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Assessment of the risks associated with the import and release of hand-reared mallards for hunting purposes

Opinion of the Panel on Alien Organisms and Trade in Endangered Species (CITES) of the Norwegian Scientific Committee for Food Safety

Report from the Norwegian Scientific Committee for Food Safety (VKM) 2017: 23
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Norwegian Scientific Committee for Food Safety (VKM)
Po 4404 Nydalen
N – 0403 Oslo
Norway

Phone: +47 21 62 28 00
Email: vkm@vkm.no

www.vkm.no
www.english.vkm.no

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Title

Assessment of the risks associated with the import and release of hand-reared mallards from Sweden for hunting purposes

Authors preparing the draft opinion

Eli K. Rueness (chair), Luis Cadahia-Lorenzo, Kristian Hoel, Pär Søderquist , Gaute Velle, Maria Asmyhr (VKM)

Assessed and approved

The opinion has been assessed and approved by Panel on Alien organisms and trade in Endangered species (CITES). Members of the panel are: Vigdis Vandvik (chair), Hugo de Boer, Jan Ove Gjershaug, Kjetil Hindar, Lawrence Kirkendall, Nina E. Nagy, Anders Nielsen, Eli K. Rueness, Odd Terje Sandlund, Kjersti Sjøtun, Hans K. Stenøien, Gaute Velle

Acknowledgment

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed a working group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority/Norwegian Environment Agency. Project leader from the VKM secretariat has been Maria G. Asmyhr. The members of the working group, Eli K. Rueness, Luis Cadahia-Lorenzo (CEES, University of Oslo), Kristian Hoel (Panel on Animal Health and Welfare), Pär Søderquist (Kristianstad University), Gaute Velle, are acknowledged for their valuable work on this opinion. The Panel on Animal health and Welfare are acknowledged for comments and views on this opinion. VKM would like to thank Carl-Martin Nygren (representative for the landowner at Løvenskiold Fossum) and Fredrik Aalerud (representative for the landowner at Astrup Fearnley) for their contributions. VKM would also like to thank Kjetil Hindar for his contribution (Appendix III), Dean Basic (VKM) for his contributions throughout the project and Lucy Robertson (NMBU) for proof reading and improving the language of the report.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

The Norwegian Environment Agency (NEA) and the Norwegian Food Safety Authority (NFSA) requested the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for Mattrygghet, VKM) for an opinion on the risks to biodiversity, nutrient status, animal health, and animal welfare resulting from the import of hand-reared mallards (*Anas platyrhyncos*) from Sweden and their release in Norway.

VKM appointed a working group consisting of two members of the Panel on Alien Organisms and Trade in Endangered Species (CITES), one member of the Panel on Animal Health and Welfare, one external expert on the release of hand-reared mallards, one external expert on birds in an ecological context, and the VKM staff. The Panel on Animal Health and Welfare commented on the draft report. The Panel on Alien Organisms and Trade in Endangered Species assessed and approved the final report.

The mallard is among the world's most popular game species and the annual harvest in Europe is estimated to 4.5 million specimens. Since the 1970s restocking mallard populations with farmed birds has been common practice in order to increase the population for hunting purposes. In Norway, the interest in introducing hand-reared mallards for hunting purposes has increased over the last few years and today approximately 10,000 birds are released annually. In comparison, the breeding population of wild mallards in Norway is estimated to be between 86,000 and 150,000 individuals.

In lack of data VKM applied a semi-quantitative risk assessment method to evaluate the possible negative effects from release of farmed mallards from Sweden on biodiversity, nutrient status, animal health, and animal welfare. As information about the number of mallards likely to be released during the coming years is lacking, VKM conducted the risk assessments based on three different scenarios with increasing releases. The geographical scale at which any potential impact was considered, differed from case to case. For example, the number of birds released nationally per year was used for assessing the risk of genetic effects and spreading of infectious diseases, whereas the risk of possible ecological effects were assessed locally.

The magnitude of the impact of the various risk factors assessed in this report is often dependent on the number and of mallards being imported and released. VKM concludes that there are several risks to biodiversity, nutrient status, animal health, and animal welfare from the release of hand-reared mallards in Norway. Overall, increasing the number and density of hand-reared mallards increases the probability of negative effects, as well as the severity of the consequences.

VKM concludes that there are risks of genetic impact, both on native mallards and on Red-Listed species of dabbling ducks. The genetic effects are expected to accumulate with time and with increasing numbers of ducks. Further, VKM concludes that there is a risk of a range

of negative ecological effects, including increased competition for food, both between native and released mallards and between released mallards and other animals with a similar diet. Moreover, there is a risk that a local increase in mallard density will attract more predators and other duck species, thus increasing predation pressure and competition for resources.

VKM concludes that a dense population of birds can be expected to have an impact on the trophic status caused by the input of nutrients, but the magnitude of the impact will be site-specific and depend on the density of mallards released and the number of consecutive years of release at the same waterbody.

VKM concludes that there is some risk of introducing a range of diseases when importing mallards from Sweden, including highly pathogenic avian influenza (HPAI) and Newcastle disease (ND). Also the risk of introducing new diseases increases with the number of birds imported.

Several studies have showed the first-year survival of released farmed mallards to be significantly lower than that of local wild mallard. While the high mortality rate will reduce the risk of negative long-term effects on biodiversity the causes of mortality are likely to cause suffering to the mallards prior to death. These are predation, starvation, freezing, and malnutrition, as well as hunting with a 50% probability of crippling and wounding. Consequently, VKM concludes that there is a high risk of reduced animal welfare due to the release of hand-reared mallards.

There are many knowledge gaps related to the impact of mallard release and to this end VKM provides suggestions for various science-based tools and methods that could be implemented before and after the release of mallards. These include genotyping all hand-reared mallards to assess the degree of admixture with wild ducks, ringing or other marking of all released mallards to study mobility and behaviour, monitoring of the ecosystems where ducks are released, including water quality testing. VKM further suggests measures to reduce the rates of mortality and wounding and crippling during hunting, and that thereby could contribute to improved animal welfare.

Key words: VKM, risk assessment, Norwegian Scientific Committee for Food Safety, Norwegian Environment Agency, mallards, hand-reared, *Anas platyrhyncos,*

Sammendrag på norsk

Miljødirektoratet og Mattilsynet har bedt Vitenskapskomiteen for Mattrygghet om en vitenskapelig vurdering av risiko for negative konsekvenser for biologisk mangfold, vannkvalitet, dyrehelse og dyrevelferd ved å sette ut stokkender (*Anas platyrhyncos*) fra oppdrettsanlegg i Sverige i norsk natur. VKM nedsatte en prosjektgruppe bestående av to medlemmer fra faggruppen for fremmede organismer og handel med truede arter (CITES), et medlem av faggruppen for dyrehelse og dyrevelferd, en ekstern ekspert på stokkender og utsetting av disse, en ekspert på fuglers økologi, og ansatte i VKMs sekretariat. Faggruppen for dyrehelse og dyrevelferd kommenterte utkast av rapporten. Rapporten ble endelig godkjent i faggruppen for fremmede organismer og handel med truede arter.

Stokkandjakt er populært; bare i Europa er det anslått at 4,5 millioner stokkender skytes årlig. Siden 1970-tallet har det derfor vært vanlig praksis i mange europeiske land å sette ut oppdrettsender for å øke antall fugler som er tilgjengelige for jakt. I Norge har interessen for å sette ut stokkender til jaktformål økt de siste årene, og per i dag settes det ut ca. 10 000 ender årlig. Til sammenligning er den ville norske stokkandbestanden estimert til å være på mellom 86 000 og 150 000 fugler.

I mangel av data fra tidligere effektstudier brukte VKM en semi-kvantitativ metode for å vurdere om import og utsetting av stokkender kan ha negativ effekt på biologisk mangfold, vannkvalitet, dyrehelse og dyrevelferd.

VKM har ingen informasjon om hvor mange ender som planlegges satt ut i Norge de kommende årene, men generelt vil risikoen for negative effekter øke proporsjonalt med antall utsatte ender. Mulige miljøeffekter av utsetting ble derfor vurdert for tre ulike scenarier med økende antall eller tetthet av utsatte ender. Den geografiske skalaen varierer også for de ulike vurderingene av risiko. For eksempel er risiko for genetiske effekter og spredning av sykdommer vurdert på nasjonalt nivå, mens risiko for mulige økologiske effekter er vurdert på lokalt nivå.

VKM konkluderer at import og utsetting av tamme ender i Norge gir risiko for negative konsekvenser for både biologisk mangfold, vannkvalitet, dyrehelse og dyrevelferd. Generelt vil økt utsetting av oppdrettsender både øke sannsynligheten for at negative konsekvenser vil inntreffe, og øke alvorlighetsgraden av konsekvensene.

Import og utsetting av stokkender gir risiko for negative genetiske konsekvenser, både på ville stokkender og på rødlistede gressender. De genetiske effektene forventes å hope seg opp over tid og med økende antall ender.

VKM konkluderer at import og utsetting av stokkender gir risiko for negative økologiske effekter, som økt konkurranse om mat, både mellom ville og tamme ender, og mellom utsatte ender og andre dyr med lignende kosthold. Det er også en risiko for at økt, lokal tetthet av ender vil tiltrekke seg andre andearter og byttedyr, som igjen vil gi økt press og konkurranse om ressurser.

VKM konkluderer at høy tetthet av utsatte ender vil føre til økt tilførsel av næringssalter som kan ha negativ innvirkning på vannkvalitet. Alvorlighetsgraden vil være stedsavhengig og øker med antall fugler som settes ut, og med antall år på rad med utsettingen i ett og samme vann.

VKM konkluderer at import og utsetting av ender fra Sverige gir risiko for å innføre en rekke sykdommer, som fugleinfluensa (HPAI) og Newcastle disease (ND). Risikoen for å introdusere nye sykdommer øker med antall fugler som importeres.

Dødeligheten for ender som er satt ut, er blitt målt til å være høyere enn for ville ender. Høy dødelighet reduserer risikoen for negative langtids effekter på biologisk mangfold, men vil sannsynligvis forårsake lidelse for fuglen før den dør. Dødeligheten er forårsaket av at fuglene blir spist av rovdyr, sult, frost, feilernæring og også jakt, ettersom det er antatt av halvparten blir skadeskutt. VKM konkluderer derfor at det er en høy risiko for redusert dyrevelferd.

Det er stor mangel på kunnskap om konsekvenser av utsetting av stokkender, og VKM foreslår en rekke forskningsbaserte verktøy og metoder som kan iverksettes både før og etter at endene settes ut. Tiltakene inkluderer genetisk kartlegging av alle ender som skal settes ut for å kunne studere i hvor stor grad de blander seg med ville ender, ringmerking eller annen merking for å finne ut mer om mobilitet og adferd, samt undersøkelser av økosystemene som endene settes ut i, inkludert rutinemessige vannprøver.

For bedret dyrevelferd foreslår VKM en rekke tiltak for å redusere dødelighet og skadeskytingsprosent.

Glossary

Abiotic – Abiotic factors in the environment are non-biological (non-living) factors such as geology, climate, or inorganic nutrients.

Acidification – A decrease in pH due to e.g. acid rain.

Agonistic behaviour – Social behaviour related to competition or fighting.

Anoxia – Without oxygen.

Anthropogenic – Caused by humans.

Back-crossing – Crossing of a hybrid with an individual from one of its parents strains.

Biodiversity – The Norwegian Nature Diversity Act § 3 letter c defines biodiversity as "the variability among ecosystems and species, intraspecies genetic variation, and the ecological relationships between ecosystem components". The Convention on Biological Diversity (CBD) defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Boreal - Characterized by long winters and short, mild or cool summers.

Carrying capacity – Maximum number of individuals that can be supported by a given environment.

Clade – Branch of a phylogenetic tree containing all organisms descending from a common ancestor.

Common garden experiments (transplant experiments) - Experiments to investigate genetic and environmental contributions to phenotypic variation. Typically performed by cultivating or rearing two or more taxa (populations, species) in a common environment.

Conspecifics – Belonging to the same species.

Crossbreeding – Mating of two individuals of different breeds.

Ecosystem services – Processes, material and energy in an ecosystem that directly or indirectly benefit human wellbeing.

European water framework directive - See *Water framework directive.*

Eutrophic – Waters that are rich in nutrients (30-100 µg P L^{-1}) and usually with a high primary production and low levels of oxygen.

Eutrophication – Enrichment of water bodies by inorganic nutrients (e.g. nitrate or phosphate). Eutrophication may cause cascading effects on the biota.

Extrinsic factor – Originates from outside the organism.

Fixation index (F_{ST}) - A measure of genetic differentiation between populations due to non-random breeding.

Flyway – Route commonly used by migrating birds.

Founder effects – Genetic differences between an original population and an isolated subpopulation due to alleles in the small number of founder members of the new population being unrepresentative of the original population.

Genotype – For a diploid organism, the particular pair of alleles present for a given gene.

Gizzard – An organ found in the digestive tract of e.g. ducks. A muscular stomach that helps grind up food.

Gregarious – Tending to herd together.

Hand-reared – Individuals that are bred in captivity for generations with the purpose of producing offspring that will restock exploited populations. The term is synonymous with farmed, which is also used in this report. In publications cited here, similar terms such as 'captive-bred', 'captive-reared', and 'farm-reared' may be used with the same definition.

Heterospecific attraction - using the presence of closely related species as an indicator of whether breeding wetlands or other habitats are suitable.

Holarctic – A zoogeographic region comprising the habitats of the northern continents.

Hybridization – Formation of a hybrid by a cross between parents of different species or strains.

Hypereutrophic – Extremely rich in nutrients (100 µg P L^{-1}). Hypereutrophic water bodies have extensive algal growth such that light becomes a limiting factor for primary production.

Intrinsic factors – Originates from inside the organism.

Introgression – Gene flow between one species or hybrid into the gene pool of another. In this report, gene flow between hand-reared mallards and wild populations of waterfowl.

Longevity – In this report, defined as time from ringing until recovery.

Macrophytes – Large aquatic plants.

Mesotrophic - Lakes with an intermediate level of productivity.

Nutrient pollution – See *eutrophication.*

Nutrient status – Classification of a water body based on the concentration of nutrients (most often of phosphorus, P), synonym with trophic status.

Oligotrophic – Nutrient-poor (5-10 µg P L^{-1}) and with a low primary production and high levels of oxygen.

Omnivorous – Can eat both plants and animals.

Panmictic – A population that is characterized by random mating.

Passerines – Perching birds.

Phenotype – The visible characteristics of an organism, including both physical features and behaviors.

Phylogeography – The study of the geographic distribution of individuals and genetic variants, and of the historical causes for the patterns observed.

Profundal zone - A deep zone in a body of freestanding water below the range of light penetration.

Representative Concentration Pathways (RCP) – Greenhouse gas concentration trajectories used for climate modeling.

Resilience – Ability of a living system to return to its original state after a disturbance.

Restocking – The intentional release of an organism into an existing population of conspecifics.

Single nucleotide polymorphism – SNP, a difference between two individuals in a single nucleotide in the genome.

Sympatric – Species inhabiting the same geographic area.

Ultraoligotrophic – Extremely poor in nutrients (<5 µg P L^{-1}) and often with very clear water.

Water framework directive (WFD) - An European Union directive that commits Member States and agreeing partners to achieve good status of all waters. The status is defined according to biological quality, hydromorphological quality, physico-chemical quality, and with chemical quality as support.

Zoobenthos – Invertebrates that live in, at or near the bottom (benthos) of aquatic environments.

Zooplankton – Free-floating (planktonic) animals in aquatic environments.

Background as provided by the Norwegian Environment Agency and the Norwegian Food Safety Authority

Since the 1970s, there has been an increasing interest in introducing hand-reared mallards to Norway for hunting purposes. To this end, landowners in Norway have established contact with rearing facilities in Sweden and introduced about 10 000 ducklings for release in Norway annually.

The import and release of hand-reared mallards requires a permit under the Regulation on Alien Species pursuant to the Norwegian Nature Diversity Act. In order to assess permit applications, there is a need for more knowledge on the effects of the release of mallards on biodiversity, both on a local, regional and national scale. There is also a need for an evaluation of which science-based tools and methods should be applied to increase our knowledge further.

The import and release of hand-reared mallards also concerns animal health and welfare. The Norwegian Food Safety Authority (NFSA) requests that conditions affecting health and welfare of mallards are described and, if possible, risk assessed in the report.

The import of mallards from Sweden is regulated under The Regulation for intra-Community trade of poultry and hatching eggs[1]. The Regulation takes into account most aspects concerning animal health in regard to import of live poultry, however, it does not cover all diseases. The NFSA therefore request an assessment of the risks of introducing diseases not previously found in wild birds or poultry in Norway when importing mallards.

The Animal Welfare Act **states that** animals have an intrinsic value irrespective of the benefits they may have for humans. It further states that all animals shall be treated well and be protected from unnecessary stress and strains (§ 3). In addition, there is a Regulation that bans hunting of released birds, unless some specific criteria are fulfilled. The timing of the release and potential feeding of the birds should be so that there is left sufficient time for the birds to adapt to life in the wild before the onset of the hunting season. Adaptations to life as a wild bird include natural foraging behaviour, shyness towards humans and improved flying skills. In addition, the released birds should possess the same level of fitness as wild birds. Birds shall be released into the wild no later than July 20th. If feeding takes place, the feeding procedure should ensure that birds develop natural foraging

[1] Forskrift 28. desember 2001 nr. 1616 om samhandel med levende fjørfe og rugeegg i EØS https://lovdata.no/forskrift/2001-12-28-1616

behaviour, and the use of automatic feeders is therefore not allowed. The NFSA requests an assessment of the risks of reduced animal welfare for mallards that are released for hunting

Terms of reference as provided by the Norwegian Environment Agency and the Norwegian Food safety Authority

1) The Norwegian Environment Agency (NEA) requests the Norwegian Scientific Committee for Food Safety (VKM) to undertake an assessment of the risks of negative impacts on biodiversity in Norway stemming from introduced mallards. The Norwegian Nature Diversity Act § 3 letter c defines biodiversity as the variability among ecosystems and species, intraspecies genetic variation, and the ecological relationships between ecosystem components.

If permission is granted, the Norwegian Environment Agency may put forward terms and conditions that are deemed necessary in order to prevent negative impacts on native biodiversity. A possible influence upon ecosystems and other species, and the risk of "hitchhiker organisms" should be included in the assessment. The assessment should include:

- Interbreeding between released and wild mallards, and the potential for genetic impacts on native populations.
- Ecological interactions between released and resident mallards.
- The impact of duck release on local fauna, including the potential for increased abundance of small and medium-sized predators.
- Mallard release and water eutrophication, including the potential for downstream effects on local ecosystems.

If there are specific measures or limitations that may affect the risk, this must be stated in the assessment. If the introduction and release of mallards may affect ecosystem services, this must be stated in the report, but not as a part of the actual risk assessment. The time frame for the risk assessment of negative impacts on biodiversity should be 50 years

2) NEA also requests a scientific evaluation of which science-based tools and methods to apply for increasing our knowledge on this subject; e.g., methods to investigate effects on biodiversity, tagging of chicks before release (capture-recapture methods), and mapping/surveillance of indicator species in waters.

3) The Norwegian Food Safety Authority (NFSA) requests VKM to undertake an assessment of
   - The risk of introducing new diseases when releasing mallards from Sweden.
   - The risk of reduced animal welfare as a result of the current routines for releasing hand-reared mallards in the wild. In particular, we wish the survival rate of released mallards and the risk factors influencing their survival to be assessed. When relevant, possible measures for risk reduction should be described.

NEA and NFSA request the Norwegian Scientific Committee for Food Safety (VKM) to answer the assignment in a single report. The report should be written in English, with a summary in Norwegian. We request the report to be delivered latest 15. June 2017, or otherwise as agreed upon.

1 Introduction

The mallard (*Anas platyrhynchos*) is among the world's most popular game species and the annual harvest in Europe is estimated at 4.5 million (Hirschfeld and Heyd, 2005). Restocking mallard populations with farmed birds to increase the population for hunting purposes is a practice that became common in the United States in the early 1900s (Lincoln, 1934). The mallard releases were intended to compensate for overharvest or increased mortality during cold winters and to enlarge the breeding population. However, as survival of released ducks was low, releases were deemed impractical and expensive in North America (Brakhage, 1953; Lincoln, 1934). In Europe, the extent of releases of farmed mallards was limited until Denmark and Great Britain started releasing them for hunting purposes at a larger scale during the 1950s (Boyd and Harrison, 1962; Fog, 1958). Since the 1970s, the practice has increased in other European countries (Table 1), such as France (Champagnon et al., 2009), Sweden (Wiberg and Gunnarsson, 2007), and the Czech Republic (Hůda et al., 2001). The present-day total number of farmed mallards released annually in Europe is hard to estimate, but certainly exceeds 3 million (Champagnon et al., 2013).

