on breeding territories only. (red indicate the most suitable areas).

Figure 3.4 (right). Potential distribution of Mandarin Duck in the Netherlands - based on all observations in the breeding season. (red indicate the most suitable areas).

3.4.3. Conclusions

Detailed habitat descriptions of sites with established populations show a strong preference for parks, estates, villa gardens (combination of old woodland and ponds), but also more natural habitat such as forested streams. Based on some reports from Flanders it could not be excluded that some Mandarin Ducks are able to settle on ponds in open landscape if nesting habitat is present.

Based on regression models based on breeding territories of Mandarin Duck and a large set of environmental variables the species shows on landscape scale a strong preference for forest and nearby water. A model including also casual observations of Mandarin Ducks shows a strong preference for built-up areas. The potential distribution could cover habitat in the higher, eastern parts of the Netherlands and parts of the coastal dune area and possibly also urbanised areas also in the lower parts of the country. The potential distribution of Mandarin Duck includes some protected areas of high conservation value.

3.5. Success of establishment and limiting factors

In this section the factors that may account for the establishment of Mandarin Duck populations in its non-native range and enhancing and limiting factors for further population growth are discussed.

3.5.1. Success of establishment of non-native populations of Mandarin Duck

According to Lever (1993 and 2013) the general success of establishment of non-native populations of Mandarin Duck can be explained by:

- existence of a vacant ecological niche for a hole-nesting duck which feeds on aquatic invertebrates on spring and summer and on tree seeds in winter
- availability of suitable habitats
- at least in Britain the founder stock is descended directly from the wild
- suitable climate
- abandonment of migratory instinct, so they are able to become established without the distraction of the urge to migrate.

With respect to the last point it is important to mention that abandonment of migratory instinct is only advantageous if the new habitat is suitable to live in all year round as is the case in the Netherlands. In Europe Mandarin Duck was observed to undertake short migratory movements to escape from harsh winter weather (Blair *et al.* 2000).

3.5.2. Enhancing and limiting factors for establishment and or spread of Mandarin Duck populations in the Netherlands.

Climate

In its native range the species occurs in areas with continental climate with harsh winters (section 2.2., figure 3.2). So it is not likely that low temperatures are a limiting factor in the Netherlands in winter. It is unknown whether the climate, temperature and precipitation levels in spring could affect breeding-effort.

Availability of habitat

As is shown in section 3.2.2. large areas of potential habitat for the species are available that are currently not occupied or in low numbers.

The number of nesting sites could be a limiting factor (e.g. Bijlsma 1994). If the number of nesting sites is limited there could be competition for nesting sites with other cavity-nesting species (section 3.6.1). F. Majoor (*unpublished*) presumes for his study site near Arnhem that availability of natural nesting sites is not a limiting factor for the Mandarin Ducks there. Furthermore the species seems to benefit from the provision of nest boxes (e.g. the establishment of the population in the north-Veluwe; Gerritsen & van den Bergh 1995) and may even be able to breed in buildings (section 3.3.1). Van Deursen (2009) relates the decline of Mandarin Ducks near Haarlem amongst others to the increase of the Egyptian Goose (*Alopochen aegyptiacus*), that may take over nesting places from Mandarin Duck.

Food availability

Availability of food, in particular during hard winters and e.g. if there is little (beech, acorn) mast could possibly be a limiting factor. In particular in park-like settings sometimes supplementary food is given to waterfowl. Its dependence on provided food is not clear. Lever (2013) presumes that cessation of supplementary winter feeding in parks and gardens etc. may result in increased winter mortality. The population in the North-Veluwe was attracted by provision of winter food (corn) (Gerritsen & van den Bergh 1995). On the other hand F. Majoor (*unpublished*) presumes that winter feeding is of little significance in his study site in the South Veluwe; it prefers acorns to bread.

Reproduction

In general the reproductive output could be affected by predation, weather and food availability. In the Netherlands breeding success was studied by Bijlsma (1994) near Renkum: 3 out of 14 recorded breeding attempts failed (2 abandoned, 1 destroyed probably by a predator, *Martes spec.* The following losses were recorded after the ducklings had left the breeding holes: 1-10 days: 9.5 ducklings per female (N=4), 11-20 days: 8 (N=1), 21-30 days: 6.3 (N=3), >30 days: 6.2 (N=5). The causes of death were unclear. F. Majoor (*unpublished*) recorded a low reproductive output at his study site near Arnhem.

Predation may suppress the reproductive success (or population number of adults directly), but to what extent is unclear. Van Deursen (2006) relates the decline of Mandarin Ducks near Haarlem amongst others to the establishment of Pine Marten (a potential predator) in the area.

In Dresden high mortality rates among chicks were caused by predation by Carrion Crow (*Corvus corone*), cats, dogs and Red foxes (*Vulpes vulpes*). Also predation of Mandarin Ducks by Tawny Owls was recorded (Töpfer & Katzer 2003). However Davies & Baggott (1989) recorded negligible predation at their study site in Surrey, England. Near Frankfurt duckling mortality was recorded due to e.g. Grey Heron (*Ardea cinerea*), Carrion Crow (*Corvus cornone*) and predatory fish (Meierjürgen 2009). Here predation was the main factor causing low breeding success. Other limiting factors were weather and food availability.

Lever (2013) also mentions Common Magpies (*Pica pica*), Red Fox (*Vulpes vulpes*), Weasels (*Mustela nivalis*) and Stoats (*Mustela ermine*) and (Brown) rats (*Rattus norvegicus*) as predators of ducklings of Mandarin Duck in Britain and Continental Europe.

Dispersal capacity

Although the European population is considered sedentary, several ringing recoveries demonstrate that species is able to cover large distances in its non-native range:

A bird ringed in London in summer 1930 was reported the next spring in Hungary, and two birds ringed in Oslo in November 1962 were reported the next day from 900 km further in Northumberland, England (Witt 2003). Furthermore Lever (2013) mentions a bird ringed in Berkshire, England and recovered in Psov, south of Leningrad, Russia. Dubois (2007) mentions a ringing recovery from a bird from the Channel Isles in Les Landes (Southwestern France).

A Dutch ringed Mandarin was recovered in Strathspey, Scotland on 19 April 1998. It was hatched in Rotterdam Zoo in June 1991 and escaped in 1994, before making its own way to Scotland (Pete Moore pers comm in Cosgrove 2003). This indicates that the species is able to colonise new habitat from established populations. A male Mandarin duck of 1 year old that was ringed in Velp, near Arnhem on 10-8-2005 was reported dead (probably killed by predator) on 8-9-2013 in Svorksjøen, Sør-Trøndelag, Norway at a distance of 1259 kilometres from the original ringing site. In the mean time it was seen in the surroundings of Velp on 25-9-2005, 15-10-2005, 28-10-2005, 8-3-2006 en 12-3-2006. After that the duck was never observed until reported dead (Frank Majoor, unpublished).

Apart from movements over large distances it is likely that the species is capable of colonizing nearby habitat from established populations (section 3.2.1 and 3.2.2.).

Commonly held in captivity

The species is commonly held in waterbird collections throughout the country. These could be a source for continuous new introductions. Escaped birds with rings from waterbird collections have been observed in free living populations, suggesting that they contribute to the population of Mandarin Ducks in the Netherlands (F. Majoor, unpublished). There are no exact figures available on numbers of birds in private collections and how many birds escape or are released to the wild. Private owners usually clip the wings to prevent escape.

3.5.3. Conclusions

It is likely that availability of breeding habitat is not a limiting factor for population growth of the Mandarin Duck in the Netherlands. Neither is its dispersal capacity. Introductions from captivity could be a source for continuous new introductions.

Little information is available about reproductive output and the extent to what factors such as weather and predation may influence reproductive output. Also little information is available on food-availability in particular its dependence on supplied food in the Netherlands. So it is hard to estimate how these factors may affect population growth and future prospects of the species in the Netherlands.

3.6. Impact

In this chapter the possible impact of Mandarin Duck on ecological, economic, social and health aspects is discussed.

3.6.1. Negative ecological impact

Competition for nesting sites

Mandarin Ducks use cavities in trees as a nesting site which may cause competition with birds or mammals using the same sites. The largest European population of Mandarin Duck is found in the United Kingdom where the population has expanded and dispersed considerably especially in the last century. In a recent monography of the Mandarin Duck by Lever (2013) competition for nest sites is observed. Lever (2013) mentions Stock Dove (*Columba oenas*), Little Owl, Tawny Owl (*Strix aluco*), Barn Owl (*Tyto alba*), Jackdaw (*Corvus monedula*), Common Kestrel (*Falco tinnunculus*), Great Tit (*Parus major*), Mallard (*Anas platyrhynchos*), and Grey Squirrel (*Sciurus carolinensis*) as possible nest-competitors in England. Besides that, he mentions competition with Common Goldeneye (*Bucephala clangula*) and Goosander in Scotland. The following observations were mentioned concerning competition for nesting-sites:

- Chasing away Mandarin Duck from her clutch by Kestrel and Stock Dove, the intruder subsequently laying her eggs alongside those of the Mandarin
- Take over of Mandarin nests before they start laying eggs (Great Tit, Mallard, Tawny Owl, Grey Squirrel) sometimes taken over by Mandarin again by laying eggs on top of those of the intruder (Great Tit and Tawny Owl) and trampling an laying on a Grey Squirrel drey.
- Egg-laying synchronously with Mandarin in the same site (Mallard, Stock Dove),
- Nest inspection at the same time (Tawny Owl, Jackdaw, Stock Dove)
- Using the same type of site in the same area but in different years (Barn Owl, Little Owl, Kestrel and Stock Dove).
- In some nest boxes Mandarin eggs have been found alongside those of Goosanders (*Mergus merganser*).
- There were occasions when Mandarin Ducks hatched the eggs of the other species together with their own (Anderson and Pertty (1996) in Lever (2013). In Marple Bridge in 2010 two Mandarin Ducklings hatched together with two owlets in a Tawny Owl box.