Table 1 Comparison between number of wild mallards and the number of mallards released annually. Note that the numbers are not directly comparable as some studies use winter population numbers and others number of breeding pairs.

Region/Country	Number of wild mallards	Number of released mallards annually
North America	9.2 million[1]	300,000 [2]
France	300,000 (winter population)[1]	1,400,000[3]
Czech Republic	30-60,000 individuals [4]	300,000 [5]
Sweden	200,000 breeding pairs[6]	250,000 [7]
Denmark	20,000-50,000 breeding pairs[7]	400,000[8]
Norway	86,000-150,000 individuals[9]	10,000[10]

1. Deceuninck et al., 2014, 2. U.S Fish and Wildlife Service, 2013, 3. Mondain-Monval and Girard, 2000, 4. Čížková et al., 2012, 5. Hůda et al., 2001, 6. Ottosson et al., 2012, 7. Söderquist, 2015, 7. BirdLife International, 2004, 8. Noer et al., 2008, 9. Shimmings and Øyen, 2015, 10. Miljødirektoratet

The European population of wild mallards has been estimated to be 5,700,000-9,220,000 mature individuals, and to be stable (BirdLife International, 2015). Increasing numbers have been reported for the Nordic population up until 2010 (Dalby et al., 2013b).

1.1 Mallard release in Norway

The breeding population of wild mallards in Norway has been estimated to be between 86,000 and 150,000 individuals (Shimmings and Øien, 2015). The number of mallards reported as being shot in Norway during the 2015-2016 hunting season was 13,470 (https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/srjakt/aar/2016-08-11). Releases of farmed mallards for hunting purposes have taken place in Norway at a local scale and at low numbers (50 to a few hundred birds annually, Fredrik Aalerud, representative for landowner at Astup Fearnley, pers. comm. and Appendix I) since at least the late 1970s, but has increased over the last couple of years to annual numbers of releases in the range of 10,000. The hand-reared birds that are released into nature have, to date, been imported from Swedish duck farms. This breeding stock originates from wild, trapped birds and have also possibly interbred with semi-domestic ducks (that could also have originated from other European countries like Denmark or France). Breeding birds are sometimes exchanged between facilities and also renewed by new offspring (Söderquist, 2015). The rate of survival to the next breeding season of the birds released in Norway is unknown, but high mortality at all stages of their first year has been confirmed elsewhere (e.g. Champagnon, 2011). In order to increase survival, the management at hunting estates includes predator control and supplementary feeding. According to the Animal Welfare Act (see background) "The timing of the release and potential feeding of the birds should be so that there is sufficient time for the birds to adapt to life in the wild before the onset of the hunting season." Nevertheless, feeding of birds is commonly practiced, both before and after the onset of the hunting season, in order to discourage the ducks from leaving the hunting grounds (Carl-Martin Nygren, representative for landowner at Løvenskiold Fossum, pers. comm. and Appendix II).

1.2 Global phylogeography and genetic structure of mallards

The mallard is the most numerous Holarctic waterfowl species (estimated to ca 20 million individual birds) and occurs throughout the Northern Hemisphere (Wetlands International, 2012). As a general pattern, northern breeding populations migrate to more southerly non-breeding areas during the winter, whereas birds breeding in temperate regions can be resident. Mitochondrial DNA (mtDNA) studies of mallards throughout their global distribution range (Kraus et al., 2011b; Kulikova et al., 2005) have suggested that North American and Eurasian birds are genetically differentiated into two clades (clade A Eurasia and clade B North America). They found little phylogeographical structuring within each clade. This indicates that the migrating birds ability to change flyways (migration routes) within continents is high. Kraus et al. (2011a) identified thousands of single nucleotide polymorphisms (SNPs) within wild mallards and between wild and domestic ducks. A subsection of these were used to infer the genetic structure of 800 mallards collected from 45 locations worldwide (Kraus et al., 2013). Their results confirmed the lack of genetic sub-structuring within continents and also revealed significant connectivity between Eurasia and North America. This suggests that the global wild mallard population is more or less panmictic (i.e. randomly mating). The exception being an isolated population on Greenland

(Kraus et al., 2013). Lack of genetic structuring was also demonstrated between sympatric migratory and non-migratory mallards (Kraus et al., 2016). Noteworthy, pronounced genetic divergence has been detected between farmed and wild mallards and among populations of farmed mallards (Čížková et al., 2012). This structuring seems largely to be explained by low genetic diversity within the breeding stocks of farmed mallards and that they represent different breeding strains. Previous studies of ringing recoveries of mallards show that some Norwegian mallards move to the British Isles, South Western Europe, Sweden and Finland during winters, but that also the Norwegian coast is an important wintering area (Nygård et al., 1988). This is consistent with newer data from the Stavanger Museum Recovery Atlas (http://stavangermuseum.no/en/ringmerkingssentralen/ringmerkingsatlas), see section 3.3.1 for details.

1.3 Hybridization among duck species

Waterfowl (*Anatidae*) are particularly well known for producing fertile hybrids (e.g. Kraus et al. 2012) and numerous hybridization events have been recorded between mallards and other duck species (McCarthy, 2006). Since these species also have the ability to migrate over large distances (migration routes often exceed hundreds of kilometres), the potential for sharing and spreading of genetic material is exceptionally high. The mallard is one of about 50 species of dabbling ducks (genus *Anas*, "gressender") worldwide. Seven of these species breed in Europe and all of them have been found breeding in Norway. In addition to the mallard, these are: wigeon (*Anas penelope*, "brunnakke"), gadwall (*Anas strepera*, "snadderand"), teal (*Anas crecca*, "krikkand"), pintail (*Anas acuta*, "stjertand"), garganey (*Anas querquedula*, "knekkand"), and shoveller (*Anas clypeata*, "skjeand"). All of them are sympatric with mallards and thus the potential for hybridization exists, and hybridization and has been documented elsewhere in Europe (McCarthy, 2006). However, identification of hybrids on morphological grounds alone is often difficult or impossible, particularly after several generations of backcrossing (introgression).

1.4 Morphological and behavioural impact of captive breeding

When using a breeding stock to produce and rear individuals in a captive environment, there is always a risk of changing genotypes and phenotypes, potentially producing individuals which are different from their wild conspecifics (Price, 1999). In captivity, there are several mechanisms that may lead to genetic change in individuals, e.g. founder effects, inbreeding, and anthropogenic selection regimes (Price, 1999). Artificial selection may keep captive individuals wild-like, decreasing genetic change from the wild phenotype. However, it can also be used by breeders to promote specific traits, for instance to increase production, and thus promoting genetic change from the wild population. Besides such deliberate selection of some traits, relaxation of natural selection in breeding facilities may occur. In captivity, some behaviours are not as crucial as in the wild, e.g. predator avoidance, shelter-seeking, social interactions, and feeding skills (Price, 1999).

The Temporary Regulation about the Prohibition of Hunt for Released Birds (https://lovdata.no/dokument/SF/forskrift/1990-08-24-761) states that "Adaptations to life as a wild bird include natural foraging behaviour, shyness towards humans, and improved flying skills. In addition, the released birds should possess the same level of fitness as wild birds". Several changes in behaviour have been recorded in captive breeding stocks of mallards, including habituation to humans (Desforges and Wood-Gush, 1975), altered sexual behaviour (Desforges and Wood-Gush, 1976), changed mate preferences (Cheng et al., 1978; Cheng et al., 1979), and shorter migration distances (Söderquist et al., 2013). Morphological changes have also been documented for captive mallards, e.g. a reduction in brain volume (Guay and Iwaniuk, 2008), larger body size (Pehrsson, 1982), altered bill size (Champagnon et al., 2010; Söderquist et al., 2014), and changes in their digestive systems (cf. Champagnon et al., 2012).These behavioural and morphological changes are likely to impact fitness. However, the genetic component and the actual effects on survival and reproductive success are difficult to quantify.

1.5 Intraspecific and interspecific effects

The release of a large number of individuals of the same species in a particular area where the species already occurs will suddenly and dramatically increase the population density. This is likely to impact the functioning, and hence the dynamics, of populations, altering the mechanisms that affect population sizes over time (Williams et al., 2002). The effects will be even stronger should survival of the released individuals be favoured by supplementary feeding and by predator control. In addition, the sudden increase of a population size will affect the dynamics of other species through changes in predation pressure, competition, hybridization, by introducing pathogens or parasites, or through indirect changes in the ecosystem (Goodenough, 2010; Hulme, 2011; Spear and Chown, 2009). For mallards, these impacts may be important in both a short- and long-term perspective. First, during the immediate months after release when the population size and density increase dramatically. Then, surviving mallards may continue to impact the population in the long run, either by interbreeding and modifying the genetic make-up of the native population (Champagnon et al., 2013; Čížková et al., 2012) or by affecting its ecology both directly (competition) or indirectly (effects through changes on other parts of the food-web or by abiotic changes, e.g. Noer et al., 2008; Søndergaard et al., 2006).

1.6 Eutrophication and the effect on water chemistry

Freshwaters provide valuable ecosystem services, including supply of water, fishing, recreation, and tourism. The ecological status of these waters can be transformed by anthropogenic impacts into less desired states that threaten the ecosystem services (Scheffer et al., 2001), and ultimately cause loss of ecosystem functioning. The European Water Framework Directive (WFD) (http://ec.europa.eu/environment/water/water-framework/index_en.html) was endorsed in 2000 in an attempt to safeguard such waters. An important implication of the WFD is that the ecological status of any waters shall not be degraded as a consequence of human actions. Since the late 1980s, water quality has improved in many areas in response to reductions in atmospheric pollution. Yet, nutrient pollution (also referred to as eutrophication) has accelerated towards the present and is considered as one of the most pervasive problems that degrade waters (Duncan et al., 2012; Kristensen et al., 2010). Eutrophication is caused by phosphorus and nitrogen added to water in the form of phosphate and nitrate, in addition to input controlled by naturally occurring processes. An increase of these nutrients can cause a nutrient imbalance and increased growth and change in the species composition and diversity of plants and algae. If the accumulation of organic matter is faster than the rate of breakdown, then organic matter will accumulate. The breakdown process consumes oxygen, causing reduced oxygen levels in the short term, or permanent anoxia in the long term. The whole freshwater ecosystem, including algae, macrophytes, fish, and invertebrates, is vulnerable to the input of nutrients. Lakes and ponds are particularly vulnerable because the nutrients carried into them continue to accumulate, whereas nutrients in rivers are carried away downstream.

Some lakes, for example some large deep lakes, may respond linearly to eutrophication (Carpenter et al., 1999), but there is now increasing evidence that many lakes do not respond in such a smooth way, and that they have alternative states (or regimes) separated by an unstable equilibrium (Carpenter et al., 1999; Scheffer et al., 2001; Scheffer and van Nes, 2007). Shallow lakes, in particular, have the potential to switch between two alternate stable states: a clear macrophyte-dominated state and a turbid phytoplankton-dominated state (Carpenter et al., 1999; Jeppesen et al., 1990). The clear-water state is often preferred because it has higher biodiversity and provides valuable ecosystem services, such as drinking water and recreational purposes. In addition, conservation of an ecosystem in its current state is ensured by national and international guidelines and laws, such as the WFD and the Norwegian Biodiversity Act (*Lov om forvaltning av naturens mangfold*: https://lovdata.no/dokument/NL/lov/2009-06-19-100). Gradual trends in external conditions, such as climate change, land-use, acidification, or eutrophication, can directly induce the regime shifts. Sudden stochastic events, such as climate extremes (e.g. droughts, storms), may provoke abrupt shifts. The overall consequence of such stressors in an ecosystem may also be additive, with the various factors acting together.

For management purposes, it is important to adhere to the precautionary principle as the switch to an alternate stable state may occur with or without prior warning (Dakos et al., 2015). It is more cost-effective to prevent shifts, than to try to restore systems that have already tipped to a less-desirable alternative state. In addition, sites with increased nutrient status may not necessarily return to their pre-eutrophication reference status, despite implementation of measures to reduce external nutrient loading (Battarbee et al., 2012). A management strategy should therefore aim at promoting ecosystem resilience (resilience-building management), such as maintaining and improving ecological status and biodiversity (Willis et al., 2010). Although control of stochastic events is not possible, managers can act on local conditions (e.g., prevent input of point-source nutrients) (Scheffer et al., 2001).

Mallards have a rapid metabolism, and consequently ingest relatively large quantities of organic material. Mallards are omnivorous and flexible in their food choice. Depending on availability, season, and age they eat plants and invertebrates in shallow waters (Dessborn et al., 2011a). Adult mallards mainly excrete their waste into the water, whereas young mallards defecate both on shore and in the water (Gere and Andrikovics, 1994). Nitrogen and phosphorus from the faeces are more readily available subsequent to digestion and thereby increase the input and turnover of nutrients in the ecosystem. Waterfowl, including hand-reared mallards, can therefore have a significant impact on the nutrient status of the water (Callaghan and Kirby, 1996; Cote et al., 2010; Gere and Andrikovics, 1994; Manny et al., 1994; Noer et al., 2008; Wiberg-Larsen et al., 2000). In addition, hand-reared mallards are often fed after release into the wild, thereby enhancing the eutrophication process by bringing new nutrients to the system.

1.7 Anticipated effects of future climate change

Climate influences both intrinsic factors in mallards, such as timing and distance of migration, timing of egg-laying and hatching, and winter survival, and extrinsic factors, such as habitat and food availability and the occurrence of diseases and/or parasites (Fox et al., 2015). Warmer winter temperatures are expected to result in less long-distance migration, more available habitat and food (fewer frozen lakes) and increased survival (e.g. Gunnarsson et al., 2012b). Milder winters in Norway in the future have been predicted by climate modelling (see section 2.4), and this will probably result in fewer frozen lakes with less ice during winters. For mallards, this means more available habitat, less long-distance migration, and increased survival. Hence, other possible anthropogenic influences aside, the density of ducks in Norway is expected to increase in 50 years.

1.8 Disease

Mallards and other waterfowl are susceptible to many different diseases e.g. reviewed by Wobeser (2012). Wobeser defines disease to include any impairment that interferes with, or modifies the performance of normal functions, including responses to environmental factors such as nutrition, toxicants, climate, infectious agents, inherent or congenital defects, or combinations of these factors. Disease has been present in the populations of waterfowl throughout their evolution, but the recognition of disease occurrence is a recent event. In this risk assessment, we consider diseases that are infectious and have the ability to spread from imported animals to the resident populations of wild and domestic animals. The disease situation of wild waterfowl in Norway is poorly known, but the disease situation of poultry is, in general, good and will be the premise for imported birds, independent of use.

Waterfowl are particularly susceptible to disease as their gregarious behaviour during autumn and winter facilitates transmission of infectious pathogens. The vulnerability to disease will be elevated with increased density of birds. Moreover, their migratory habits increase the risk of spreading disease considerable distances from the source of an outbreak.

The mallard is one of the principal natural hosts of avian influenza Type A viruses (Huang et al., 2013) and released mallards may facilitate spread (e.g. Fox et al., 2015). Dabbling ducks (*Anas* spp.), and in particular the mallard, have been implicated as the most important reservoir and vector for low pathogenic avian influenza (LPAI) viruses (Gunnarsson et al., 2012a).

1.9 Animal welfare

The term animal welfare has been defined in a number of ways. A Norwegian working group (NFR, 2005)(suggested the following definition of animal welfare: "the individual's subjective experience of its mental and physical condition as regards its attempt to cope with its environment". VKM has previously elaborated on the concept of animal welfare in a report on marking of fish (VKM, 2016).

When farmed mallards are released into the wild, the animals are considered as wild. In Norway, nobody owns wildlife. Nevertheless, the Animal Welfare Act has several general paragraphs that regulate the issue of the welfare of such animals.

- § 3 Animals have an intrinsic value, which is irrespective of the usable value they may have for man. Animals shall be treated well and be protected from danger of unnecessary stress and strains.
- § 14 b) It is forbidden to abandon animals in a helpless condition
- § 20 Hunting, catching and fishing shall be carried out in such a way as to be conducive with appropriate animal welfare standards.
- § 28 An animal can only be released from captivity into nature to live wild if the animal has a good possibility to adapt to and survive in its new environment.

When mallards are released for the purpose of being hunted the same year measures are taken to keep as many as possible in a good condition and on the premise until the hunting season.

Release age is selected on the basis of a trade-off between higher survival rates when the ducks are older, and greater release site fidelity and less habituation to humans, and thereby more wild-like behaviour, when release is at a younger age. In Sweden, ducklings are released when about 2-3 weeks old and when they are still unfledged. In France, however, ducklings are released at about 7-8 weeks of age, at which age they start to learn to fly. In Norway, farmed ducklings are released at the age of about 2-4 weeks and release is scheduled, according to present regulations, prior to July 20th (https://lovdata.no/dokument/SF/forskrift/1990-08-24-761), which is some weeks before the onset of the hunting season for ducks from August 21th to December 23 (https://lovdata.no/dokument/SF/forskrift/2017-01-25-106).

According to representatives for landowners at Løvenskiold Fossum and Astrup Fearnley, (see appendices) predators, such as American mink (*Neovison vison*) and red fox (*Vulpes*

vulpes), are removed from the areas prior to release. Furthermore, the birds are provided with food after release, sometimes throughout the hunting season.

During the hunting season, released mallards are hunted in the same way and according to the same regulations as wild mallards. The ducks are hunted while flying, which entails a risk of wounding and crippling from poorly placed shots, and thereby serious welfare consequences. These may vary from slight pain to fractures and inflammation causing long-lasting disease and suffering.

The Norwegian Council of Animal Ethics evaluated ethical aspects of releasing animals into nature for hunting purposes in 2005 (www.radetfordyreetikk.no/Utallelser/Jaktfiske-hegnsteng-endelig-utt.doc). They concluded that humans' moral obligation towards animals are particularly strong when natural habitats are modified and hunting actively managed. Animals kept by people should be killed humanely, and this is usually incompatible with releasing them for later shooting. The Animal Ethics Council therefore concludes that hunting should not be allowed within the same year as the animals are released. The ethical aspects of releasing farmed animals for the purpose of being targets for recreational hunting are not addressed in this report.

1.10 Contradiction between environmental and animal welfare concerns

From this assignment, it is evident that it might be impossible to act in accordance to the requirements from NEA and NSFA at the same time. In order to minimize the negative environmental effects of mallard release, the shorter their life span in the wild the better, and the mortality of the birds by the end of the hunting season should ideally be 100%. This would prevent mating between hand-reared and native birds and hence the risk of genetic admixture. It would also reduce the ecological impact on native mallards, on the ecosystems and on the water nutrient conditions. In contrast, from an animal welfare perspective, mortality other than that from hunting should be minimized.

2 Literature and methodology

2.1 Literature search

Data on the distributions and population statuses of mallards and other dabbling ducks internationally were retrieved from the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (www.iucnredlist.org), The Birds Directive (http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm), and BirdLife International (http://www.birdlife.org).

Information on mallard phylogeography and hybridization between released mallards and other duck species worldwide was obtained from the on-line databases and libraries ISI Web of Science and PubMed. Google searches were made for the following words and expressions: «mallards» and/or «dabbling ducks» «hybridization» and/or «introgression» and/or «genetics» and/ or «SNP». In addition, references cited in the retrieved papers were searched for further relevant studies not identified in the original search.

The web resources of Norsk Ornitologisk Forening, BirdLife Norway: http://www.birdlife.no/ and http://www.fuglevennen.no, were used for obtaining information about hybridization events between mallards and other dabbling ducks in Norway.

Data on migration patterns of mallards ringed in Norway and abroad were gathered from the Recoveries Atlas at the Stavanger Museum website, http://must.ringmerking.no/kart.asp.

Information about population sizes and distribution of duck species in Norway was obtained from the NBIC database (http://artsdatabanken.no/).