There were no indications found that competition lead to reduction of population numbers of the species involved. Lever (2013) mentions that competition for nest sites with other cavity breeders, in this case Common Goldeneye may be one of the possible causes of decline of the Mandarin Duck near the Tay in Scotland.

The Mandarin Duck is mentioned as a potential competitor in the Netherlands for the Common Goldeneye because they prefer the same nesting habitat The Common Goldeneye is a rare breeding bird in a part of the IJssel river basin where Mandarin Ducks are absent. The presence of Mandarin Ducks in neighbouring areas is given as a possible explanation why colonisation of suitable neighbouring areas did not occur (Voskamp & Driessen 2003). It is however unlikely that nesting cavities are a limiting factor in this area and food competition does not occur due to different foraging strategies. In conclusion we find it unlikely that competition is influencing the breeding population of Common Goldeneye. The precarious occurrence of the latter species might be caused by climate change effects. This boreal species in the Netherlands reaches its south-western boundary within continental Europe. Its breeding range is believed to decline in a northwards direction due to climate change (Huntley *et al.* 2007). The Common Goldeneye is not considered to be a threatened species internationally (www.iucnredlist.org). Witt (2003) also mentions that in Schleswig-Holstein competition for nesting sites with Common Goldeneye was discussed. He considers this unlikely as the Mandarin Ducks mostly breed in or near urbanised areas, contrary to Common Goldeneye. He states that the species occupies a unique niche. Lever (2013) states that the British population of Goldeneye is not threatened by Mandarin Duck. There may be some competition for nest sites (vice versa) that may cause to some extent limitation of numbers of breeding Goldeneye, but there are more important factors limiting the population. The principal source of nest failure for both species in Scotland is predation by Pine Marten and to a lesser extent by American Mink (*Neovison vison*).

Kretzschmar (2013) discusses possible competition with Tawny Owl and Common Goldeneye in the area of Nordrhein-Westfalen (NRW). He does not expect a negative impact for Tawny Owl because it is not restricted to water-rich woody areas and the Mandarin Duck would certainly lose in a confrontation. The Common Goldeneye does not occur in NRW. He personally observed Mandarin Duck to expell a Ringed Teal (*Callonetta leucophrys*)(a non-native species) from a nest box.

Cosgrove (2003) discusses the possibility that Mandarin Duck is a competitor for Common Goldeneye in Scotland. Although he cannot exclude competition for nest boxes he also states that there is lack of data. He observed that within the Goldeneye population there were a lot of unoccupied nest boxes. The most important factor limiting the local Goldeneye population was predation by Pine Marten. Also birds in nest boxes that were closer to the water were more successful, so these may be preferred sites.

Meierjürgen (2009) studied Mandarin Duck in the Stadt Wald in Frankfurt am Main (Germany) where they mainly breed in old woodpecker holes. She concludes that there is no evidence that the Mandarin Duck was a serious competitor for other hole-breeding birds like Tawny Owl. Witt (2003) mentions it was suggested that the decrease of Tawny Owls in Großer Tiergarten in Berlin could be explained by Mandarin Ducks occupying nest boxes of this species. However he considers this unlikely as the Tawny Owl is an early breeder compared to Mandarin Duck and the decline of Tawny Owl was also reported from other parts of Berlin where Mandarin Duck was absent.

Töpfer & Katzer (2003) report that in the Großer Garten in Dresden the competitors for nesting locations were Mallard, Jackdaw and Tawny Owl. In all observed confrontations the Mandarin Duck lost. They conclude that with respect to nesting locations the Mandarin Duck is not a very competitive species to indigenous cavity nesting birds. They start breeding a month later than Mallard.

In the countries of the AEWA² region a review was made of the status of non-native waterbird species by Blair *et al.* (2000) based on questionnaires. This was updated by Banks *et al.* (2008) who states “little is known about the effect of introduced Mandarins on native species and habitats, with questionnaire respondents from many countries reporting that they were unsure whether or not this species displaced natives or posed a threat to other species”. In captivity, Mandarins are known to destroy the nests and eggs of other species using nest boxes (Blair *et al.* 2000, no source specified); and this is also thought to occur in the wild (Rehfishch *et al.* 2006). In captivity this does not happen often and when it occurs it usually happens as a result of a shortage of nest boxes where too many ducks are cramped in a small space (pers. com. P.Eyma Aviornis).

Competition for food

Competition for food is rarely mentioned in literature. In the Netherlands, Mandarin Duck occupies a vacant ecological niche for a hole-nesting duck which feeds on aquatic invertebrates in spring and summer and on tree seeds (acorns, chestnuts and beech mast) in winter. Cosgrove (2003) excluded food competition with Common Goldeneye: Although their diets seems the same, their foraging strategy is different with Common Goldeneye eating benthic organisms and Mandarin Duck picking food from the water surface.