Norwegian hunting statistics for mallard were retrieved from Statistics Norway (https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/srjakt/aar/2016-08-11)

Information about intraspecific and interspecific effects of mallard releases was also obtained from three recent PhD theses (Champagnon, 2011, Dessborn, 2011 and Söderquist, 2015) that specifically address these topics. The reference lists of these theses cited further publications that were retrieved and consulted. Additional searches on the ISI Web of Knowledge and general Google searches provided further relevant literature. Searches were made for the following words and expressions: «mallards» and/or «density dependence» and/or «competition» and/or «predation» and/or «food web» and/or «population increase».

Information on the effects of nutrients was found through on-line databases and libraries, such as the ISI Web of Science. Information was also obtained through Google searches, including information from the grey literature, by searching for «Mallards» and/or «water fowl» and/or «eutrophication» and/or «nutrient input» and/ or «macrophytes» and/or «algae» and/or «fish» and/or «invertebrates». The searches were performed with the use of wildcard (*). In addition, citations for further relevant studies were searched for in the retrieved papers.

For the animal health and welfare assessment, literature searches were performed in ISI Web of Science and Google scholar using the following search terms: «hand reared mallard» and/or «release mortality» and/or «animal welfare» and/or «animal health» and/or «Avian influenza» and/or «duck hepatitis» and/or «duck enteritis» and/or «disease» and/or «survival» and/or «predation» and/or «displacement» and/or «aggression» and/or «flight response» and/or «body condition».

One of the members of the working group has been conducting research on mallards and the release of farmed mallards for several years, and has collected a vast library of literature related to these topics. Other members of the working group also had their own literature libraries and these were used as a starting point before searching for additional literature on-line.

2.2 Legal basis of import

2.2.1 European legislation

The import of live ducks from Sweden to Norway is harmonized in the EU (and in EFTA-countries through the EEA-agreement) and regulated by Council Directive 2009/158/EC of 30 November 2009 on animal health conditions governing intra-community trade in, and imports from third countries, of poultry and hatching eggs. Game and hatching eggs of game are included in the term "poultry and hatching eggs". There are also the following additional demands for poultry older than 72 hours that are to be released as game birds (Article 12):

At the time of consignment, poultry over 72 hours old, intended for restocking supplies of wild-game shall come from a holding:

a) Where it has been held since hatching or for more than 21 days and where it has not been placed in contact with newly-arrived poultry during the two-week proceeding consignment;

b) Which is not subject of any animal health restrictions applicable to poultry;

c) Where health examination carried out by the official veterinarian during the 48 hours preceding dispatch of the flock from which the consignment is to be drawn has not revealed within the flock any clinical sign of suspicion of contagious poultry disease;

d) Which is not located in an area which for animal health reasons is subject to prohibition in accordance with Community legislation as a result of outbreak of disease which poultry is susceptible.

2.2.2 *Salmonella*

The Council Directive 2009/158/EC Article 13 includes special clauses regarding *Salmonella* with respect to import of poultry to Sweden and Finland (which, according to the EEA agreement, also refers to Norway). Intra-community trade in accordance with these regulations is considered to be safe with regards to poultry health.

2.2.3 Industry-imposed legislation concerning imports of poultry

In Norway, the poultry industry has imposed their own regulations regarding import of poultry (Animalia, 2016) in order to reduce the risk of importing exotic diseases. These regulations are a supplement to the National Regulations and demands the import of hatching eggs or day-old chickens of the grandparent or parent generation instead of animals of the user-generation in order to reduce the number of imported animals/imports and thereby the risk of introducing diseases. There is also a demand for disposable packaging during transport, direct transport from approved establishments in the export country to the place of destination, and 8-weeks of isolation prior to release. These regulations therefore demand some kind of domestic breeding facilities or hatcheries that guarantees that animals of the user-generation are of Norwegian origin or of a disease status equal to that of Norwegian poultry.

According to the representatives for the landowners from Løvenskiold Fossum and Astrup Fearnley (summaries of personal communication can be found in Appendix I and II), import of mallards is according to EU regulations and Norwegian regulations. These companies are not members of the control committee for import of poultry (Kontrollutvalget for import av fjørfe; KIF) which is the organ responsible for enforcing the industry-imposed legislation. Therefore, the extra demands imposed by KIF are not followed concerning these imports.

The import of live mallards from Sweden is relatively limited compared with the total import of poultry, but as mallards are imported at an age that defines them as production animals (over 72 hours of age), this import is therefore not in accordance with the industry-imposed regulations. In 2016, the Norwegian Environment Agency approved the import of about 10 000 2-3 week old mallards (for release) from Sweden in 4 imports. In 2015, the number of live poultry were 28 787 day old chickens divided in 14 imports while the number of hatching eggs of poultry imported were 2 312 808 in 57 imports (Animalia, 2016). The counts of commercial imports of poultry are fairly constant during the last years and the counts from 2015 may therefore act as a useful number also for 2016.

2.3 Presentation of risk

We have chosen to apply a semi-quantitative risk assessment adapted from the Panel of Animal Health and Welfare (e.g. used in http://vkm.no/dav/a0c6dfa615.pdf).

Risk is given as the product of:

The magnitude of the consequences of the event (as judged by the group of experts) multiplied by the probability that the event will occur (as judged by the group of experts).

Table 2.3-1 Definition of terms used for negative consequences

Consequence		
3	Serious	Serious effect on environment or animal health or welfare
2	Moderate	Short-term (reversible) effects on environment or animal health or welfare
1	Limited	Negative effects are limited or insignificant on environment or animal health or welfare

Table 2.3-2 Definition of terms used for probabilities

Probability		
3	High	Negative consequences would be expected to occur (P = 0.5-1.0)
2	Medium	There is less than an even chance of negative consequences (P = 0.05-0.5)
1	Low	Negative consequences would be unlikely to occur (P < 0.05)

Figure 2.3-1 Risk summary

Risk (1,2,3,4,6,9) = Probability (1,2,3) x Consequence (1,2,3)

Green = Risk (1,2) = Low risk of negative effects.

Yellow = Risk (3,4) = Medium risk of negative effects.

Red = Risk (6,9) = High risk of negative effects.

Example:

Consequence: Imported and hand-reared ducks have a higher mortality after release than wild ducks.

Consequence: Serious (3) implications for the released ducks

Probability: High (3), given the frequencies in the literature

Consequence x probability = Risk = 3 x 3 = 9 = High risk (red zone)

In the risk assessments presented in this report, the negative effects of mallard release increase relative to the number of birds released. There are also many uncertainty factors pertaining to the number of birds anticipated to be released, the status of local populations of wild mallards, other dabbling ducks, other competitors or predators and the nutrition status of the lakes where mallards are released.

We have therefore assessed the risk of environmental effects under three different scenarios with increasing mallard releases: Scenario I, II and III. Scenario I is, in most cases, comparable to today's level of release (10,000 mallards annually), which is considered low compared with that of other European countries where mallards are released (Table 1). The most appropriate way to measure the impact of mallard release differs from case to case and is described for each assessment.

The risks of introducing new diseases and reduced animal welfare have been assessed for the current level of release (10,000 mallards annually).

The geographical scale considered most relevant also differs between assessments, for example, the number of birds released nationally per year is used to assess the risk of genetic effects and infectious diseases, whereas the risk of possible ecological effects is assessed locally.

The risks of environmental effects are also assessed from a long-term (50-year) perspective, taking into consideration potential future climates (see Section 2.4 on climate modelling). There are many considerable uncertainties around this part of the assessment, and we have chosen to present a low-density and high-density scenario.

In the background of the terms of reference as provided by the NEA and NFSA, it is specified that the hand-reared mallards are imported only from Sweden. VKM has therefore not considered the risks related to the import of mallards from elsewhere.

2.4 Climate scenarios

Climate envelope modelling can be used to assess the suitability of new habitats for non-native species. However, this approach must be augmented with an understanding of the species' ecological niche, including both climatic and other ecological requirements (Jimenez-Valverde et al., 2011). The following climate modelling analysis is taken from the VKM report "Assessment of the risks to Norwegian biodiversity from the import and keeping of terrestrial arachnids and insects" (VKM, 2016a).

The globally averaged combined land- and ocean surface temperature shows a warming of 0.85 °C (0.65 to 1.06) over the period 1880 to 2012, for which multiple and independently produced datasets exist (IPCC, 2013). The rate of the warming has accelerated towards the present. Future climate change is expected to vary heterogeneously between and within regions and according to season. Currently, the warmest annual mean temperature in Norway is found in coastal southern Norway at 8.0 °C (period 1971-2000). The warmest summer temperatures are in the southern part of Østlandet and the coastal areas of Sørlandet, with an average of about 17 °C. Given the mid-range CO_2 emission scenario (RCP4.5), warm areas can expect an annual temperature increase of 2.0 °C by the year 2066, with the highest increase (2.4 °C) during the winters (Table 2.4-1). The increase in temperature is more pronounced given the emission scenario RCP8.5. The number of growing season days will also increase under both climate scenarios (Table 2.4-1).

Table 2.4-1 Modelled climate change (increase in temperature, precipitation, and growing season days) from the period 1971-2000 and towards year 2066 under the CO_2 emission scenarios RCP4.5 (emission peak 2040-2050, then decline) and RCP 8.5 (business as usual). These two scenarios are recommended by the IPCC. The projections are based on an ensemble of ten different climate models. Source: klimaservicesenter.no.

	Whole of Norway **RCP 4.5**	**S / E Norway** **RCP 4.5**	**Whole of Norway** **RCP 8.5**	**S / E Norway** **RCP 8.5**
Annual °C	2.2	2.0	3.3	3.0
Summer °C	2.0	1.9	2.9	2.6
Winter °C	2.5	2.4	3.5	3.2
Annual ppt %	6.7	2.4 / 6.0	10.7	6.6 / 10.2
Winter ppt %	5.6	6.7 / 17.2	7.1	6.7 / 17.2
Summer ppt %	10.5	1.6 / 2.3	12.5	1.5 / 2.3
Growing season days	0-60	0-60*	0-60	30-60

Summer= June, July, August; winter= December, January, February. *Small areas in southernmost Norway may experience up to 60 days increase. Ppt= precipitation.

Given a realistic temperature increase of 2 °C, the average annual temperature will reach a maximum of 10 °C in Norway in 2066. The mean temperatures of coastal southern Norway will increase to about 4.5°C during winter. However, periods with sub-zero temperatures and snow cover can be expected to be even shorter in 2066 than suggested by the modelled increase in winter temperatures. This is because the daily minimum temperatures are increasing about twice as fast as the maximum daily temperatures (IPCC, 2013).

Given the model errors involved (about +/-0.7) and a precautionary principle, VKM assumes an annual temperature of 11 °C, which is in accordance with scenario RCP8.5. Using this scenario has been recommended by the Norwegian Biodiversity Information Centre (Sandvik et al., 2015).

Box 1

Lessons from 45 years of salmon farming

The commercial production of Atlantic salmon (*Salmo salar*) in Norway started in the late 1960s. In 2015, the production was 1.38 million tonnes of fish, equalling about 300 million individual fish. Despite efforts to prevent farmed salmon from spreading to the wild, 170 000 fish escaped in 2015 (source: Norwegian Directorate of Fisheries). This is the official number - the real number is assumed to be higher. Escapees from salmon farms are known to result in ecological (Jonsson and Jonsson, 2006; Thorstad et al., 2008) and genetic interactions with wild populations (Ferguson et al., 2007; Hindar et al., 1991). Norwegian farmed salmon originate from a diverse range of Norwegian wild populations (Glover et al., 2017). They hatch in land-based freshwater facilities before being transferred to seawater sea-pens. The fish are kept in the pens until they reach market size of 3-6 kg. Fish that escape will have to migrate up-river to a spawning area in order reproduce and interbreed with native fish. Survival to sexual maturity of feral escapees is low, and only a few thousand escapees manage to enter rivers to breed. Nevertheless, in some rivers the numbers are high relative to the number of wild spawning fish (Anon, 2016).

There are many potential environmental threats related to commercial salmon production. One of the most severe threats involves the exchange of genes between farmed and wild salmon, so-called introgression. The most recent and extensive investigation of introgression included 147 Norwegian salmon rivers (i.e., 75% of wild salmon spawners) (Karlsson et al., 2016). Statistically significant introgression was found in half of the wild populations. Several differences in genetic-based phenotypic traits between farmed and wild salmon have been observed, and long-term introgression is expected to lead to changes in life-history traits (Bolstad et al., 2017), reduced population productivity, and decreased resilience to future pressures, such as climate change, on the native populations. A recent review by Glover et al. (2017) concludes that "it is important to make it unequivocally clear that only a substantial or complete reduction in the number of escapees in rivers, and/or creating a reproductive barrier through sterilization of farmed salmon, will represent a solution to the challenge".

In Norway, the number of farmed salmon is many orders of magnitude greater than the number of hand-reared mallards. However, comparison with the number of escaped farmed fish that migrate up river to spawn and the number of wild spawning fish is more relevant for considering potential introgression caused by mallards. In 2015, the number of escapee farmed salmon that migrated up-river to spawn was monitored in 165 Norwegian rivers. Farmed salmon constituted more than 10% of the population of spawning wild salmon in 17 of the rivers (Anon, 2016). A proportion of 4% corresponds to the threshold that marks a moderate risk of introgression for wild salmon, and 10% corresponds to the threshold that marks a high risk of introgression in wild salmon (Taranger et al., 2014).

3 Interbreeding between released and wild mallards and the potential for genetic impact on resident populations

3.1 Hazard identification and description

Interaction (including crossbreeding) with domestic relatives is an increasing threat to the conservation of many wildlife species (Allendorf et al., 2010; Randi, 2008; Rhymer and Simberloff, 1996). The risk is particularly high when animals bred in captivity are released into the wild in areas where conspecifics (or other species with which they can interbreed) exist (Laikre et al., 2010). The most extreme genetic consequence of massive releases of captive-bred animals into the wild is that the local population goes extinct through displacement by the introduced population or complete interbreeding between introduced and local populations. In less severe cases, the local population may be reduced or demographically changed (e.g. changes in gender ratios) and thereby lose genetic variability. If the genetic diversity of the released populations is significantly lower than that of the wild populations, hybridization will also lead to diversity loss. Diversity loss may also result in lowered adaptability. Finally, the local population may become less fit as a consequence of hybridization through breakdown of locally adapted genotypes or spread of less favourable genotypes from the introduced population. The actual impact of large-scale releases of native species on wild populations is not well documented (Champagnon et al., 2010; Laikre et al., 2010). However, the experiences from several decades of salmon farming in Norway could give some insight into possible outcomes (Box 1). A statistical model describing how captive and wild populations of mallards may interact to maintain genetic variability (the so-called Ryman-Laikre effect, cf. Ryman and Laikre, 1991) is presented in Appendix III.

The breeding season for mallards and other dabbling ducks in Norway is the early spring, which means that farmed mallards that are released in nature must survive the hunting season and subsequent winter in order to hybridize with wild mallards or other ducks. In studies performed in France, after the initial peak in mortality of released mallards, survival continued to decrease throughout the first year (Champagnon et al., 2012). The same trend can be found in northern Europe, such as Sweden and Finland (table 3.1-1). After the hunting season released mallards will spread and even though the releases are focused on a few lakes breeding could take place in other parts of Norway. Moreover, farmed mallard genes when first introgressed into a wild population will have large potential for geographical dispersal.

Table 3.1-1 Estimated survival of released hand-reared mallards in France, Sweden, and Finland.

Note that there are discrepancies between the methods used for estimating these numbers, which makes direct comparison difficult.

Country	Survival 1st year	Monthly survival after 1st year	Reduction in mean longevity compared with wild mallards	Reference
France	3.7 %	76 % (similar to that of wild ducks)	-	Champagnon et al., 2012
Sweden	<25 %	-	55% (longevity for wild mallards: 575 days and longevity for farmed mallards: 258 days)	Söderquist et al., 2013
	21-42 %			Gunnarsson et al., 2008
Finland	<10 %	-	67% (calculated as above)	Söderquist et al., 2013

In a more recent study from France, the probability of released juveniles surviving until the onset of the next breeding season was 18%, equivalent to half the first-year survival of local wild mallards (Champagnon et al., 2016a). The survival rate of mallards released in Norway during their first year is unknown, but due to lower winter temperatures it is reasonable to assume that it could be lower than in France and Sweden. In recent decades an increase in wintering numbers of mallards has been observed in the Nordic countries; however, whether this results from changes in migratory patterns due to milder winters or the contribution by restocking is uncertain (Dalby et al., 2013a; Gunnarsson et al., 2012b). Moreover, the age of the released ducklings in Norway is lower than that commonly practised in France (2-4 weeks vs 7-8 weeks). This difference would also be expected to result in lower survival rate in Norway, as a higher age at release has been shown to be an important factor for early survival (Söderquist, 2015).

The reasons for the differences in survival are likely to be intrinsic constraints, such as poor body condition and inability to acquire enough reserves, or depressed immune system, due to poor sanitary conditions. These factors have been attributed to captivity, and could decrease the reproductive potential of released mallards (Champagnon, 2011; Söderquist, 2015). There are few data on the breeding success of either wild or released mallards, but an attempt to establish a self-sustaining breeding population of farmed mallards in North America failed (Stanton et al., 1992).

In summary, the proportion of released mallards surviving their first year varies among countries and studies (Table 3.1-1). In Finland where winter temperatures are most equal to those of Norway it has been estimated to < 10% (Söderquist et al., 2013). The proportion of surviving birds engaging in reproduction is unknown. For the assessment of risk for effects of interbreeding between mallards and native populations (of mallards or other dabbling ducks), the proportion of released mallards relative to the size of the resident population will determine the probability of hybridization. In the short term, the consequence of hybridization might be negative for the offspring, especially in the case of cross-species mating, but will have minor impact on the population as a whole. However, the consequences of hybridization and introgression will increase with time as the genetic impact will accumulate in the gene pool if crossbreeding and back-crossing occur over many generations. For the long-term perspective, climate change (see Section 2.4 on climate modelling) is expected to affect winter survival and migration patterns. It is well documented that ducks migrate shorter distances in mild winters than in cold ones (Ridgill and Fox, 1990) and several studies have found decreasing trends in migration (Sauter et al., 2010 Gunnarsson et al., 2012b). It has further been observed that the distribution pattern of dabbling ducks has changed with increasing population trends in countries on the northeastern end of the wintering range and decreasing trends in countries further south-west (Calbrade et al., 2010; Hornman et al., 2011; Nilsson and Månsson, 2010). Mallards ringed in Sweden during migration show higher survival rates in the 2000s than in the 1960s–1980s (Gunnarsson et al., 2012b). Warmer winter temperatures are thus predicted to result in less long-distance migration, more available habitat and food (fewer frozen lakes with less ice cover), and thereby increased survival. Hence, other possible anthropogenic influences aside, the density of ducks in Norway is expected to increase in 50 years.

3.2 Hybridization between mallards and other duck species

In North America, mallards are known to crossbreed with a number of closely related species e.g. mottled duck (*A. fulvigula*) and black duck (*A. rubripes*). In particular, hybridization with black duck has been so extensive that specimens of this species are now indistinguishable from mallards. Farmed mallard releases on the East Coast USA (Atlantic Flyway) during the 20th century allowed mallards to colonize areas previously dominated by black ducks. By 1969 mallards outnumbered black ducks in the area (Heusmann, 1974). A study comparing museum samples taken before 1940 with modern birds revealed that introgression has drastically reduced the genetic differentiation from 0.146 to 0.008 (measured as fixation indices, F_{ST}) between the two species (Mank et al., 2004). In Mexico, extensive hybridization with mallards led to the endangered Mexican duck (*A. diazi*) being considered as conspecific with the mallard in 1983 (Rhymer and Simberloff, 1996). The mallard was introduced to Australia and New Zealand in the late 1860s and is now found on a number of South Pacific Islands where they hybridize with resident grey ducks (*A. superciliosa*). In some areas, none of the grey ducks investigated were considered to be pure, despite efforts to cull mallards

(Tracey et al., 2008). It has been suggested that the hybrid *A. superciliosa* x *A. platyrhynchos* is more vigorous than any of the parental species (McCarthy, 2006). In Eurasia, hybridization has been confirmed with eastern spot-billed duck (*A. zonorhyncha*) in Far East Russia (Kulikova et al., 2004). These examples show that introduced/increased mallard populations can have a substantial impact on closely related species.