Lever (2013) mentions that Mandarin Ducks are competitive feeders especially on land and he has observed them driving away Eurasian Jackdaw, Common Starlings *Sturnus vulgaris*, Common Moorhens *Gallinula chloropus*, Stock Doves, Common Woodpigeons *C. palumbus* and Eurasian Collared Doves *Streptopelia decaocto*.

Hybridisation

Hybridisation with native species is possible but is not likely to be successful which is related to chromosomal differences (Lever 2013) or to the specific niche and habitat needs of Mandarin Duck (Madge & Burn 1988 in Kestenholz 1997). In the Netherlands a mixed pair was observed of Mandarin Duck and Mallard in 1968 (Lensink, 1996). Wood Duck has not been recorded to hybridise with native

² AEWA: African-Eurasian Agreement on Waterbirds

species in the wild but was recorded to hybridise with introduced Mandarin in France in 2003, producing 2 young (Dubois 2007 in Banks *et al.* 2008). Breeding attempts with Mallards have been recorded in Poland, but these are not known to have successfully produced hybrids. Introduced Mandarins are not known to hybridise in the wild in other countries (Banks *et al.* 2008).

Töpfer & Katzer (2003) recorded in Großer Garten, Dresden once a bird with features of both Mandarin Duck and American Wood Duck and also mixed displaying behaviour. Blair *et al.* (2000) reported that the Mandarin Duck has hybridized with at least four species of duck in captivity including the very closely related American Wood Duck, although very seldom with the latter. According to Kestenholz (1997) there are only a few cases of hybridisation with other Anatidae-species (Gray 1958, Johnsgard 1960, Schere & Hilsberg 1982 in Kestenholz 1997). In Florida the Mandarin Duck will breed with American Wood Duck but cannot hybridize (Stevenson & Anderson, 1994). Interspecific mating between male Mandarin and female Wood Duck had been observed at Indian Meadow Ranch (USA). In only two cases they had eggs which were abandoned after 30 days and were found to be infertile (Lever 2013).

Conservation

In its origin in the eastern part of Asia populations have been dramatically reduced by habitat changes (mainly logging) and over-hunting. The European populations might be of some importance for the species, especially if there is no demonstrated impact (Kestenholz 1997, Wittenberg 2005)

Conclusion

Although some competitive behaviour has been observed there is no evidence of a negative impact as a consequence of competition for nesting cavities or food in the wild between Mandarin Duck and other native species. Hybridisation with native species rarely occurs and is not likely to cause any negative impact.

The probability of ecological impact is low.

3.6.2. Positive ecological impact

Conservation

In its origin in the eastern part of Asia populations have been dramatically reduced by habitat changes (mainly logging) and over-hunting. The European populations might be of some importance for the species, especially if there is no demonstrated impact (Kestenholz 1997, Wittenberg 2005). The Mandarin Duck is threatened in its native range and the European population may have a conservation value.

3.6.3. Economic impact

There is no negative economic impact of Mandarin Duck reported nor expected from any of the studied sources.

3.6.4. Social impact

Mandarin Duck is a much loved species because of the beauty of its plumage and therefore it often occurs in private or public waterfowl collections. There is no evidence of any negative social impact of Mandarin Duck reported nor expected from any of the studied sources.

3.6.5. Health impact

Wild waterbirds are known to be a carrier and reservoir for different pathogens like viruses and bacteria. There are a few studies from Asia which include Mandarin Duck.

Dong-Kun *et al.* (2011) tested (HI test) 1316 wild waterbirds from different areas in Korea for Japanese encephalitis virus (JEV) among which were 310 individuals of Mandarin Duck. In Korea the incidence of JEV is increasing from 7 cases in 2007 to 25 cases in 2010. One hypothesis is that wild migratory birds may be a vector, especially due to changing migratory patterns as a result of climate change. 86,7% of all samples tested positive (all waterbirds) and 78,7% of the Mandarin Ducks tested positive. The HI test which was used causes a cross reaction with WNV but a more specific test in a previous study in Japan showed similar results. No relationship was found between the seropositive rates in the capture area and the JEV incidence rate in humans.

Guo *et al.* 2005 isolated five new hepadnaviruses from exotic birds held in captivity. The virus isolated from a Mandarin Duck was virtual identical to the virus isolated from a Ross Goose. Both individuals came from waterfowl collections in different states in the USA with no obvious contact. Also in the wild it would be highly unlikely that these species would be in contact, so there is a high possibility that neither viruses are native to these species in the wild.

Uchida *et al.* (2012) studied the genetics and infectivity of H5N1 highly pathogenic avian influenza viruses isolated from chickens and wild birds in Japan during 2010-11. Two isolates from chicken and wild Mandarin Duck were compared in their ability to infect and be transmitted to chickens. There was a significant shorter survival time for chickens infected with the isolate from chickens as compared to Mandarin Duck. The transmission rate between infected chickens was significantly higher for the isolate from chickens. Higher levels of excreted virus from infected chickens correlated with a higher transmission speed. The wild bird isolate appeared to become attenuated in chickens which could have been caused by passage and adaptation to wild birds.

Conclusion

There is no evidence that Mandarin Duck has caused a specific negative impact on the health of humans or live-stock.

3.6.6. Status of Mandarin Duck in European alien invasive databases and lists

Mandarin Duck has been assessed in several international risk assessments and horizon scans. In this paragraph a short overview is given of the available sources and the risk assessment information on impact.

AEWA countries

A review of the status of Mandarin Duck based on questionnaires in the countries of the Atlantic-Eurasian Waterbirds Agreement concludes that based on behaviour in captivity there may be an impact on native species, but there is no clear evidence so further research would be necessary (Banks *et al.* 2008).

NOBANIS

The NOBANIS database gives an overview and assessment of invasive species in North-West Europe except the United Kingdom. The Mandarin Duck is considered to be not invasive except for Belgium and Poland where it is considered to be potentially invasive (www.NOBANIS.org).

Ireland

In Ireland then Mandarin Duck is placed on the Amber list: Uncertain risk (www.invasivespeciesireland.net). This means it is rated as medium risk due to the score of the overall assessment. However, their impact on conservation goals remains uncertain due to lack of data showing impact or lack of impact.

Switzerland

In Switzerland, Wittenberg (2005) concluded that there is a possibility of competition with Goldeneye and other cavity-nesting bird species for tree holes and that there is probably no economic impact. He states that while the current small population could still be eradicated, the necessity for this is

questionable. The main point to take into consideration is the small populations in its native range. Information gaps are the range of potential distribution in Europe and impacts.

Belgium

Belgium uses the ISEIA protocol to score potential ecological risks. Mandarin Duck is scored as a low risk species <http://ias.biodiversity.be/species/all>

Norway

In June 2012, the Norwegian Biodiversity Information Centre published Alien species in Norway – with the Norwegian Black List 2012 (Gederaas *et al.* 2012).

This contains an overview of alien species recorded in Norway and an assessment of their impacts on Norwegian nature. Mandarin Duck is considered to be a low risk.

3.6.7. Risk assessment of Mandarin Duck using the ISEIA protocol

The potential risk of Mandarin Duck was assessed by means of the ISEIA protocol (table 3.3). This protocol assesses potential ecological risks based on dispersion potential or invasiveness, colonisation of high conservation value habitats, adverse impacts on native species and alteration of ecosystem functions. Information on the methodology can be found in appendix 1. The protocol results in a score of 8 points which means that the Mandarin Duck is considered to be no threat to native biodiversity or ecosystems.

Score of dispersion potential or invasiveness

According to the fact that the Mandarin Duck is a bird, it automatically scores in the high risk category and gets 3 points.

Score of colonisation of high conservation value habitats

The Mandarin Duck breeds in nest boxes or in natural cavities in trees in the vicinity of water like ponds in parks or along streams in old forests, the latter having a high potential conservation value. Based on the high conservation value of old forests the score is 3 points.

Score of adverse impacts on native species

There is no evidence of adverse impacts on native species. Although there is a potential competition with native species for nesting spaces in cavities in old trees there is no evidence that there is an adverse impact on these species. The score is 1 point.

Predation/Herbivory: low
Competition: unlikely

Disease transmission: unlikely
Genetic effects: low

Score of potential to alter ecosystems functions

There is no evidence that the Mandarin Duck has the potential to alter ecosystems functions. The score is 1 point.

Nutrient cycling: low
Physical alteration: low

Natural successions: low
Food web alteration: low

Table 3.3. ISEIA score for Mandarin Duck in The Netherlands

ISEIA score for Mandarin Duck	
Aspect	Score
Dispersion potential or invasiveness	3
Colonisation of high conservation value habitats	3
Adverse impacts on native species	1
Alteration of ecosystem functions	1
Total score	8
Conclusion: No threat to native biodiversity or ecosystems, C-List	

4. Risk management

4.1. Introduction

Mandarin Duck has been included in a reasonable number of studies considering invasive alien species concluding that there was no ecological, economic or health risk and so far no specific management actions are taken for this species. For that reason the options for risk management will be addressed in a very concise manner.

4.2. Prevention

The Mandarin Duck has been introduced to the wild by escape from waterfowl collections. In the Netherlands the establishment of a self-supporting population was promoted with additional help from humans by providing nest boxes and food and by digging ponds (Lensink 1996). It is currently the most popular and widely kept duck in private collections. Within the European Union there is no restriction of trade between the member states and movement of non-native birds across national borders is commonplace and is not monitored. Dealers in the Netherlands and Belgium regularly transport birds to other countries (Owen *et al.* 2006).