The six other species of dabbling ducks presently found in Norway all have the potential to crossbreed and produce fertile offspring with mallards (McCarthy, 2006). In fact Kraus et al. (2012) showed that the proportion of shared SNPs between mallard, pintail, wigeon and gadwall sampled in Eurasia and North America is an order of magnitude higher than that previously reported between any pair of eukaryotic species with comparable evolutionary distances. Published records from Norway are lacking, but numerous photographs can easily be found on expert monitored ornithologist web sites (e.g. http://www.fuglevennen.no), providing evidence for the existence of hybrid birds here also. It is currently impossible to distinguish between offspring resulting from hybridization with wild and farmed mallards. The representatives from Astrup-Fearnley and Løvenskiold-Fossum reported that wild ducks and waders thrive in the release areas. Hence, it is possible that the phenomenon of heterospecific attraction (see Section 5.6) may lead to increased probability of mating between hand-reared mallards and other dabbling ducks. However, as we have no data to evaluate this theory, it is not considered in our risk assessment.

For assessing the risk of hybridization between released mallards and other dabbling ducks, we decided that the most appropriate measure of impact is the total number of mallards released in Norway per year. Of the seven species of dabbling ducks found in Norway, mallard, wigeon (brunnakke), and teal (krikkand) are common and their conservation statuses in Norway were considered to be of Least Concern by the Norwegian Biodiversity Information Centre (Artsdatabanken) in 2015 (Henriksen and Hilmo, 2015). The same year the gadwall (snadderand) was given the status Near Threatened (previously Endangered), the pintail (stjertand) Vulnerable (previously Near Threatened), the shoveller (skjeand) Vulnerable (previously Endangered) and the garganey (knekkand) Endangered (previously Critically Endangered) on the Norwegian Red List (Henriksen and Hilmo, 2015). The latest estimates of the numbers of individuals that reproduce in Norway by the Norwegian Biodiversity Information Centre (NBIC; Shimmings and Øyen, 2015) are: mallard 86,000-150,000; teal 40,000-60,000; wigeon 10,000-30,000; gadwall 24-100; pintail 430-1,100; shoveller 40-200; and garganey <50. These species breed in low densities over vast areas, which makes it difficult to determine the demographic rates of adult survival and annual reproductive output. According to NBIC there is no monitoring programme for the breeding populations of ducks in Norway, and therefore no information about population trends. The potential for negative effects of hybridization with released mallards will be larger for the species on the Norwegian Red List and we have therefore assessed the risk for these species separately. Information about presence of gadwall (snadderand), garganey (knekkand), pintail (stjertand) and shoveler (skjeand) in an area (e.g. from NBIC distribution maps) could be required prior to release of farmed mallards to reduce the risk of hybridization. Worldwide, the populations of all these species are large and migratory. It is assumed that the density of mallards will be higher in 50 years due to milder winters, and the same will apply for other dabbling ducks.

3.2.1 Risk for genetic consequences on common dabbling ducks by hybridization with farmed mallards.

Scenario I (10,000 mallards released annually; i.e. release similar to today's level)

Scenario I is in all the assessments, based on current number of mallards released annually in Norway. This is considered to be low compared with other European countries where ducks are released.

The resident population will outnumber the number of released mallards, and the **Consequence** of hybridization could be large for any hybrid offspring, but **Limited (1)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the number of released mallards anticipated to engage in breeding the next season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (20,000 mallards released annually; i.e., release double today's level)

The resident population will be larger than the number of released mallards and although the **Consequence** of hybridization could be large for any hybrid offspring, it is **Limited (1)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the number of released mallards anticipated to engage in breeding the next season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario III (100,000 mallards released annually; i.e., ten times greater than today's level)

The resident population will be smaller than the number of released mallards and the **Consequence** of hybridization could be large for any hybrid offspring and **Limited (1)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Medium (2). Risk assessment conclusion**: GREEN zone (low risk).

50-year perspective with mallards released over consecutive generations.

Scenario I (10,000 mallards released annually; i.e., release similar to today's level)

The resident population will be larger than the number of released mallards, but the **Consequence** of hybridization and introgression over generations is considered to be **Moderate (2)** for the Norwegian population. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the number of released mallards anticipated to engage in breeding each season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (100,000 mallards released annually; i.e., ten times greater than today's level)

The resident population will be smaller than the number of released mallards and the **Consequence** of hybridization and introgression over generations is considered to be **Moderate (2)** for the Norwegian population. The **Probability** of crossbreeding with released mallards is considered to be **Medium (2)**. **Risk assessment conclusion**: Yellow zone (medium risk).

3.2.2 Risk of genetic consequences for the Red Listed species of dabbling ducks by hybridization with farmed mallards.

Scenario I (10,000 mallards released annually; i.e., release similar to today's level)

The resident population will be outnumbered by the released mallards and the **Consequence** of hybridization could be large for any hybrid offspring and **Moderate (2)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the likelihood of encountering between released mallards and rare dabbling ducks in the breeding season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (20,000 mallards released annually; i.e., release double today's level)

The resident population will be outnumbered by the released mallards and the **Consequence** of hybridization could be large for any hybrid offspring and **Moderate (2)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the likelihood of encountering between released mallards and rare dabbling ducks in the breeding season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario III (100,000 mallards released annually; i.e., ten times greater than today's level)

The resident population will very small compared with the number of released mallards and the **Consequence** of hybridization could be large for any hybrid offspring and **Moderate (2)** for the Norwegian population as a whole. The **Probability** of crossbreeding with released mallards is considered to be **Medium (2)**. **Risk assessment conclusion**: Yellow zone (medium risk).

50-year perspective with mallards released over consecutive generations.

Scenario I (10,000 mallards released annually; i.e., release similar to today's level)

The resident population will be smaller than the number of released mallards, and the **Consequence** of hybridization and introgression over generations is considered to be **High**

(3) for the Norwegian population. The **Probability** of crossbreeding with released mallards is considered to be **Low (1)** as the likelihood of encounters between released mallards and rare dabbling ducks in the breeding season is low. **Risk assessment conclusion**: YELLOW zone (medium risk).

Scenario II (100,000 mallards released annually; i.e., ten times greater than today's level)

The resident population will be much smaller than the number of released mallards, and the **Consequence** of hybridization and introgression over generations is considered to be **High (3)** for the Norwegian population. The **Probability** of crossbreeding with released mallards is considered to be **Medium (2). Risk assessment conclusion**: RED zone (high risk).

3.3 Interbreeding between released and wild mallards

Hybridization between wild and farmed mallards, with subsequent introgression of farmed 'genes' into the wild population, has been demonstrated in several studies of populations in Italy (Baratti et al. 2014), the Czech Republic (Čížková et al., 2012), France (Champagnon et al., 2013), and Sweden (Söderquist, 2015). However, when comparing the genetic profiles (SNPs) of wild mallards prior to large-scale releases (i.e before the 1970s) with contemporary birds, few differences between these two groups were detected (Söderquist, 2015). This indicates that the genetic impact of farmed birds could be low, may be due to the low survival of released farmed mallards. Nevertheless, farmed duck genotypes were detected in all of the current wild mallard populations examined, with the exception of the Norwegian populations. It is, however, worth noting that only a small number (n=21) of individuals from the Norwegian population was analysed. For Denmark, where the number of released ducks by far exceeds the wild population, genetic data have not yet been published.

The studies described above focus on neutral genetic variation. However, differences between wild and farmed mallards have also been observed in traits that are probably adaptive, such as migration patterns (Söderquist et al., 2013) and bill shape (Champagnon et al., 2010; Soderquist et al., 2014). It is uncertain whether changes in morphological or behavioural traits have a genetic basis or whether they are triggered by environmental cues (phenotypic plasticity). The possible impact of these traits on the ecological interactions between released and wild mallards is discussed in Section 4. While highly maladaptive 'genes' will be selected against, traits with slightly negative effects may spread in a population with the same probability as neutral genotypes. Despite the high mortality of released mallards, if very large numbers are released, they still may have a significant impact on the wild population (Champagnon et al., 2016a). Champagnon et al. (2016) concluded that massive releases of captive-bred mallards in Europe should be better monitored from the conservation perspective of wild mallard genetics.

3.3.1 Risk caused by interbreeding between released and wild mallards

When assessing the risk of hybridization between released mallards and resident wild mallards, we decided that the most appropriate measure of impact is the total number of mallards released in Norway per year. When a large number of mallards are released locally the risk of hybridization with wild mallards will be larger locally, however, we lack information about local populations and farmed mallard genes when first introgressed into a wild population will have large potential for geographical dispersal.

The worldwide absence of genetic structure observed in mallards is indicative of large, long-term population sizes and massive gene flow. However, data from the Recoveries Atlas at the Stavanger Museum website (http://stavangermuseum.no/en/ringmerkingssentralen/ringmerkingsatlas) show little evidence of long-distance migration for the Norwegian population. Among 823 recovered mallards ringed in Norway, only 78 were recovered abroad, and of these the majority were found in Sweden (20), Denmark (18), Finland (18), and Great Britain (17). Of recovered mallards ringed abroad and recovered in Norway, the majority (80/140) were from Great Britain, and the rest from Sweden (18), Denmark (17), the Netherlands (15), Belgium (6), and Finland (4). and recovered in Norway, the majority (80/140) were from Great Britain, and the rest from Sweden (18), Denmark (17), the Netherlands (15), Belgium (6), and Finland (4).

Hand-reared mallards in Sweden and Finland have been shown to migrate shorter distances than their wild conspecifics (Söderquist et al., 2013). It has also been reported that farmed birds that survived the hunting season tended to settle in parks where waterfowl were commonly fed by humans (e.g., Osborne et al., 2010). In a study conducted in southern France, as many as 92% of captive-bred mallard recoveries were reported from the same lake where birds had been released (Champagnon, 2011).

Both the probability and consequences of hybridization with released mallards will be larger for non-migratory mallard populations. For these, the most important risk caused by extensive hybridization with farmed mallards over generations is reduced effective population size and thus loss of adaptive potential. There is also a risk for less favourable genotypes being spread into the resident population from the released mallards, should these be less fit. Genetic monitoring of both released and resident populations and collection of recovery data would provide more information about survival and migratory patterns of released birds. It is assumed that the density of mallards will be higher in 50 years due to milder winters, and this will apply to both released and native birds.

Scenario I (10,000 mallards released annually; i.e., release similar to today's level)

The resident population will outnumber the released mallards by approximately 10/1, and the **Consequence** of hybridization is considered to be **Limited (1)** for the Norwegian mallard population as a whole. The **Probability** of breeding with released mallards is considered to be **Low (1)** as the number of released mallards anticipated to engage in breeding the next season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (20,000 mallards released annually; i.e., release double today's level)

The resident population will outnumber the released mallards by approximately 5/1 and the **Consequence** of hybridization is considered to be **Limited (1)** for the Norwegian mallard population as a whole. The **Probability** of breeding with released mallards is considered to be **Low (1)** as the number of released mallards anticipated to engage in breeding the next season is low. **Risk assessment conclusion**: GREEN zone (low risk).

Scenario III (100,000 mallards released annually; i.e., ten times greater than today's level)

The resident population will be about the same size as the number of released mallards and the **Consequence** of hybridization is considered to be **Limited (1)** for the Norwegian mallard population as a whole. The **Probability** of breeding with released mallards is considered to be **Medium (2)**. **Risk assessment conclusion**: GREEN zone (low risk).

50-year perspective with mallards released over consecutive generations

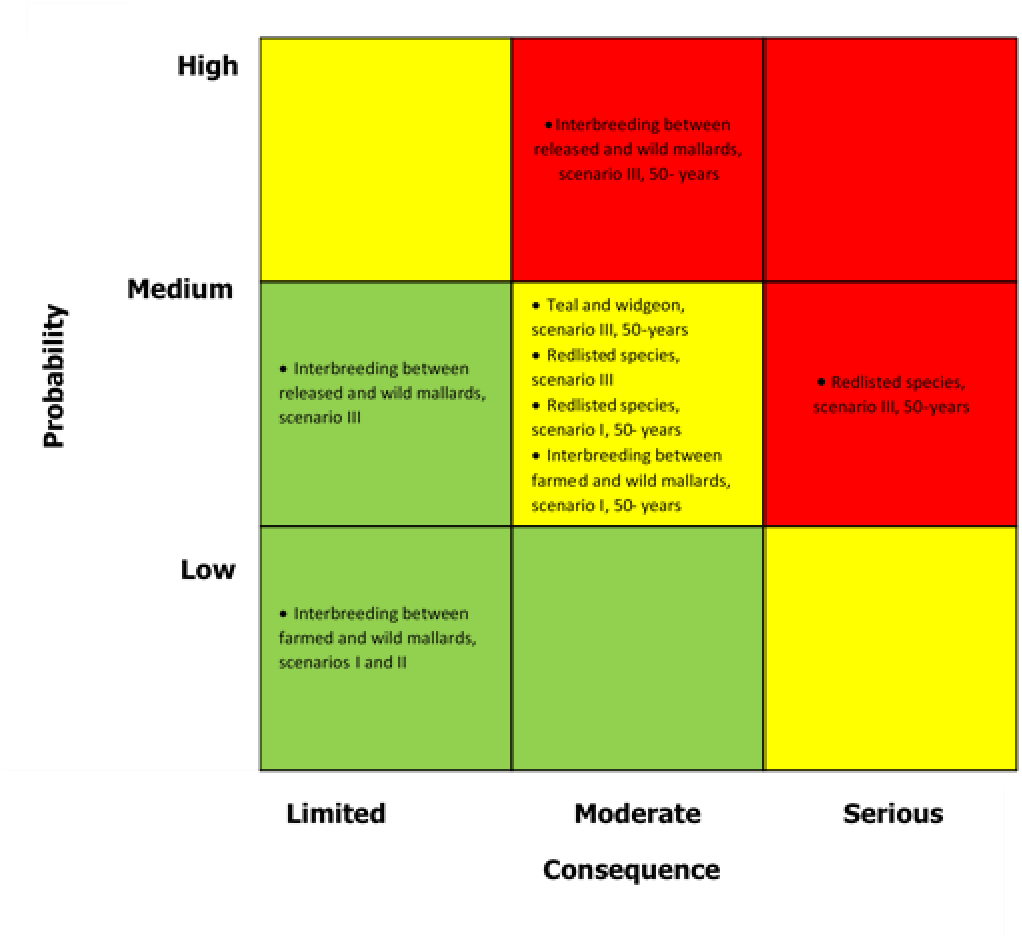
Scenario I (10,000 mallards released annually; i.e., release similar to today's level)

The resident population will outnumber the released mallards by approximately 10/1, and the **Consequence** of hybridization is considered to be **Moderate (2)** for the Norwegian population as a whole over generations. The **Probability** of breeding with released mallards or mallards with introgressed farmed mallard genes is considered to be **Medium (2)**. **Risk assessment conclusion**: YELLOW zone (medium risk).

Scenario II (100,000 mallards released annually; i.e., ten times greater than today's level).

The resident population will be about the same size as the number of released mallards, and the **Consequence** of hybridization could be **Moderate (2)** for the Norwegian population as a whole. The **Probability** of breeding with released mallards or mallards with introgressed farmed mallard genes is considered to be **High (3). Risk assessment conclusion**: RED zone (high risk).

Risk summary: genetics



4 Ecological interactions between released and resident mallards

4.1 Hazard identification and description

The release of farmed mallards will have effects on the native populations, mainly due to competition and density-dependent effects. Effects will depend on the ratio between the number of individuals released and the size of the local, native population. In addition, the effects can be divided into short-term effects (i.e., occurring during the few weeks after release), and long-term effects (i.e., occurring over months and years after release). These effects are directly related to the fate of the released individuals and the probability that these will survive. The effects can also vary at different spatial scales. Because mallards move, the genetic effects considered in the previous section may be thought of as occurring at a regional (or national, with respect to legislation) scale. However, mallards are released as ducklings and these have lower mobility than adults. Therefore, the ecological effects, both at the intraspecific and the interspecific level, can be expected to be highest at the local scale and in the immediate vicinity of the release area, and during the release period and on a short-term. Thus, we have focused the risk assessment at the local scale.

4.1.1 Density dependence

Density dependence refers to the fact that the population size is determined by exogenous and stochastic factors, and by endogenous factors related to the density of the population. Density dependent effects are usually understood as being synonymous with negative feedback on vital rates with increasing population density, often expressed as increased mortality rate or decreasing fecundity and birth rate as the carrying capacity is approached (Gunnarsson et al., 2013). Apart from this, density dependence may play a role in the transmission of diseases and parasites, and, hence, add an extra dimension to the negative effects associated with the release. Health-related effects are considered in Chapter 7 of this report.

For mallard restocking, density depends on two factors: (i) the size of the release area, and (ii) the sum of local released and wild mallards. In general, increased population density will translate into increased competition for resources, especially if the population is near its carrying capacity. As a matter of fact, whether or not the native mallard population is near carrying capacity will determine how strong density dependence will be and, hence, the strength of the impact caused by the releases. However, gathering information on this for each specific population is a challenge, and, accordingly, studies on duck populations have reported diverse findings. For example Gunnarsson and Elmberg (2008) and Gunnarsson et al. (2008) found general effects of density dependence on mallard populations in Sweden and Finland, the most pronounced effects being found during the breeding season and when ducklings were still young. In contrast, Sæther et al. (2008) found relatively low levels of density dependence and density regulation on the populations of mallard and other duck species in North America. This is an example of two studies with the same species that yield opposite results with regards to density dependence regulation. A hypothetical release of mallards in these two populations would most likely have very different effects. In addition to this, the levels of density dependence vary both temporally and spatially, making the use of general reference values practically impossible. If a population is under strong density regulation (high levels of density dependence; e.g., those from Gunnarson et al., 2008), then doubling of its original size might have severe consequences. In contrast, a similar increase in a population under weak density regulation (e.g., those from Sæther et al., 2008) might cause only minor changes (Steinar Engen, pers. comm.).

Given the high level of variation, it is not straightforward to provide general rules on the effects of duckling releases on the native populations. In order to assess site-specific effects, the release area should be surveyed for information concerning the size and density of the native population, along with the size of the area where the release is planned. Such information is lacking for the present assessment. For this reason, we have decided to find a middle ground for the scenarios we propose, taking into account the two extreme examples presented above. For the sake of our risk assessment, we assume that any given native mallard population in Norway will be present at moderate levels of density dependence, and, hence, an increase that doubles its size (i.e., a 100% increase) will have moderate consequences. This is obviously a working generalization.

Based on this assumption, we have used the following scenarios:

- Scenario I: number of released mallards represent less than 50% of the local, native population.
- Scenario II: number of released mallards represents between 50% and 150% of the local, native population.
- Scenario III: number of released mallards represents more than 150% of the local, native population.

Surveys of the areas where releases are planned should provide an approximate indication of the specific conditions for which these three general scenarios can be useful. Expected effects are site-specific, and these scenarios are therefore adhered to in the current and in the subsequent sections (Chapters 4 and 5).

4.1.2 First weeks after release: survival and competition for food resources

Released and native ducklings compete for food and such a direct competition might be detrimental for the native ducks. However, hand-reared ducks might be less adapted to the natural conditions and, hence, be less successful competitors ("burden of captivity"; Champagnon et al., 2011). In addition, released ducklings may be fed artificially for weeks or months after release. The intention of such feeding is to maximise survival, but might simultaneously reduce competition for natural food resources with native ducks.

It has been suggested that since breeding of captive animals always occurs at higher densities than in the wild, agonistic behaviour (e.g., aggression) might be promoted. It is not known if released mallards display agonistic behaviour. However, it is important to discern the number of released mallards compared to the number of native mallards. If the number of released mallards is much higher, then they can be expected to deplete resources more rapidly. This would potentially have a negative effect on the native population.

The survival rate of hand-reared versus native mallards will also influence the consequences of the release. Several studies have shown that hand-reared mallards have lower survival rate than native mallards (Dunn et al., 1995; Söderquist et al., 2013; Champagnon et al., 2016; see Table 3.1-1). A reduced survival might to some extent counteract negative effects associated with the release. The lower survival rate is generally considered to be caused by a "burden of captivity". This is a potential genetic maladaptation resulting in bills that are less efficient for sieving and with smaller gizzards, and with a greater dependency on anthropogenic food (Champagnon et al., 2012). The dependence of feeding will translate into a reduced ability to exploit natural food resources and, probably, reduced body condition. In addition, a less efficient immune response and a lack of adequate anti-predator behaviour have been suggested as potential causes for reduced survival for released mallards (Champagnon et al., 2011). Survival is especially low during the first month after release. This low survival is likely caused by predators that are attracted to the increased number of prey (Champagnon et al., 2012), as has also been observed for other species (Gortázar et al., 2000; Kostow, 2009). It has also been suggested that hand-reared mallards are more vulnerable at the onset of the hunting season, due to deficient anti-predatory behaviour and their familiarity to humans. However, Champagnon et al. (2011) did not find a difference in the survival of released individuals between hunted and non-hunted estates, suggesting that the high mortality during the first months after release is mostly natural.