The society of private keepers of ornamental park and waterbirds Aviornis advise their members to wing clip adult birds or pinion ducklings to prevent escapes. They prefer pinioning because wing clipping needs to be repeated every year and sometime birds can be overlooked. It takes a greater effort and also causes more disturbance. Pinioning will be prohibited from 1 January 2018 onwards. Both measures should in itself be effective and sufficient to prevent most escapes, but they will not be effective if Mandarin Ducks are deliberately released to the wild.

A further measure could include the prohibition of keeping Mandarins in open air collections and the obligation to keep them in a cage or otherwise covered construction that prevents escape. The obligation to ring adult and young birds in captivity could lead to more insight in the sources of introduction and the number of individuals that escape.

Blair *et al.* (2002) suggests that juveniles are frequently "set free" on moments when there is a surplus of young ducks and not enough demand on the market and that it is also likely that Mandarins in private collections in the UK, the Netherlands and Germany originate from feral sources. He states that "it is quite difficult to sell excess stock privately because the market is geared to first-time buyers who have no means of knowing any other sources than those advertised. Many of the larger collections not only no longer purchase Mandarin, they no longer stock them....".

4.3. Eradication

Eradication in this context would mean complete elimination of the entire Mandarin Duck population in the Netherlands. In the European countries where it has established smaller or larger populations no measures are taken to manage or reduce the population so there is no experience specifically with this species. The means of eradication of ducks would be the same as are applied to geese in the Netherlands including shooting, catching in the moulting period and removing from the wild or killing, destroying eggs or preventing eggs from hatching by different treatments. The Dutch breeding population is still small enough to be considerably reduced by these measures. Complete elimination

would be possible but asks a considerable effort and it is very likely that there will also be a continuing supply of new introductions from waterbird collections.

4.4. Management

Measures for management of the population are the same as mentioned under 4.3. Further measures for management would be to stop stimulating population growth by no longer providing additional nest boxes or additional feeding in the winter.

4.5. Effectiveness, efficiency and costs

It is likely that prevention of escapes would ask a considerable effort because the Mandarin Duck is one of the most frequently found species in private collections and so far there are no restrictions on the trade and transportation between the EU-member states. Elimination is possible but will also take a considerable effort and it will have to be repeated every few years as long as prevention of escapes is not completely possible. Concerning prevention and elimination the costs would not counterbalance the benefits. Management is an option to maintain or reduce the current numbers. Whether this is desirable or not falls outside the scope of this project.

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Appendix 1. Applying the ISEIA protocol on Mandarin Duck

Introduction

In this section the potential risk of Mandarin Duck is assessed by means of the ISEIA protocol. It was developed to quantify the potential hazard of non-native species, with an emphasis on the impact on biodiversity and ecosystem functions. The ISEIA protocol allows to assign species to 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 species, that are not considered as a threat for native biodiversity and ecosystems (low environmental risk).

The full text of the ISEIA protocol can be found on <http://ias.biodiversity.be>

ISEIA score Mandarin Duck

The ISEIA score for Mandarin Duck in the Netherlands when judged by strictly following the criteria is 8 points (table 1) which is the same as the score in Belgium

(<http://ias.biodiversity.be/species/show/18>). A more realistic score based on the actual situation would be lower, see the explanation on the scoring that is given below. However for both approaches the conclusion for the Mandarin Duck would be the same as a score of 4-8 points results in an assignment to the Categorie C list of non-native species that are not considered a threat for native biodiversity and ecosystems.

Tabel. ISEIA score for Mandarin Duck in The Netherlands

ISEIA score for Mandarin Duck	
Aspect	Score
Dispersion potential or invasiveness	3
Colonisation of high conservation value habitats	3
Adverse impacts on native species	1
Alteration of ecosystem functions	1
Total score	8
Conclusion: No threat to native biodiversity or ecosystems, C-List	

ISEIA 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. 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, the ISEIA approach favours the use of documented invasion histories in

previously invaded areas of Western Europe 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 already proved to do 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).

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 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

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 commensalisms.

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 > 1km/year and initiate new populations. Are to be considered here plant species that take advantage of anemocory (*Senecio inaequidens*), hydrochory (*Ludwigia grandiflora*) and zoochory (*Prunus serotina*), insects like *Harmonia axyridis* and all bird species.

Explanation score Mandarin Duck:

According to the fact that the Mandarin Duck is a bird, it automatically scores in the high risk category and gets 3 points.

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:

Low risk. Populations of the non-native species are restricted to man-made habitats (low conservation value).

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.

High risk. The non-native species often colonises high conservation habitat (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.

Explanation score Mandarin Duck

The Mandarin Duck breeds in nest boxes or in natural cavities in trees in the vicinity of water like ponds in parks or along streams in old forests, the latter having a high potential conservation value. Based on the high conservation value of old forests the score is three points.

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 ecomorphological 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.

High risk. The development of the non-native species often cause local severe (>80%) population declines and the reduction of local species richness. At a regional scale, it 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.

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

Explanation score Mandarin Duck

There is no evidence of adverse impacts on native species. Although there is a potential competition with native species for nesting spaces in cavities in old trees there is no evidence that there is an adverse impact on these species. The score is one point.

Predation/Herbivory: low

Disease transmission: unlikely

Competition: unlikely

Genetic effects: low

Alteration of ecosystems functions

This section addresses the potential of an exotic species to alternative 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.

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.

High risk. The impact on ecosystem processes and structures is strong and difficult to reverse.

Ecosystem impact score = maximal score recorded for nutrient cycling, physical alteration, natural successions and food web sections. When impact is strongly dependent on the type of ecosystem, one should consider the worst case scenario, with a special focus on vulnerable ecosystems.

Explanation score Mandarin Duck

There is no evidence that the Mandarin Duck has the potential to alter ecosystems functions. The score is one point.

Nutrient cycling: low

Physical alteration: low

Natural successions: low

Food web alteration: low

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

Appendix 2. Technical details of the modelling of potential habitat of Mandarin Duck in the Netherlands

Observations of Mandarin Ducks

Data on breeding territories (2009-2013) of Mandarin Ducks were selected from the databases of the Dutch Breeding Bird Census scheme (BMP, <https://www.sovon.nl/nl/BMP>), Rare breeding bird Database and de Breeding Bird Atlasproject (<http://www.vogelatlas.nl/>). Furthermore casual data of observations of Mandarin Ducks in March – August were selected from Waarneming.nl (<http://waarneming.nl/>), Telmee.nl (<http://www.telmee.nl/index.php?c=portal&m=home>) and the Sovon BSP-nb database (<https://www.sovon.nl/nl/content/bijzondere-soorten-project>). These casual observations do not consider breeding territories according to the Sovon-guidelines (<https://www.sovon.nl/nl/soort/1780>), but the presence of Mandarin Ducks on a location in this period may indicate a breeding territory.

Explanatory variables

From a wide set of spatial data sources environmental data that might be relevant for the presence of Mandarin Duck were selected (table 3.2.2.).

Table 3.2.2. Environmental data used in the spatial model describing the presence of Mandarin Duck in the Netherlands.

Variable
Clay soil
Clay on peat soil
Loam soil
Peat soil
Sand soil
Northern red oak (<i>Quercus rubra</i>) forest
Beech (<i>Fagus sylvaticus</i>) forest
Douglas fir (<i>Pseudotsuga menziesii</i>) forest
Norway spruce (<i>Picea abies</i>) forest
English oak/Sessile <i>Quercus robur</i> / <i>Quercus petraea</i> forest
poplar (<i>Populus spec</i>) forest
Forest age (germination year) <1900
Forest age (germination year) 1900-1930
Forest age (germination year) 1930-1960
Forest age (germination year) >1960
Mixed forest with Northern red oak (<i>Quercus rubra</i>)
Mixed forest with Beech (<i>Fagus sylvaticus</i>)
Mixed forest with English oak/Sessile <i>Quercus robur</i> / <i>Quercus petraea</i>
Mixed forest with poplar
Built up area
Forest
Marsh
Water body
Average spring groundwater table
Average altitude
Altitude range
Water salinity
Openness landscape in 2009
Small deep water bodies
Shallow water bodies on sand soil
Fens

Regression analyses

The relationship between the observations of Mandarin Duck and explanatory variables was analysed using boosted regression trees (BRTs) (Elith et al. 2008), a method recommended for spatial analyses (Hawkins 2012). Two models were made: one including only breeding territories and the other including all observations from March-August 2009-2013.

In order to validate the quality of the model an evaluation dataset containing 20% of the records was kept apart from the analysis-dataset. The model quality was evaluated using the AUC-ROC-method (Area under the Curve – Receiver operating characteristic) and explained deviance

The AUC-ROC measures the quality of prediction of binomial observations by the model

(http://en.wikipedia.org/wiki/Receiver_operating_characteristic and

<http://nl.wikipedia.org/wiki/ROC-curve>). The AUC-value ranges between 0.5 and 1. 0.5 means a poor model prediction (as a random model) and 1 means a perfect model-prediction.

An explained deviance value of 0 means that the model cannot explain any of the variation in the observations. An explained deviance of 100% means a perfect description of the observations, but the model is probably not suited to predict to unknown sites (“overfitting”). Presence-absence models with an explained deviance of more than 20% are already fairly good.

Technical analyses

The spatial modelling was carried out in TRIMmaps (Hallmann, Kampichler & Sierdsema 2013). This program was developed for spatial modelling and it can handle different sources of data (both presence-only data and data from monitoring schemes). It comprises several scripts and uses several R-functions for the modelling. R is a statistical open source software package (R Development Core Team 2004-2013), version 2.12.0 (64-bits version).