4.1.3 Winter survival, competition for space and food resources, interbreeding and introgression, migration

The contribution of released mallards to the wild population may be limited as long-term survival of hand-reared mallards is generally lower compared to native mallards (Champagnon et al., 2012; Söderquist et al., 2013; see Table 3.1-1). Long-term effects will depend on the number of mallards that are released compared to number in the native population. The number of mallards that survive until the subsequent breeding season may be substantial if many mallards are released, and particularly if this practice is maintained over many years, even if the survival rate is low (Söderquist, 2015). The few individuals that survive until the subsequent spring can be expected to enter the breeding population and compete with their native counterparts for space and resources. In such a situation, there is a risk of interbreeding and introgression of potentially maladaptive genes from the farm-reared mallards into the native population. This is particularly important with regards to bill morphology and foraging efficiency, but is also of relevance regarding movement and migration distances. Söderquist et al. (2014) showed that farm-reared mallards have wider, shorter, and higher bills, with proportions that make them more "goose-like", along with a lower lamellar density, although this is only in males. They also showed that this phenotype is spreading in natural populations in northern Europe, even in areas where mallards have not been released. Such introgression of farmed mallard traits may lead to a maladapted and genetically compromised wild mallard population. It has been proposed that these "goose-like" bills in farmed mallards are more adapted to feeding on larger food particles on land, such as agricultural crops or food pellets, rather than filtering water for food (Champagnon et al., 2010). If this phenotype becomes more frequent among wild populations, this might have negative consequences, as individuals with the "goose-like" phenotype might be less competitive than those showing a wild, sieving phenotype. However, whether or not this "farmed" phenotype has any fitness consequences remains to be seen.

An important fact regarding the mallards surviving beyond the first month is that hand-reared mallards migrate shorter distances than native mallards (mean distance in Swedish birds, 676 km versus 523 km; in Finnish birds, 1,213 km versus 157 km; Söderquist et al., 2013). This pattern is related to both shorter lifespan and lower migration speed in hand-reared birds, even if they follow the same migratory strategy as the native mallards. This raises the question on the connection between populations or areas, and the potential impact that the released birds might have on other areas where they might migrate and potentially reproduce.

4.2 Risk assessment scenarios

The mallard population can be considered to be a mixture of two duck groups with different qualities: native mallards and released mallards. Native mallards have relatively stable mortality and are mostly breeding among themselves: Released mallards have a high mortality (natural or hunting) during the first year prior to the first breeding season, and a low breeding success, which limits the hybridization opportunities with their native conspecifics (Champagnon, 2011). Experiments carried out by Cheng et al. (1978) found some support for native and hand-reared male mallards preferring to mate with their own original groups (native or hand-reared, respectively), whereas females did not show any specific preference. Thus, the opportunities for cross-breeding will depend both on the survival of the released individuals and on the mating preferences shown by both groups.

4.2.1 Effects during the first weeks after release

Consequence: Native individuals have restricted access to food due to competition with released individuals at and around the release area.

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Moderate (2).**

Probability: **Low (1)**, given, first, the low number of individuals released, and, second, their lower foraging efficiency, caused by their habituation to food provided by people and larger particle sizes.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Moderate (2).**

Probability: **Medium (2)**, as a limited amount of resources has to be shared between a similar number of native and introduced animals. However, hand-reared mallards are less efficient at exploiting natural food resources and have higher mortality during the first weeks / months after release.

Risk assessment conclusion: YELLOW zone (medium risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Moderate (2).**

Probability: **High (3)**, despite their lower foraging efficiency, the high number of individuals released might generate high levels of competition.

Risk assessment conclusion: RED (high risk) zone.

4.2.2 Effects after hunting season, during the first winter, and later

Consequence 1: Native individuals have restricted access to nesting and food resources because of competition with released individuals around the release area or in other areas where released and surviving individuals settle for breeding.

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Limited (1).**

Probability: **Low (1),** given the low number of individuals released and that most of them are unlikely to survive for long enough to breed.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Low (1)**, even if the number of individuals released approximately equals the native population, the low survival during the first year of farmed mallards entails that probably only a few will enter the breeding population the following year, with low chances for competition.

Risk assessment conclusion: GREEN zone (low risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Low (1)** to **medium (2)**, even with low first year survival, a very big increase in population size and density is likely to generate some competition.

Risk assessment conclusion: GREEN zone (low risk).

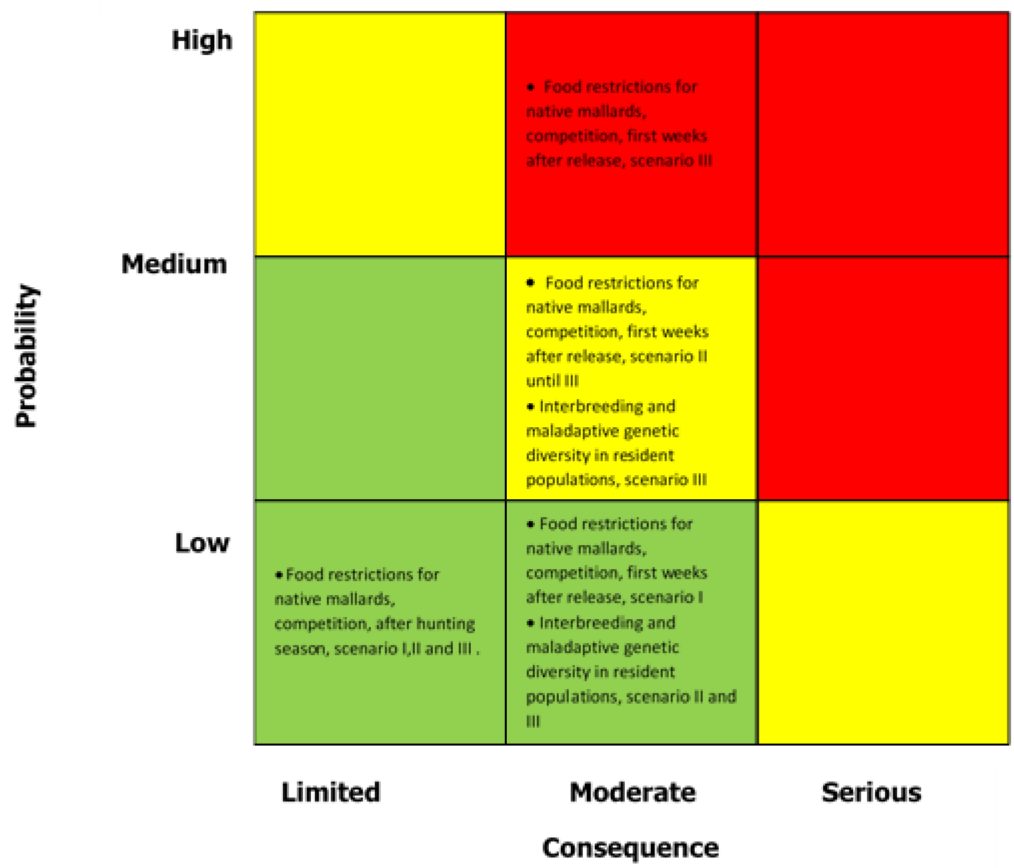
Consequence 2: Interbreeding between native and hand-reared mallards resulting in introgression of maladaptive genetic diversity on the natural populations.

This assessment is performed in detail in Chapter 3, section 3.3 (see above).

4.2.3 Effects from a 50-year perspective with mallards released over consecutive generations

A continuous release of hand-reared mallards will likely prolong the effects mentioned, especially if the numbers released are high enough to counteract the losses due to natural mortality and hunting of hand-reared mallards. In addition, future winters are expectedly milder (see section 2.4) causing increased survival of released mallards and greater effects on the natural population. High uncertainty is associated with these statements, due to variation in the number of individuals released, their survival in each case, and the uncertainty associated with future climate projections.

Risk summary: effects on resident mallards



5 The impact of farmed mallard release on local fauna and flora, including potential for increased abundance of small and medium-sized predators

5.1 Hazard identification and description

Ducks are generally omnivorous, and thus may act at several trophic levels (Figure 5.1.-1). They can influence the food web directly as predators of fish/amphibians, invertebrates, or macrophytes (e.g., Woollhead, 1994; Klaassen and Nolet, 2007). They can also compete with other groups of organisms that feed on plants and invertebrates.

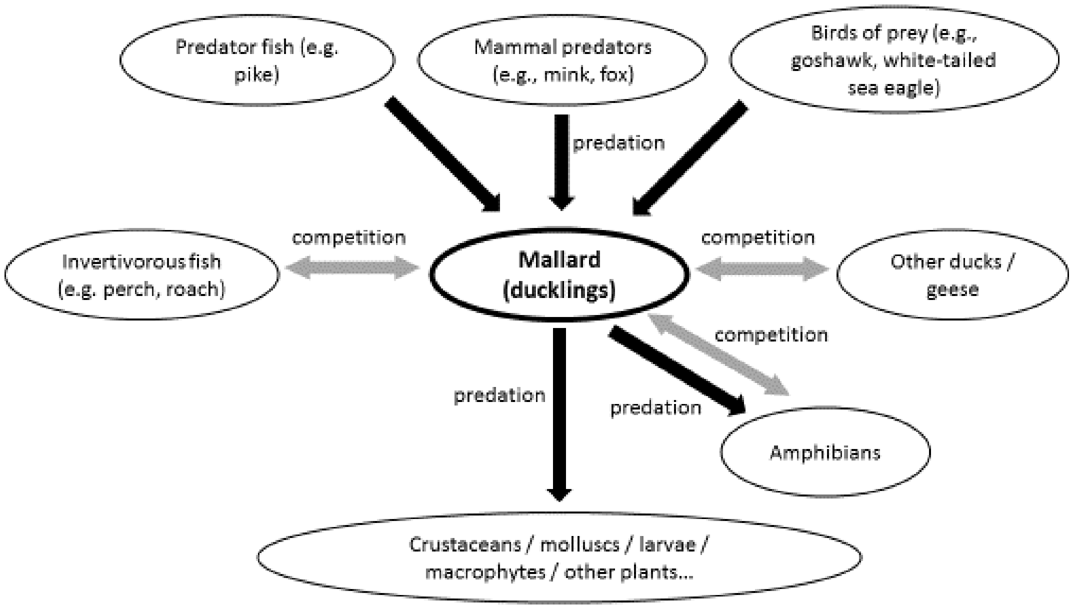


Figure 5.1-1. Simplified food web representing the position and types of interactions of mallards with other organisms on the ecosystem. Note that not all potential interactions are shown, both for the sake of clarity and because here we focus on those interactions in which both native mallards and the released ducklings are directly involved.

Mallards are potentially subject to predation by fish, mammals, and birds. They may also compete for food with other ducks, geese, and fish, and feed on invertebrates and macrophytes. Here, we mostly consider the effects during the first weeks after release, normally indicating an increase in mallard population size and density in a specific area. Given the low long-term survival rate of released mallards (Champagnon et al., 2012, Söderquist et al., 2013, Champagnon et al., 2016), the effects and interactions with other species are likely to be much lower in the long term.

In the following, we describe the potential interactions with other species and the resulting effects that may occur from the release of mallards. Some of these interactions may take place with endangered or "Red List" species, depending on the site of release. Therefore, the risk assessments presented below could be considered as being at least one degree higher when endangered species are involved.

5.2 Predation on mallard ducklings

Ducklings are potential prey for aquatic, terrestrial, and aerial predators. In nature, ducklings have low a survival rate during the first two weeks after hatching (Dessborn, 2011). For released ducklings, although of similar age or a few weeks older, their inexperience in a natural environment makes them at least as vulnerable as the native ducks. During these early stages, energy requirements are high and food shortage often leads to starvation or an increased vulnerability to diseases or cold weather. However, these risks may decrease if the released ducklings are artificially fed. During this period, ducklings easily become prey to predators such as pike (*Esox lucius*), goshawk (*Accipiter gentilis*), American mink (*Neovison vison*), or large gulls (*Laridae sp.*) (Dessborn, 2011; Sargeant and Raveling, 1992). Ducklings are expected to have a tailored response to each of the different types of predation, including responses to imminent threats, such as predatory attacks, as well as general avoidance of predators. However, some studies have shown that ducklings apparently exhibited neither avoidance nor recognition of pike or mink, despite some broods displaying an innate reaction to predatory birdcalls (Dessborn, 2011). Ducklings that can obtain a surplus of food while avoiding predation have a strong advantage. These foraging/avoidance behaviours are traded against each other, as increased foraging often leads to reduced vigilance (Guillemain et al., 2007).

A sudden increase in the population size of mallard ducklings due to release is likely to attract predators to the release areas. This applies mostly to mammal and avian predators that can cover long distances and move between wetlands. However, an increased population size of predators is likely to occur temporarily and probably a matter of weeks, given the high mortality of farmed mallards during the first month.

5.2.1 Fish predation

Pike have long been described as predating on ducklings (Solman, 1945), and many fishermen, hunters, and ornithologists can give anecdotal accounts of pike attacks on broods (Dessborn et al., 2011b). Pike are stalking predators that generally stay passive, and strike at moving prey-size objects within a distance of less than 2.5 m, even if the object is a brightly painted lure (Solman, 1945). Few studies have quantified the effects of pike on breeding duck populations, although Solman (1945) and Lagler (1956) used the gut contents of pike to estimate the annual number of ducklings lost due to predation by fish.

Some studies have shown that the breeding success of mallards in natural populations was significantly lower lakes with pike than in lakes without pike (Dessborn et al., 2011b; Elmberg et al., 2010). Thus, as pike predation can significantly impact the survival of ducklings, avoidance behaviour in the females or ducklings would be expected. However, no clear strategy for avoidance or response to fish predation has been described in ducks. In experiments performed by Dessborn et al. (2012), ducklings did not avoid pike, although they displayed a very strong response to simulated pike attacks. The release of hand-reared mallards onto lakes with pike might cause two opposing consequences for the native mallard population: (i) the increase in movement in water may attract pikes and hence more ducklings will be predated upon, and (ii) native ducklings might be better at escaping predation, and the main mortality might take place among farmed ducklings. The pike population might be favoured by a sudden increase in prey abundance, but a longer-term effect will depend on the mortality rate of ducklings during the first weeks after release, both from natural causes and by hunting. Given the great mortality of released ducklings (Champagnon et al., 2012; Söderquist et al., 2013), a long-term positive effect on pike populations seems unlikely.

The presence of pike, however, might have an indirect positive effect on the duck population. Pike might limit the number of fish that feed on invertebrates and thereby indirectly increase the abundance of invertebrates as a source of food for the ducklings (Dessborn, 2011).

Risk assessment

Consequence 1: Increased population size of pike in water bodies where mallards are released.

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Limited (1),** given the pike distribution is limited to those lake(s) where mallards are released.

Probability: **Low (1),** given the low number of released individuals compared with the population as a whole.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Medium (1)**, there will likely be more prey available for pike on a short-term when a higher number of mallards are released. A higher number of mallards will survive on a long-term, even if the proportion of survivors is small, and this might provide more potential prey for pike.

Risk assessment conclusion: GREEN zone (low risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Medium (2)** to **high (3)**, since the high numbers of individuals released will result in a higher proportion of those surviving in the long-term and potentially contributing as prey for pike.

Risk assessment conclusion: YELLOW zone (medium risk).

5.2.2 Mammal predation

The main mammalian predators that prey on ducklings are mink and fox. Mink have a diet that includes fish, birds, and mammals (Bartoszewicz and Zalewski, 2003). Mink may have a large impact on ducklings and could be a principal cause of mortality in some areas (e.g., Talent et al., 1983; Bartoszewicz and Zalewski, 2003; Dessborn, 2011). A representative from Astrup Fearnley, who have been releasing mallards in Norway since 1979, informed us that the released farmed mallard ducklings attract mink to the wetlands where they are released. The increase in mink population is so significant that the species is hunted after the ducklings are released in order to reduce predation and control the mink population.

Fox also predate on the released ducklings. Carl-Martin Nygren, the representative from Løvenskiold Fossum informed VKM that they did have more problems with fox than mink. Foxes are hunted to control the population and to reduce predation on the released ducklings, and in 2016 as many as 50 foxes were shot before the ducklings were released.

Risk assessment

Consequence 1: Local increases in mink and / or fox populations

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Moderate (2),** both mink and fox seem to be easily attracted by the sudden abundance of ducklings.

Probability: **Medium (2),** given the small number of individuals released compared with the population as a whole.

Risk assessment conclusion: YELLOW zone (medium risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Moderate (2).**

Probability: **High (3)**, since the more individuals are released, the more mink and fox are likely to be attracted.

Risk assessment conclusion: RED zone (high risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Serious (3).**

Probability: **High (3).**

Risk assessment conclusion: RED zone (high risk).

5.2.3 Predation by raptors and other birds

Various species of birds may have an impact on the survival of ducklings. Birds of prey are natural predators, and experimental trials carried out with goshawks and dummies showed that, unlike with pike, naïve ducklings recognised and responded to calls from predatory birds (Dessborn et al., 2012). In addition, although gulls and corvids pose no direct threat to adult ducks, they can prey upon ducklings and eggs (Sargeant and Raveling, 1992). Anecdotal evidence of cranes predating on ducklings has also been reported.

Birds of prey, like goshawk, may be opportunistic regarding prey selection, and it is thus expected that they will attack a flock of newly released ducklings, mixed with the native ducklings. However, given the high mobility of avian predators, it is unclear whether there will be any prolonged and significant increase in their population.

Risk assessment

Consequence 1: Local increase in avian predator populations, especially birds of prey.

Scenario I (farmed mallards represent less than 50% of the local, native population).

> **Consequence**: **Moderate (2),** as the presence of new prey may attract these predators.
>
> **Probability**: **Low (1),** given the small number of released mallards, predator birds are less likely to discover them as a new food resource.
>
> **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

> **Consequence**: **Moderate (2).**
>
> **Probability**: **Medium (2)**, an average doubling in size will be conspicuous enough to attract the highly mobile birds of prey.
>
> **Risk assessment conclusion**: YELLOW zone (medium risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

> **Consequence**: **Moderate (2).**
>
> **Probability**: **High (3)**, a very high and sudden increase of duckling numbers is unlikely to go unnoticed to many of the birds of prey in the area.
>
> **Risk assessment conclusion**: RED zone (high risk).

Risk summary: predation

Probability \ Consequence	Limited	Moderate	Serious
High	• Pike predator, scenario III	• Mammal predators, scenario II • Bird predators, scenario III	• Mammal predators, scenario III
Medium	• Pike predator, scenario II to III	• Mammal predators, scenario I • Bird predators, scenario II	
Low	• Pike predator, scenario I	• Bird predators, scenario I	

5.3 Competition

Species at the same trophic level can be competitors, either for food or habitat. The two main groups with which the farmed mallards will compete are fish feeding on invertebrates, and other species of ducks and geese. In addition, amphibians might also experience competition for space or resources. This can be especially problematic in the case of interactions with vulnerable species, like the northern crested newt (*Triturus cristatus*, stor salamander), where, besides competition, predation by ducks sometimes occurs (see section 5.5).

5.3.1 Competition with fish feeding on invertebrates

Fish communities have a strong impact on aquatic environments and can reduce invertebrate numbers, both directly and indirectly, and are therefore likely to affect the breeding success of ducks (Phillips and Wright, 1993). Fish feeding on invertebrates can reduce the total biomass of invertebrates (Giles et al., 1995), as well as change the average size of species in the invertebrate community by selectively feeding on large individuals (Bertolo et al., 2005; Rosenfeld, 2000). Most studies have therefore concluded that fish have a negative influence on breeding ducks, and this is widely understood to be a result of competition between ducklings and fish for common invertebrate prey. Fish removal experiments have resulted in increased usage by broods and greater duckling survival (Giles, 1994). Experiments have also demonstrated that fish have a strong negative effect on lake use and breeding success of ducks (e.g. Mallory et al., 1994; Rask et al., 2001). Negative correlations were observed between fish presence and the number of free-swimming and benthic invertebrates, which affected the abundance of breeding ducks as well as the total species richness of waterfowl in the lakes with fish. It is, hence, expected that fish feeding on invertebrates will also interact with released mallards and that competition between the two groups will arise. Some studies have demonstrated a diet overlap (Winfield and Winfield, 1994) and a reduction in breeding ducks in waters with high fish densities (Haas et al., 2007). Other studies have shown that high densities of fish reduce suitability of a lake for ducks (Eriksson, 1983). However, a naturally diverse and dense fish community might reflect a nutrient-rich lake with high invertebrate levels, which would be positive for both fish and ducks (Paszkowski and Tonn, 2000).