The Boosted-regression-tree models were made using a script made by Elith et al. (2008), based on the gbm (general boosted regression models)-package (Ridgeway 2012) and TRIMmaps (Hallmann, Kampichler & Sierdsema 2013)

Model Quality

Only territorial observations:

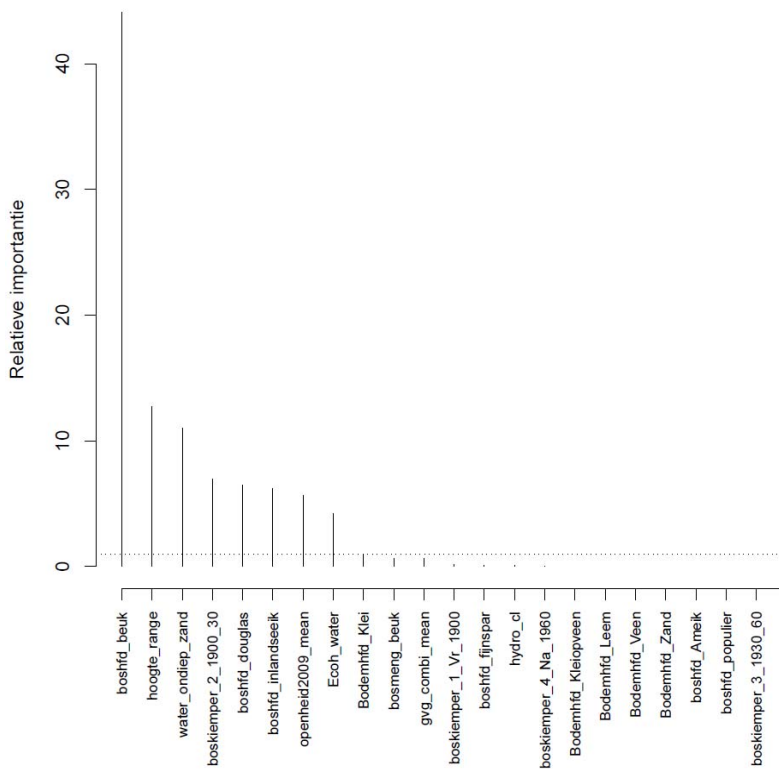
The model-quality based on the explained deviance (26.0) is moderate and based on the AUC (0.83, five-fold cross validation-range 0.78-0.90) is fairly good

All observations:

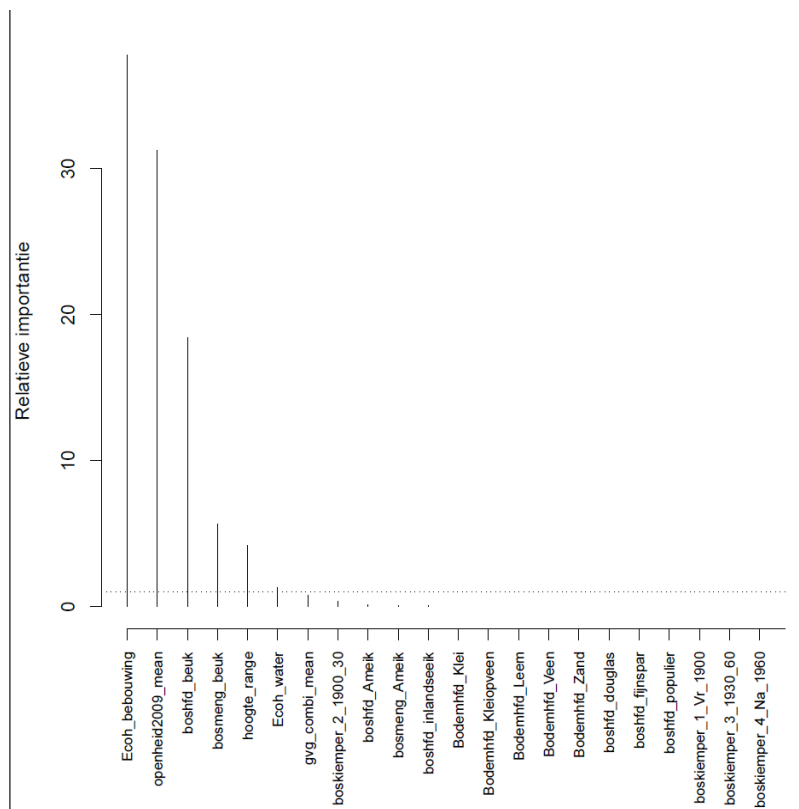
The model-quality based on the explained deviance (23.2) is moderate and based on the AUC (0.87, five-fold cross validation-range 0.86-0.88) is good.

Both models perform reasonably well. Models including regionality would perform better, but these were not included in the models to show the potential distribution of the species and not the current distribution.

Results



The relative importance of the variables, model including breeding territories only.



The relative importance of the variables, model including all observations in breeding season.



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