Effects on the ducks may vary according to the composition of the fish community. A complex food web with many fish species may have a different impact on breeding ducks than a lake with only one fish species. Duckling survival therefore needs to be analysed in a more complex food web to determine the effects of both the competitors and the predators in a natural environment.

As fish- eating predators, such as pike, may limit the population size of fish feeding on invertebrates, the predators might have indirect positive effects on ducklings by reducing the number of competitors. However, studies by Dessborn (2011) showed that fish had a negative impact on ducklings, despite pike being present. It is therefore unlikely that all aquatic systems are controlled by top predators.

This variation suggests that there are several scenarios regarding how the release of hand-reared mallards may affect the communities of competing fish. Released mallards will compete with fish for invertebrate prey. The fish may be negatively affected if the number of released mallards is high. On the other hand, pike will predate both on ducklings and on other fish, suggesting a reduced predation pressure on the fish. Such an effect may outweigh negative effects on fish caused by competition with mallards.

Risk assessment

Consequence 1: The community of fish feeding on invertebrates decreases due to competition with hand-reared mallards.

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Limited (1),** especially because released mallards are likely to be artificially fed for a period of between several weeks to several months, reducing competition with fish. Also, they might be less efficient at exploiting natural resources than native mallards.

Probability: **Low (1),** given the small number of released individuals compared with the full population.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Medium (2)**, doubling, on average, the duckling population will increase the likelihood for competition with fish, even in the presence of artificial food sources for the released mallards.

Risk assessment conclusion: GREEN zone (low risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **High (3)**, a high increase in mallard population density is likely to cause an increased competition with fish.

Risk assessment conclusion: YELLOW zone (medium risk).

Note that there is considerable uncertainty related to these assessments and these are discussed in chapter 9.

5.3.2 Competition with other ducks or geese

In nature, several duck species often occur in the same wetlands and feed largely on the same food items, especially if they are dabbling ducks, such as mallards. Some studies have proposed a number of adaptations that could reduce niche overlap and, therefore, competition. These might include differences in bill lamellar density (Nudds and Bowlby, 1984) or in neck- and body length (Pöysä, 1983). However, niche differentiation is not always straightforward among dabbling duck species (Gurd, 2008) and ducklings, in particular, have highly overlapping diets (Cramp and Simmons, 2004). It has been suggested that there is little interspecific competition among dabbling ducks, even if they have little degree of niche differentiation. This is because the habitats of dabbling ducks are often not close to the carrying capacity and food not a limiting factor (Dessborn, 2011). However, this may change abruptly subsequent to a release of mallards where intraspecific and interspecific competition may increase. Behavioural mechanisms, such as dispersal, might reduce the competition. Deeper changes, such as morphological adaptations causing niche differentiation, will not occur since these need much longer time.

The presence of ducks at a site seems to attract more ducks. Ducks prospecting for breeding wetlands or identifying good habitats are assumed to use the presence of closely related species as an indicator. This has been referred to as *heterospecific attraction* (Sebastián-González et al., 2010). Representatives from Astrup Fearnley and Løvenskiold Fossum confirmed that released ducks attract wild ducks and wading bird. These other species include common goldeneye (*Bucephala clangula,* kvinand) and common teal (*Anas crecca,* krikkand). Other birds present in the release areas are herons, cranes, and snipes. Heterospecific attraction may have three main consequences: (1) increased competition for resources, both for the released mallards and for other species present, (2) increased attraction of predators, and (3) a higher risk of eutrophication due to the larger number of birds in lakes or water bodies.

Risk assessment

Consequence 1: Other duck species experience greater competition because of the released mallards.

Scenario I (farmed mallards represent less than 50% of the local, native population).

> **Consequence**: **Limited (1),** as released mallards will be fed for a period of several weeks to several months, thereby reducing competition with other duck species. Also, released mallards might be less efficient at exploiting natural resources than both native mallards and other species.

Probability: **Low (1),** given the low number of released mallards compared to the full population.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Medium (2)**, an increase of 50-150% of the native population will correspondingly increase the chances for competition with other species, especially if heterospecific attraction takes place.

Risk assessment conclusion: GREEN zone (low risk).

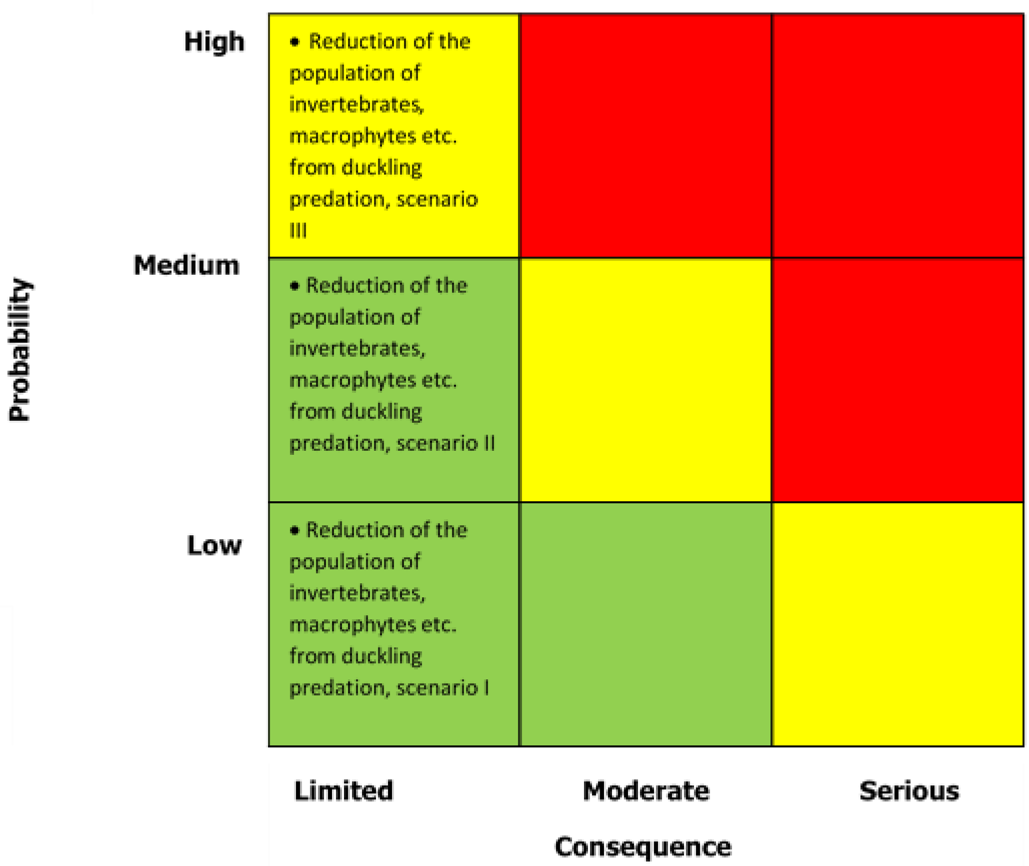
Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **High (3)**, given the high number of released mallards, along with heterospecific attraction that increases the number of other birds, competition is very likely.

Risk assessment conclusion: YELLOW zone (medium risk).

Risk summary: competition



Consequence 2: The population of predators increases due to heterospecific attraction, i.e., other duck species are attracted to the release areas, which, in turn, attract predators (see previous section).

Scenario I (farmed mallards represent less than 50% of the local, native population).

Consequence: **Moderate (2),** this assessment is based on an average of the high risk of attracting mammalian predators and the lower risk of attracting avian predators or pike (depending on whether pike is already present in the lakes).

Probability: **Medium (2)**, a low number of released ducklings is not likely to attract many other birds, and, hence, not many predators. Depending on the nature of these predators, some of them, like mammals, might appear quickly, attracted by the combined increased population of mallards and other birds.

Risk assessment conclusion: YELLOW zone (medium risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Moderate (2).**

Probability: **Medium (2)**, both scenario I and II are considered to have a more or less similar probability in order to represent the wide range of possibilities that may occur with regards to the number of individuals of other birds and predators that are attracted.

Risk assessment conclusion: YELLOW zone (medium risk).

Scenario III (farmed mallards represent more than 150% of the local, native population).

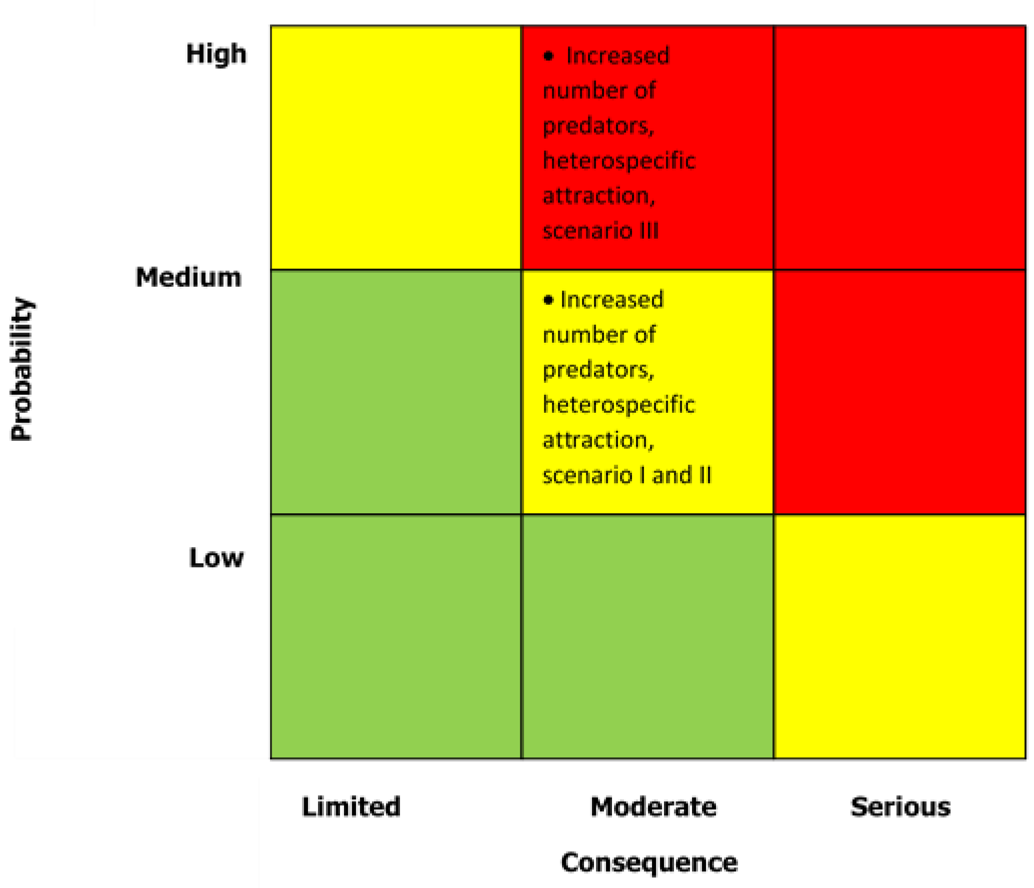
Consequence: **Moderate (2).**

Probability: **High (3)**, the high number of released ducklings will inevitably attract more waterfowl and, hence, more predators to the release areas.

Risk assessment conclusion: RED zone (high risk).

Consequence 3: Increased eutrophication, due to the presence of more waterfowl on the lakes as a result of heterospecific attraction. The native and released mallards, along with other species that are attracted, will increase the input of nutrients to the waterbody. See section 6 for effects on eutrophication.

Risk summary: heterospecific effects



5.4 Feeding ("predation") by ducklings on lower levels of the food web

Mallards are generalist foragers that may eat a wide variety of food. Adult mallards most often feed in shallow waters where they dabble for food. They also roam around on the shore and pick at vegetation and prey on the ground. Mallard diet can consist of both plant and animal matter. The plants in their diet may include roots, tubers, leaves, seeds, and buds, and they can also take agricultural seed and grain. With regards to animals, common prey are mainly invertebrates, including insects and insect larvae (e.g., Coleoptera, Odonata), molluscs like aquatic snails or bivalves, crustaceans like freshwater shrimps, or annelids like earthworms (see examples in Brochet et al., 2012a, Brochet et al., 2012b Swanson et al., 1985). Mallards may occasionally eat vertebrates, particularly fish and amphibians. Cases of predation on amphibians are scarce, but existing (e.g. Fabião et al., 2002) and the following references in Brochet et al., 2012a: Dementiev and Gladkov, 1967, Sterbertz, 1967).

Mallard ducklings feed primarily on newly hatched invertebrates, but their diet gradually includes more plant items as they approach fledging (Cramp and Simmons, 2004). From feeding almost exclusively on the surface, ducklings start to feed more on aquatic invertebrates after a few weeks, first by submerging their bills under the water, and later by up-ending (Chura, 1961). Ducklings also feed on terrestrial invertebrates, either from the water or from land.

Some invertebrate taxa can be of special importance to ducklings due to their general availability. Non-biting midges (Chironomidae, fjærmygg) belong to one such taxonomic group, as they are abundant in many wetland systems and are rich in protein (Baldassarre and Bolen, 2006). An abundance of chironomids may help ducklings' development, but a high number of hand-reared ducklings may impact the chironomid population.

Ducks and other waterfowl may also reduce macrophyte cover and increase turbidity in a wetland when they search for food in the sediments (Marklund et al., 2002). This can indirectly affect invertebrate numbers and fish abundance. Waterfowl are attracted to high densities of macrophytes, probably because the vegetation provides food and shelter (Rodríguez-Villafañe et al., 2007). At the same time, a high number of waterfowls has strong qualitative and quantitative effects on plant communities through effects on vegetation structure, species composition, and by reducing stand biomass (Lauritzen et al., 1993; van Altena et al., 2016). Thus, a high density of hand-reared mallards may influence the nutrient status of a lake, and also the local vegetation. In addition, grazing by herbivorous birds can be an important factor in suppressing macrophyte development in shallow lakes undergoing restoration, delaying the attainment of a stable, clear water state (Perrow et al., 1997). Eutrophication can also directly threaten species in a lake; in Norway, the red-listed algal species *Chara rudis* (Henriksen and Hilmo, 2015) is vulnerable to eutrophication. Macrophytes may also disappear locally as a result of eutrophication, drastically altering food webs, and carbon and nutrient cycling (Carpenter and Lodge, 1986). In many areas of

Europe, the phytoplankton becomes dominated by cyanobacteria during prolonged periods of the year (De Nie, 1987).

Grazing by mallards may also indirectly influence the fish, especially the fish fry. Fish fry require cover in order to hide from predators and to rest. Such cover may include cavities created by stones, dead trees, or macrophytes (Armstrong et al., 2003). The availability of cover may significantly influence the production of fish (Finstad et al., 2007), and strong grazing pressure may reduce the cover and be negative for fish populations. Such negative effects may also be caused by eutrophication, in which overgrowth of vegetation creates a dense barrier that limits available cavities in the lake- or river bed (Heggenes and Saltveit, 2002), and may reduce the availability of oxygen in the sub-littoral and profundal zone.

The effects we describe here depend on the size of the mallards since the diet and ability to feed on prey varies between ducklings and adult mallards. Ducklings are small and might not be able to prey on amphibians. However, the proportion of ducklings surviving over the winter and reaching an adult state might have an impact. In Norway, there are two species of amphibians considered to be threatened, the pool frog (*Pelophylax lessonae*, damfrosk) and the crested newt (*Triturus cristatus,* stor salamander; www.artsdatabanken.no). The release of mallards where these species are present may, pose a threat, both because of predation on tadpoles and on adult individuals. Even if predation on amphibians is rare, the impact on red-listed species will be greater than for white-listed species.

In general, in natural conditions, waterbirds are unlikely to have a strong impact on invertebrate or macrophyte biomass in boreal lakes, as the density of the birds is low and for a limited part of the year. However, the release of farmed mallards could change this in two main directions. First, the density of the native population will increase, along with the presence of other duck- and wader species, which might have a negative impact on the invertebrate and macrophyte community. However, hand-reared ducklings are used to being fed, and their ability to exploit natural food resources might be limited. In addition, artificial feeding will decrease natural feeding thereby decreasing the impacts on lower trophic levels.

Risk assessment

Consequence 1: Reduction of the population of invertebrates, macrophytes, etc., due to feeding by the released ducklings.

Scenario I (farmed mallards represent less than 50% of the local, native population)

> **Consequence**: **Limited (1),** because released ducklings are artificially fed during the first weeks/months after release and are probably less efficient at exploiting natural resources.
>
> **Probability**: **Low (1),** given the small number of released individuals compared to the full population.
>
> **Risk assessment conclusion**: GREEN zone (low risk).

Scenario II (farmed mallards represent between 50% and 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **Medium (2)**, with a higher number of released mallards, the likelihood of these exploiting more natural resources also increases, even if the receive artificial feeding.

Risk assessment conclusion: GREEN zone (low risk).

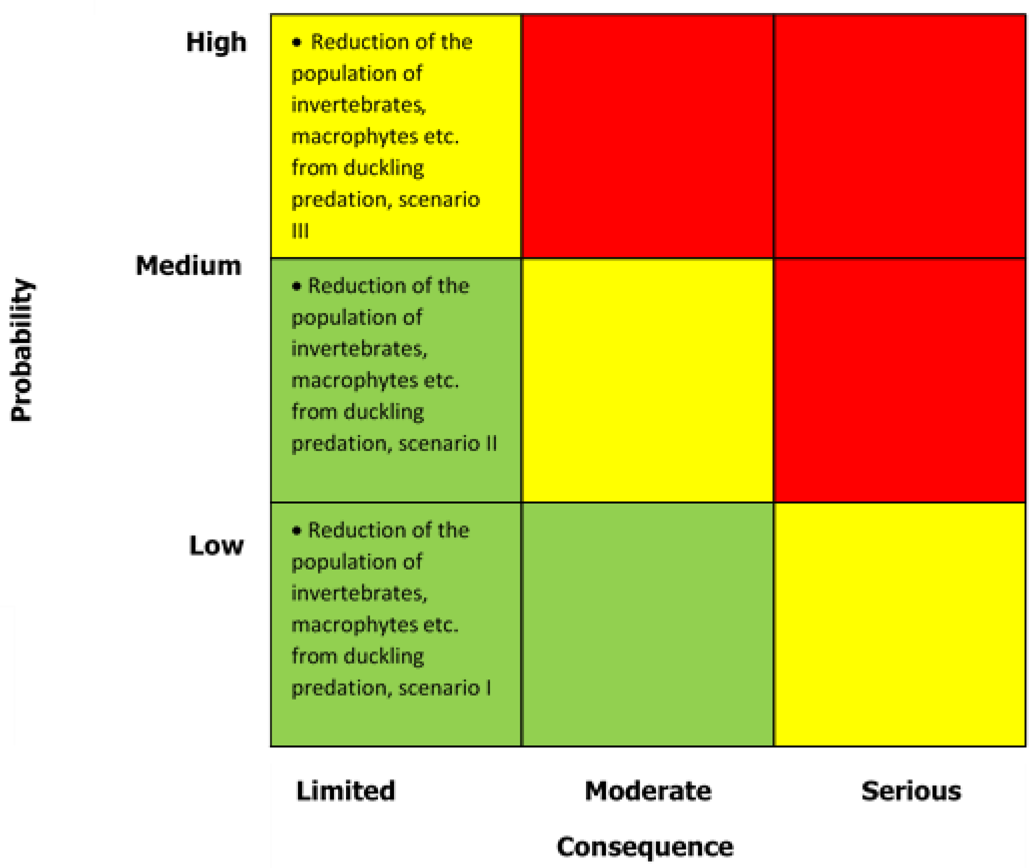
Scenario III (farmed mallards represent more than 150% of the local, native population).

Consequence: **Limited (1).**

Probability: **High (3)**, the high numbers released are likely to produce a relatively high impact caused by their feeding / predating on lower level of the food chain, which might be somewhat counteracted by how and how long they are provided with artificial feeding.

Risk assessment conclusion: YELLOW zone (medium risk).

Risk summary: predation/feeding by ducklings on lower levels of the food webs



6 Mallard release and water eutrophication, including potential downstream effects on local ecosystems

6.1 Experience from Denmark

Few studies have examined the impact of released captive-reared waterfowl on the trophic levels of freshwaters, despite about 3 million mallards being released in Europe every year. In Denmark, the number of released mallards has increased to about 400 000-500 000 annually since the 1980s. Measurements of the concentrations of phosphorous in waterbodies where mallards are released in the late 1990s revealed that the nutrient status was negatively influenced (Wiberg-Larsen et al., 2000). As a consequence, in 2001 the Danish Environmental Protection Agency enforced regulations that the maximum density of mallards should not exceed 1 per 50 m^2 surface area of open water. In 2007, a new study was conducted to examine the effect of released mallards on the water nutrient status of 143 Danish lakes. It was concluded that the phosphorus level of lakes with released mallards was higher than that of lakes without released mallards (average = 0.52 mg P/L and 0.30 mg P/L, respectively; Noer et al., 2008). However, a direct correlation between the number of mallards and the concentration of phosphorus was not detected. This is not surprising, as various factors that may influence the concentrations of nutrients at a site. The same year, the Danish Environmental Protection Agency modified the regulations. According to the current regulations, the maximum density of mallards cannot exceed 1 per 150 m^2 surface area of open water. We can assume that conclusions on the number of mallards in the studies on eutrophication above also takes into account heterospecific attraction of other birds (see section 5). If such a process is likely to occur, it probably also occurred in the Danish lakes where mallards where released.

6.2 Hazard identification: effects of mallards on the nutrient status of lakes and rivers

An adult mallard weighs about 1200 g and eats 250 g of food per day (http://www.env.gov.bc.ca/wat/wq/reference/foodandwater.html). The daily nutrient loading per bird is about 12 g of carbon, 0.75 g of nitrogen, and 0.23 g of phosphorus (Manny et al., 1994). However, at least six other factors should be taken into account when assessing the potential cascading importance for the nutrient uptake and productivity of plants and microbes subsequent to a release of captive-bred mallards:

(1) The effect will vary according to the number of mallards, with higher numbers causing more eutrophication and a higher risk of reaching a tipping point. Heterospecific attraction may also cause other birds to appear at the site. The effect on nutrient status is depending on the total number of birds.

(2) The current nutrient status of the site may have an effect, including the type of nutrient that currently limits the primary productivity of the site. The dose-response relationship in ecological status to nutrient enrichment often follows a sigmoid trend (Carvhalo et al., 2013; Iversen and Sandøy, 2013), indicating that the response for ultraoligotrophic sites is initially slow, then accelerates as eutrophication commences, then slows again as the site becomes eutrophic, and does not commence when the site is hypereutrophic. The primary production of oligotrophic sites may still increase subsequent to nutrient enrichment, even if the ecological status remains stable. Overall, mesotrophic sites or sites at the threshold of an alternative stable state will be most vulnerable to the input of nutrients.

(3) The terrestrial vegetation density and the fraction of bogs also serve as major predictors of concentrations and ratios of nutrient in downstream lakes (Hessen et al., 2009), and influence the effects from mallards.

(4) The food chain of the ecosystem can influence the effects of increased nutrient input. For example, the influence from increased input of faeces from birds can be modulated by the presence of fish. Fish eat zooplankton, resulting in a higher algal biomass as the zooplankton graze on phytoplankton. The species of fish that are present is also important. Nutrient-poor lakes with fish that eat zooplankton, including the family Cyprinidae (carps, true minnows and their relatives), vendace (lagesild: *Coregonus albula*), smelt (krøkle: *Osmerus eperlanus*), or sticklebacks (stingsild: Gasterosteidae) will be more negatively impacted from input of nutrients than a site with only trout (ørret: *Salmo trutta*) or Arctic char (røye: *Salvelinus alpinus*) (Faafeng et al., 1990).

(5) Morphological characteristics of a lake site are important, such as lake size, depth, temperature stratification, water residence time, content of particles, light regimes, and local climates (Faafeng et al., 1990).

(6) Future climates (see Section 2.4) may influence the responsiveness to nutrients. Future climate is expected to include warmer temperatures and a higher frequency of extreme events, such as snow melt and thaw followed by frost in spring, or flooding and droughts. In Norway, there has been an increase in the length of the growing season in recent decades (Karlsson et al., 2009) and future years are expected to have even longer growing seasons with longer periods of above-freezing temperatures (Hanssen-Bauer et al., 2015). Expected climate change with increased run-off and warmer temperatures will reinforce the negative consequences of man-made eutrophication and make it more difficult to improve water quality in lakes and estuaries (Moss et al., 2011).

In sum, it is difficult to make general predictions on the effects on nutrient status and oxygen levels of a freshwater site due to the introduction of captive-reared mallards. There may be local gradients of eutrophication, even within a single catchment. A dense population of birds can be expected to have an impact, but the magnitude of impact will be site-specific and depend on the number of consecutive years of release at the same lake. The true impact can probably only be determined subsequent to the release of birds through monitoring of the water (see Section 3). The risk assessment below also takes into account heterospecific attraction of other birds.

Assessing the risk caused by eutrophication

Scenario: I (1 mallard per 300 m^2 open water surface area).

Consequence: Limited to **moderate** (**1** to **2**). **Limited** effects in most waters, apart from in small catchments that have a long water residence time and where the effects may be expected to be short term and reversible. Eutrophication should always be considered as an unwanted effect. However, the dose is likely too small to cause oxygen depletion or a change to an alternate stable state.

Probability: Low (1). The accumulated input of nutrients is likely to be too small to be able to influence the overall nutrient status of the water, even in the case of multiple consecutive years of mallard release in the same area.

Risk assessment conclusion: GREEN zone (low risk).

Scenario II (1 mallard per 150 m^2 open water surface area).

Consequence: Moderate (2). Short-term reversible eutrophication is likely to occur in all catchments. More severe eutrophication may occur in small catchments including shallow lakes with multiple consecutive years of mallard release in the same area. For such waters, eutrophication may cause a slow deterioration of the Water framework directive (WFD) ecological status of the water.

Probability: Medium (2) to **high (3).** The accumulated input of nutrients is likely to cause a measurable increase in the nutrient concentration of the water and influence the water biota. The probability is likely to increase with multiple years of mallard release in the same area and to decrease with fallowing.

Risk assessment conclusion: YELLOW zone (medium risk) in up to 6 years of release at the same lake followed by a fallowing period of similar length (6 years corresponds to one period in the WFD); YELLOW zone (medium risk) if 6-12 years of release at the same lake followed by a fallowing period of 6 years; RED zone (high risk) if more than 12 years of release at the same lake**.**

Scenario III (1 mallard per 50 m^2 open water surface area)

Consequence: Moderate (2) to **Serious (3).** Eutrophication is likely to occur. As a consequence, the profundal (bottom water) of lakes is likely to become anoxic, and a change to an alternate stable state may occur, especially in shallow lakes and over time. The WFD ecological status will likely not be acceptable (status below "good").

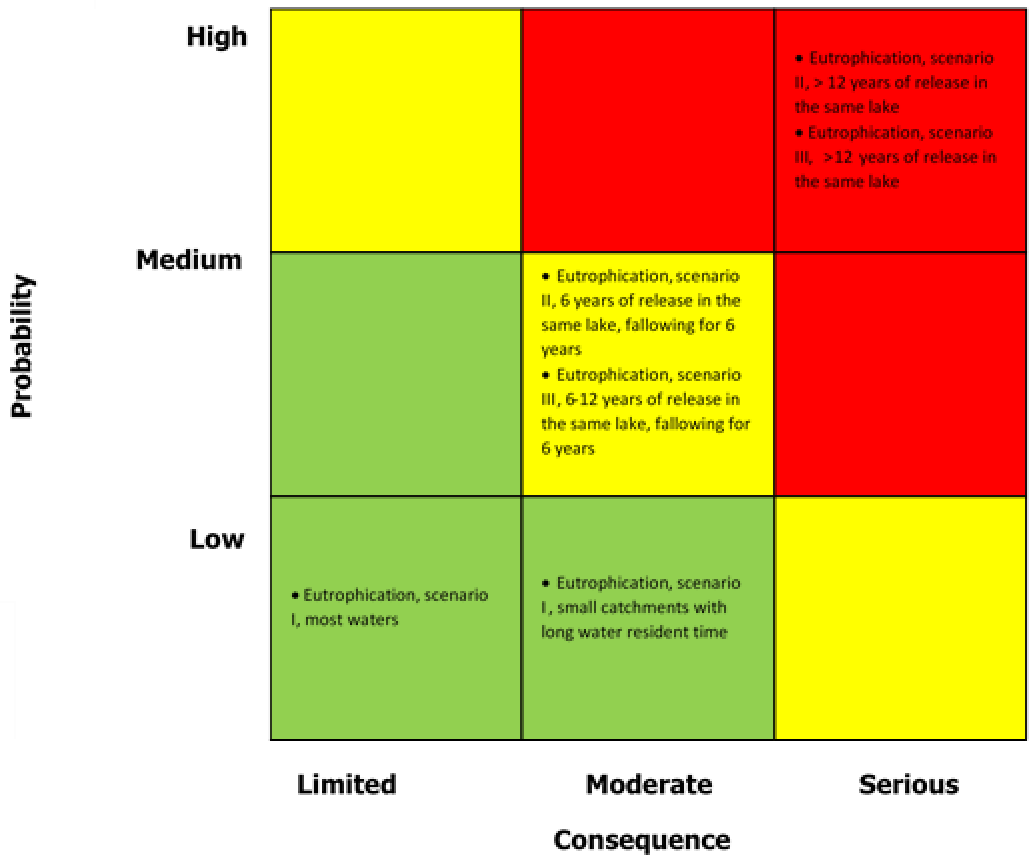
Probability: Medium (2) to **High (3).** The accumulated input of nutrients is likely to cause an increase in the nutrient concentrations of the water and influence the water biota, especially with multiple years of mallard release in the same area.

Risk assessment conclusion: YELLOW zone (medium risk) if up to 6 years of release at the same lake followed by a fallowing period of similar length; RED zone (high risk) if more than 6 years of release at the same lake.

Anticipated effects of future climate change

Nutrient conditions are often positively correlated with temperature in lakes and streams (Brodersen and Anderson, 2002; Velle et al., 2010). This suggests that freshwater ecosystems in Norway may experience an increase in the content of nutrients in the future that is linked to climate change. An increase in nutrients due to faeces from hand-reared mallards will exacerbate the climate-change related increase. The probability that eutrophication will occur, as described above, can therefore be expected to slowly increase over the next 50 years subsequent to the release of hand-reared mallards.

Risk summary eutrophication:



7 The risk of introducing new diseases when introducing and releasing mallards from Sweden

7.1 Animal health and zoonoses: hazard identification and descriptions

Imported ducks may be infected by several diseases that can be of relevance from animal health and human health perspectives. Wild ducks may be infected by several infectious agents; e.g., avian coronavirus, avian paramyxovirus and highly pathogenic avian influenza (HPAI) and low pathogenic avian influenza (LPAI) strains (França et al., 2014; Wille et al., 2015; Wille et al., 2016). In this assessment only diseases that are currently notifiable according to Norwegian legislation are considered.

7.1.1 Avian influenza:

Influenza A is caused by specific viruses that are members of the Orthomyxoviridae family and in the genus influenza virus A. There are three influenza genera – A, B, and C – but only influenza A viruses are known to infect birds. Infections in birds can give rise to a wide variety of clinical signs that may vary according to host, strain of virus, the host's immune status, the presence of any secondary exacerbating organisms, and environmental conditions. Diagnosis is done by isolation of the virus or by detection and characterisation of fragments of its genome (OIE, 2015a). LPAI strains are circulating and wild mallards are often infected by several; Wille et al. (2015) found 27 HA/NA subtype combinations of LPAI in wild mallards captured in Sweden, and co-infections with other low pathogen viruses were also demonstrated.

The HPAI strains are of considerable concern and the circulating strains vary from year to year. OIE (World Organisation for Animal Health) provide regular updates (OIE, 2016). In 2017, HPAI strain H5N8 has spread in Europe, including Sweden, in wild and domestic birds, and H5, H5N5, and H5N6 are also present in Europe. Several other strains (H5N1, H5N2 and H7N9) occur in many regions globally, but have currently not been isolated from birds in Europe (OIE, 2017a).

According to Norwegian legislation, HPAI is a Group A disease, and outbreaks in poultry should be contained and managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

During the last year, there have been several outbreaks of HPAI in Sweden. In 2016, there was an outbreak of HPAI H5 in poultry in Sweden (OIE, 2016). The most recent report from the Norwegian Veterinary Institute (March 30, 2017) (Siri Sjurseth, personal communication) reports 31 outbreaks of HPAI H5N8 in wild birds in Sweden since November 2016. In the same period, no cases have been reported in Norway, but only 32 waterfowl have been tested (NVI, 2017). HPAI has never been demonstrated in Norway to date, and around 500 ducks and gulls are tested annually in Norway.

Some strains of Avian influenza (H5N1, H7N3, H9N2) are considered important zoonoses (Van Reeth, 2007; Yuen et al., 1998).

7.1.2 Newcastle disease:

Newcastle disease (ND) is caused by virulent strains of avian paramyxovirus type 1 (APMV-1). There are ten serotypes of avian paramyxoviruses, designated APMV-1 to APMV-10. ND virus (NDV) has been shown to be able to infect over 200 species of birds, but the severity of disease produced varies with both host and strain of virus. Even APMV-1 strains of low virulence may induce severe respiratory disease when exacerbated by the presence of other organisms or by adverse environmental conditions (OIE, 2012).

One of the most characteristic properties of different strains of NDV is their wide variation in pathogenicity for chickens. Strains of NDV have been grouped into five pathotypes on the basis of the clinical signs in infected chickens (Alexander and Senne, 2008). These are:
1. Viscerotropic velogenic: a highly pathogenic form in which haemorrhagic intestinal lesions frequently occur;
2. Neurotropic velogenic: a form that presents with high mortality, usually following respiratory and nervous signs;
3. Mesogenic: a form that presents with respiratory signs, occasional nervous signs, but low mortality;
4. Lentogenic or respiratory: a form that presents with mild or subclinical respiratory signs;
5. Asymptomatic: a form that usually consists of a subclinical enteric infection.

According to Norwegian legislation, ND is a Group A disease and outbreaks in poultry should be contained and managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

In the last decade there have been several outbreaks of ND in Sweden. In 2011, 2014, and 2016 there have been outbreaks in poultry in Sweden that are now resolved (OIE, 2017b). No outbreaks of ND have been reported in Norway since 1997.

7.1.3 Avian chlamydiosis:

Avian chlamydiosis (AC) is caused by the bacterial species *Chlamydophila psittaci*. AC in humans and all birds was originally called psittacosis, but later the term ornithosis was introduced to identify the disease contracted from or occurring in domestic and wildfowl, while the name of the disease contracted from or occurring in psittacine (parrot family) birds remained psittacosis. These disease is are similar named when contracted by humans.

Depending on the virulence of the chlamydial strain and the avian host defence, chlamydiosis cause pericarditis, conjunctivitis, sinusitis, airsacculitis, pneumonia, lateral nasal adenitis, peritonitis, hepatitis, and splenitis. Generalised infections result in fever, anorexia, lethargy, diarrhoea, and occasionally shock and death. Special laboratory handling (biosafety level 3) is recommended because avian chlamydial strains are zoonotic and can cause serious illness and possibly death in humans. While the disease in psittacine birds is best known, infections in ducks and turkeys is of particular concern as transmission to humans is common during handling and slaughter of the birds (OIE, 2012a).

According to Norwegian legislation, avian chlamydiosis is a Group B disease and outbreaks in poultry must be contained; occurrence in poultry will usually be managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

Avian chlamydiosis in poultry or wild birds was not reported from either Sweden or Norway in 2015, but is nevertheless known to occur sporadically in imported psittacine birds in captivity every year (https://www.mattilsynet.no/dyr_og_dyrehold/dyrehelse/dyresykdommer/papegoyesjuke, https://www.stuefugl.no/landsutstilling-2016/).

7.1.4 Salmonellosis

Salmonellosis is an infectious disease of humans and animals caused by bacteria of the genus *Salmonella* (OIE, 2016). *Salmonella* spp. are aetiological agents of diarrhoeal and systemic infections. Infections are often subclinical, especially in pigs and poultry, and such animals may be important regarding the spread of infection between flocks and herds, and as sources of food contamination and human infection. Large numbers of bacteria may be shed in the faeces of clinical cases and carrier animals resulting in contamination of the environment. Infection in food animals often leads to contamination of meat, eggs, milk, and cheese. Salmonellosis is one of the most common and economically important foodborne zoonotic diseases in humans. The disease has been recognised in all countries and non-typhoidal *Salmonella* appears to be most prevalent in areas of intensive animal husbandry, especially pigs, intensively reared calves, and poultry.

Salmonellosis can affect all species of domestic animals, and young animals and pregnant and lactating animals are the most susceptible. Enteric disease is the most common clinical manifestation, but a wide range of clinical signs, including acute septicaemia, abortion, arthritis, and respiratory disease, may occur.

According to Norwegian legislation, salmonellosis is a Group B disease and outbreaks in poultry should usually be contained and managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

A report on salmonellosis in wild birds and poultry in Sweden from 2015 reported 1 wild bird and 8 poultry flocks as being positive (Jordbruksverket, 2015).

In Norway, 3 isolates have been reported from mallards between 1969-2000 (Refsum et al., 2002) and in 2015, one poultry flock was reported as positive (Veterinærinstituttet, 2015). Several cases occur in wild birds in Norway each year, mostly in passerines (Kristian Hoel, personal communication).

These data suggest that *Salmonella* infections occur at a very low frequency, both in Norway and Sweden.

7.1.5 Avian tuberculosis

Avian tuberculosis, or avian mycobacteriosis, is an important disease that affects companion, captive exotic, wild, and domestic birds and mammals. The disease is most often caused by *Mycobacterium avium subsp. avium*. However, more than ten other mycobacterial species have been reported to infect birds. The most significant cause of poultry disease is *M. a. avium* (OIE, 2014).

Diagnosis of avian tuberculosis in birds depends on the demonstration of the mycobacterial species, the detection of a cellular or humoral immune response, or by polymerase chain reaction (PCR) (OIE, 2014).

According to Norwegian legislation, avian tuberculosis is a Group B disease and outbreaks in poultry should be contained; occurrences in poultry should usually be managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

Avian tuberculosis occurs sporadically, but was not reported in either Sweden or Norway in 2015.

7.1.6 Duck virus enteritis:

Duck virus enteritis (DVE), or duck plague, is an acute contagious infection of ducks, geese and swans (order *Anseriformes*) caused by an alpha-herpesvirus. Diagnosis is based on a combination of clinical signs, gross pathology, and histopathology supported by identification of the virus by either isolation or PCR (OIE, 2012b).

According to Norwegian legislation, DVE is a Group B disease and outbreaks in poultry should be contained; occurrences in poultry should usually be managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

A report on DVE in birds and poultry in Sweden in 2015 reported 1 case in backyard poultry, with no information about its origin (Jordbruksverket 2015). DVE was not reported in Norway in 2015, and there are no data available about the current situation in Norway.

7.1.7 Duck virus hepatitis:

Hepatitis in ducks can be caused by at least three different viruses. The more common and internationally widespread virus is *Avihepatovirus A*, formerly known as duck hepatitis A virus (DHAV) type I, a member of the Picornaviridae in the genus *Avihepatovirus*. This virus causes a highly lethal, acute, contagious infection in ducklings under 6 weeks of age and, frequently, under 3 weeks of age. It does not occur in older birds. This infection is often referred to simply as duck virus hepatitis (OIE, 2010).

According to Norwegian legislation, duck virus hepatitis is a Group B disease and outbreaks in poultry will be contained; occurrences in poultry will usually be managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

Duck virus hepatitis was not reported in either Sweden or Norway in 2015.

7.1.8 Fowl cholera

Fowl cholera (avian pasteurellosis) is a commonly occurring disease that can affect all types of birds and is distributed worldwide. Fowl cholera outbreaks often manifest as acute fatal septicaemia, primarily in adult birds. Chronic and asymptomatic infections also occur. Diagnosis depends on isolation and identification of the causative bacterial species, *Pasteurella multocida*. Presumptive diagnosis may be based on typical signs and lesions and/or on the microscopic demonstration of myriad bacteria in blood smears, or impression smears of tissues such as liver or spleen. Mild or chronic forms of the disease also occur where the disease is endemic, with localised infection primarily of the respiratory and skeletal systems (OIE, 2015).

According to Norwegian legislation, fowl cholera is a Group B disease and outbreaks in poultry will be contained; occurrences in poultry will usually be managed by stamping out by the NFSA. Outbreaks in wild waterfowl are more difficult to contain and control.

Fowl cholera occurs sporadically, but was not reported in either Sweden or Norway in 2015.

7.2 Risk assessment concerning notifiable diseases

The following risk assessment consider the current level of import (i.e. 10,000 mallards) and the current climate conditions. However, similar to the environmental risk assessments, the risks of importing diseases increase with the number of imported and released birds.

7.2.1 Risk of import of highly pathogenic avian influenza H5 and H5N8 or Newcastle disease (Group A – animal diseases):

HPAI and ND are defined as a Group A diseases in the Norwegian legislation, and the consequences of outbreaks of these diseases are considered serious by the international (OIE, EU) and national (NFSA) authorities.

As neither HPAI nor ND are usually reported in Swedish game-breeding farms and the EU legislation is followed during the import of farmed mallards, the probability of importing a positive individual is considered low.

Risk assessment

Consequence: Imported ducks from Sweden are infected with HPAI or ND and may transmit the diseases to wild birds and poultry.

Scenario (10,000 mallards imported and released annually).

> **Consequence**: **Serious (3)** health implications for imported ducks, other wildlife, and poultry.
>
> **Probability**: **Low (1),** given the present experience with such imports.
>
> **Risk assessment conclusion**: **3, YELLOW** zone **(medium risk)**.

7.2.2 Risk of import of salmonellosis or avian chlamydiosis (Group B – animal diseases, zoonoses):

Salmonellosis and avian chlamydiosis are zoonoses, and are defined as Group B diseases in the Norwegian legislation. The diseases are not readily transmitted and the consequences of outbreaks are considered moderate by the international (OIE, EU) authorities and the national health authorities and the NFSA.

As these diseases are not usually reported in Swedish game-breeding farms and the EU legislation is followed during the import of farmed mallards, the probability of importing a positive individual is considered low. The probability of importing an infected bird increases with the number of ducks imported/number of import batches.

Risk assessment

Consequence: Imported ducks are infected with the zoonoses avian chlamydiosis or salmonellosis and may transmit the diseases to people, wild birds, and poultry.

Scenario (10,000 mallards imported and released annually).

Consequence: **Moderate (2)** implications for imported ducks, hunters, consumers, other wildlife, and poultry.

Probability: **Low (1),** given the present experience with such imports

Risk assessment conclusion: **2, GREEN** zone **(low risk)**.

7.2.3 Risk of import of avian tuberculosis, duck virus enteritis, duck virus hepatitis or fowl cholera (Group B - animal diseases):

Avian tuberculosis, duck virus enteritis, duck virus hepatitis and fowl cholera are defined as Group B diseases in the Norwegian legislation. The consequence of outbreaks of these diseases is considered moderate by the NFSA.

As these diseases are not usually reported in Swedish game-breeding farms and the EU legislation is followed during the import of farmed mallards, the probability of importing a positive individual is considered low.

Risk assessment

Scenario (10,000 mallards imported and released annually).

Consequence: Imported ducks are infected with avian tuberculosis, duck virus enteritis, duck virus hepatitis, or fowl cholera and may transmit the diseases to wild birds and poultry.

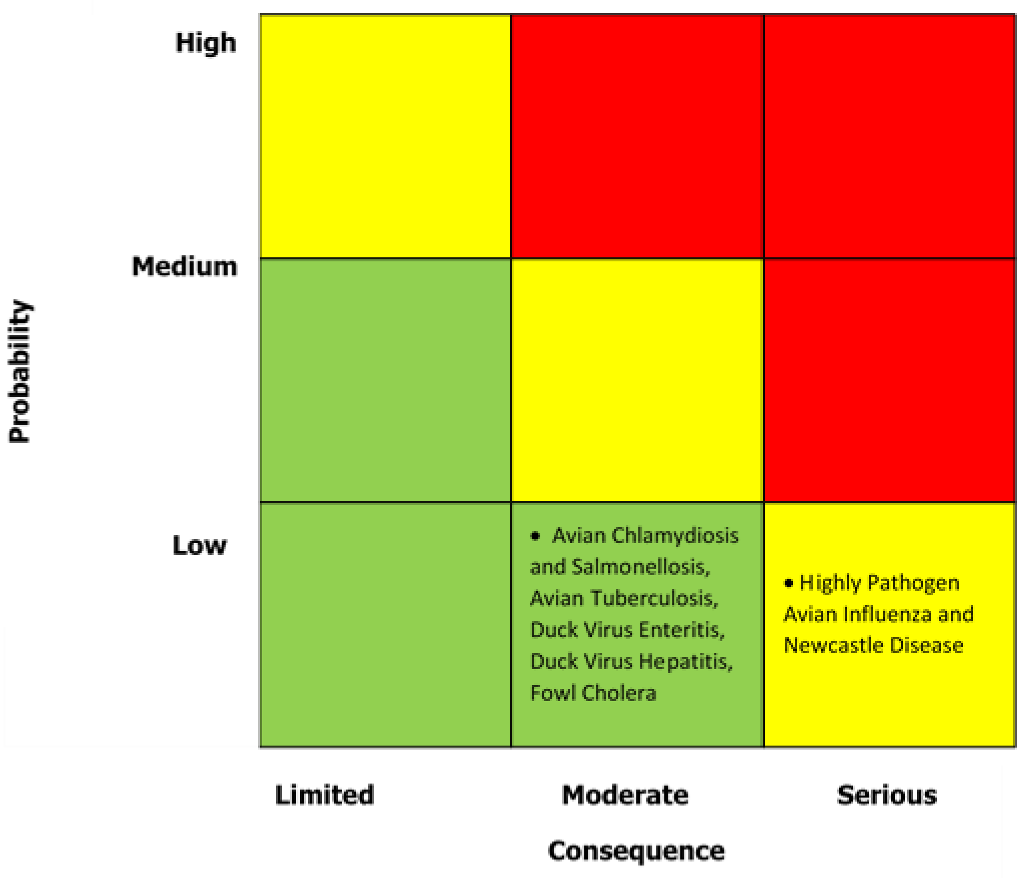
Scenario (10,000 mallards imported and released annually).

Consequence: **Moderate (2)** implications for imported ducks, other wildlife, and poultry.

Probability: **Low (1),** given the present experience with such imports

Risk assessment conclusion: **2, GREEN** zone **(low risk)**.

Risk summary: diseases



8 The risk of reduced animal welfare as a result of current routines for releasing farmed mallards in the wild

8.1 Hazard identification and description

The animal welfare of wild mallards or farmed mallards after release has not been studied extensively, and there are very few scientific papers addressing this issue. We have therefore selected two welfare indicators that might be of value for assessing the risk of reduced welfare after release of farmed mallards: mortality rate and wounding or crippling during hunting.

8.1.1 Mortality

The mortality rate for both wild and farmed mallards is high. In addition to hunting, predation, starvation, freezing, malnutrition, and diseases are major causes of mortality. Death is a natural end to every life, but if the mortality rate is increased or if there is associated suffering due to human management, mortality rate can be a relevant indicator of animal welfare to consider for the farmed and released mallards.

In order to increase survival and to prepare ducklings for life in the wild, a landowner can introduce several preventive or protective measures prior to release. Predation is a major hazard to released ducklings and therefore the anti-predator adaption, innate or learned, is of major importance. The innate responses of mallard ducklings without an accompanying adult female towards aerial, aquatic, and terrestrial predators were studied by Dessborn et al. (2012), and the ducklings were found to have an innate capacity to develop anti-predator behaviour. However, the study also showed that there is a general trade-off between foraging needs and predator avoidance. In order to minimise predation, extensive predator control can be performed in areas where farmed mallards are to be released. Local populations of mink and foxes in particular, are legal game according to the Wildlife Act and can be hunted during the hunting season to reduce predation pressure. In addition, both birds of prey and pike may harvest both wild and released ducklings (Fredrik Aalerud, pers. Comm., Appendix I), but measures are illegal against birds of prey and not implemented against pike.

Ducklings are sensitive to weather extremes. While their fuzzy down feathers are an excellent source of natural insulation in dry weather, they are of little value when wet. Ducklings also lack the additional thermal support of adult contour feathers. Cold, rainy, and windy conditions can lead to death from exposure (hypothermia) and may either reduce food availability or prevent ducklings from exploiting food resources. Experiences in Norway show that it is important to release the ducklings in a period of warm and dry weather (Fredrik Aalerud, pers. comm. Appendix I).

Farmed mallards released in nature are fed until they are able to find food for themselves. There are however various practices regarding feeding, and some of the mallards are fed throughout the year (Fredrik Aalerud/Carl Martin Nygren pers. Comm, Appendix I and II).

Ducklings released in Norway are bought from certified game-breeding holdings and are considered free from particular infectious diseases at purchase. However, control of diseases is not performed after release.

Several studies have demonstrated that farmed released mallards have a lower survival rate than native individuals (Champagnon et al., 2016b; Dunn et al., 1995; Söderquist et al., 2013). This might be due to the fact that farmed mallards carry a "burden of captivity", a potential genetic maladaptation, resulting in bills that are less efficient for sieving, smaller gizzards, and a higher dependency on anthropogenic food (Champagnon et al., 2012). The possible consequences of the burden of captivity are described in Section 4.1.2 of this report. However, probably the most important factors affecting animal welfare of released farmed mallards are: decreased ability to exploit natural food resources, reduced body condition, less efficient immune responses, and an inability to show adequate anti-predator behaviour (Champagnon et al., 2012).

Studies in Sweden and Finland (Söderquist et al., 2013) have shown that wild mallards lived more than twice as long as farmed and released individuals (1 year 7 months versus 9 months in Swedish birds and 1 year 1 month versus 4 months in Finland). Compared with wild mallards, a smaller proportion of farmed birds survived long enough to have a chance of entering the wild breeding population. Less than 25 % of the Swedish and less than 10 % of the Finnish farmed mallards lived for a year or longer, indicating a mortality of Nordic released populations of 75-90 % within one year from release. According to the Norwegian importers, 25-50 % of the released birds are harvested during the hunting season and the rest is missing. There are no attempts to control this loss. There is no observed increase in the mallard populations in the habitats where they are released in Norway (Fredrik Aalerud, pers. comm. Appendix I), even after the release of a large number of birds, and the mortality rate in Norway could be at least as high as in Sweden and maybe as high as in Finland.

8.1.2 Wounding and crippling during hunting

The Norwegian Animal Welfare Act states that hunting, catching and fishing must be exercised in accordance with appropriate animal welfare practices. Nevertheless, wounding (animals are hit, but not killed and are not felled) and crippling (animals are hit, wounded and felled, but are not killed and not retrieved) is a hazard for all hunted game, including farmed and released mallards (Noer et al., 2007).

A hit is defined as when one or more shot penetrates the bird or its skin. The animal dies when a sufficient number of shots penetrate the lungs, injure the main vessels, or destroy the brain or upper spinal cord. A crippling shot is a case where the shot penetrates the skin without killing the bird immediately or within few minutes. Andestad (2015) reports American data that indicate that between 0.9 and 0.73 birds are wounded or crippled per harvested bird. Equivalent Danish numbers are 0.49 birds being wounded or crippled per harvested bird (Noer et al., 2006). These numbers suggest that this is a global problem. Danish x-ray studies show that a large proportion of the yearlings of mallard population (15 %) carry shots in their bodies (long-term effect).

This hazard is considered an animal welfare risk factor for farmed and released mallards. However, since the only purpose of releasing these ducks is to shoot them, it is relevant to compare the risk of damage shooting or other suffering with the welfare risks present when farmed ducks are handled and stunned at slaughter.

The main cause of wounding and crippling during hunting is the hunter's lack of shooting skills (Andestad, 2015). Hunting for released farmed mallards is organized to ensure that they are harvested efficiently. The hunters are posted on one side of a lake and the ducks are flushed out by a helper with a dog or by "beaters". The ducks are shot with a shotgun at a maximum range of 30-35 meters. During an organized hunt, ducks that have been shot, both birds that have been killed and those that have been crippled should be retrieved by dogs. Crippled ducks will obviously experience pain and fear when hit and when carried by a dog, but the time of suffering is shortened as they are euthanized immediately after. The following day the lake is searched for dead or crippled individuals that were not retrieved on the day of the hunt.

From an animal welfare perspective, the most important aspect is that when a hunter pulls the trigger, they are confident that it is a good shot and that this will be a lethal hit. Various types of weapons and ammunition are legal for hunting in Norway; it is important that a hunter is knowledgeable about their weapon, has sufficient shooting skills to ensure a good shot, and knows how to address problems that might arise during the hunt, including how to find and retrieve the prey, particularly if they are crippled or wounded. Crippling and wounding are serious outcomes of any hunt, including the hunt for wild ducks, and occur frequently (Lier-Hansen and Wegge, 1983).

An article addressing this issue (Noer et. al., 2007) reported that in hunts for Svalbard pink-footed geese (*Anser brachyrhynchus*) prior to 1997, for every bird killed another one was wounded. An action plan was introduced in which the recommended shooting distance was reduced to a maximum of 25 m, and follow up studies indicated that wounding was reduced by around 60 %. Two further reports, also from Denmark "Report no 569 from DMU http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR569.PDF and "Damage shooting of game and possible measurements" (Andestad, 2015 http://www.jegeropplæring.no/hvor-mange-skudd-gar-det-med-for-a-felle-ei-rype/) provide thorough reviews of available knowledge. The issue is also thoroughly addressed in

Jegerprøveboka (Lier-Hansen and Wegge, 1983 and later) and in the brochure "Skitt jakt"(http://www.miljodirektoratet.no/old/dirnat/attachment/1181/skittjakt08.pdf).

8.2 Risk assessment concerning animal welfare

The following risk assessment consider the current level of import (i.e. 10,000 mallards) and the current climate conditions. However, similar to the environmental risk assessments, the risks of importing diseases increase with the number of imported and released birds.

8.2.1 Risk of increased mortality rates:

A mortality rate provides an indication of animal welfare, and is often the only available data as it is relatively simple to record. Nevertheless, data on survival of farmed mallard ducks after release in Norway are insufficient to support a thorough welfare risk assessment. The data available (Dunn et al., 1995; Söderquist et al., 2013; Champagnon et al., 2016) suggest that the expected mortality rate of farmed mallards after release during the first year of release will exceed 75 % and this is much higher than for wild birds.

Risk assessment

Consequence: Imported and farmed ducks have a higher mortality rate after release than wild ducks.

Scenario (10,000 mallards imported and released annually).

> **Consequence**: **Serious (3)** implications for the released ducks.
>
> **Probability**: **High (3),** given the frequencies in the literature.
>
> **Risk assessment conclusion**: RED zone (high risk).

8.2.2 Risk of wounding and crippling during hunting

The consequences of wounding or crippling during hunting may vary from slight pain that causes temporary symptoms to fractures and serious inflammations that cause long-lasting disease and suffering. Wounding and crippling may have serious welfare consequences for the animal.

The probability of wounding or crippling of the released ducks is estimated to be similar to the probability of wounding and crippling wild ducks. From the available literature (Andestad, 2015; Noer et al., 2006, 2007) this is estimated to be in the range 0.5 - 1 wounded mallard per harvested bird. This is considered a high prevalence, and the probability of suffering is estimated to be high.

Mortality of the mallards is the intended effect of a shot fired during hunting.

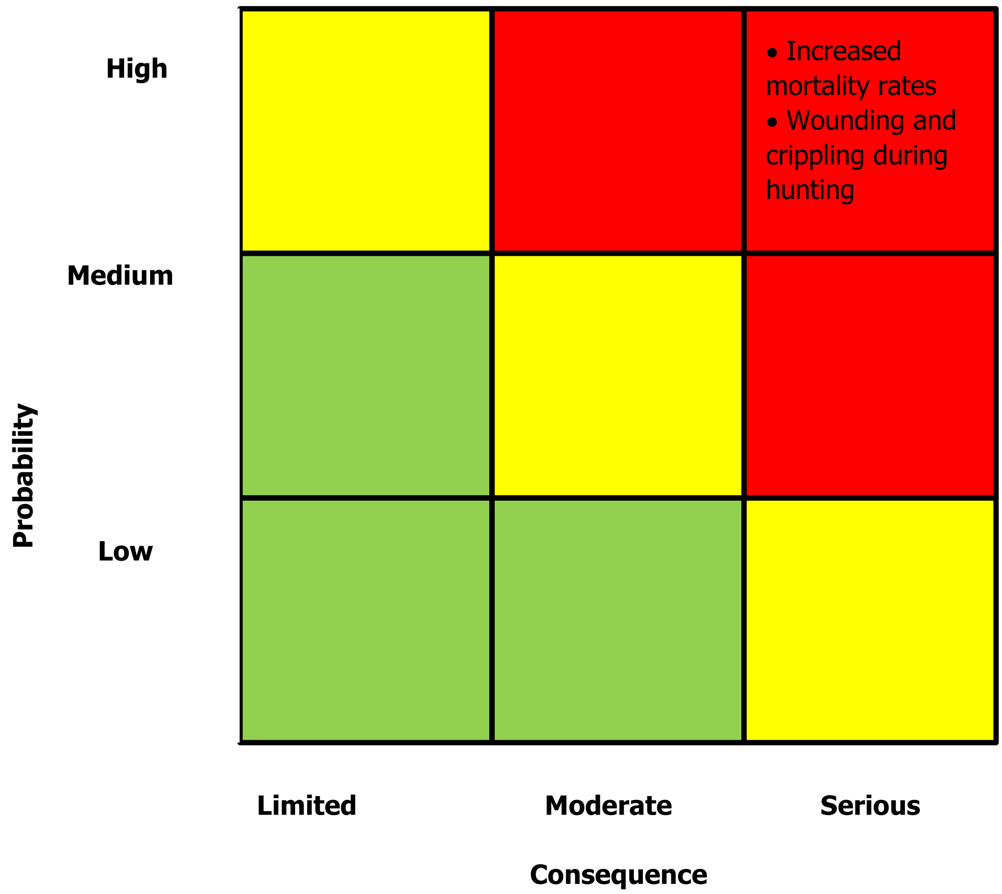
Risk assessment

Consequence: Released farmed ducks suffer from wounding and crippling due to poor shooting.

Scenario (10,000 mallards imported and released annually).

> **Consequence**: **Serious (3)** implications for the ducks that are wounded and crippled.
>
> **Probability**: **High (3),** given the frequencies in the literature.
>
> **Risk assessment conclusion**: RED zone (high risk).

Risk summary: animal welfare



9 Uncertainties

The number of mallards that will be released in Norway in the coming years is highly uncertain. As the consequences and probabilities of some of the different risks are dependent on the number of birds released, each part of the assessment has considered density scenarios.

Biodiversity

The uncertainties surrounding the population estimates of wild mallards and other dabbling ducks in Norway are high as there is no surveillance of the breeding populations of ducks in Norway. The risk of short-term and long-term effects of mallard release on biodiversity depend on the sizes of the native populations, at local or national levels.

It is uncertain whether the existing estimates of survival rates of released hand-reared mallards in different countries (Table 3-1-1) can be extrapolated to Norwegian conditions. The risk of effects on biodiversity depends on both short-term and long-term survival of the released mallards.

Released mallards have been documented to produce fertile offspring, both with wild conspecifics and with other dabbling ducks. However, there is no estimate of their breeding rate, and thus there is uncertainty in the assessments of negative genetic effects.

Admixture of genotypes from farmed ducks to wild ducks has been documented in several European countries, but was not detected in a small number of Norwegian mallards. The degree of intraspecific hybridization in Norway is thus uncertain.

Several behavioural and morphological changes that are likely to impact fitness have been documented in farmed mallards. However, their genetic component and actual effect on survival and reproductive success have not been quantified, and their possible risk of having a negative effect on biodiversity is thus uncertain.

There is a range of uncertainties regarding the ecological effects of releasing hand-reared mallards into an ecosystem. Figure 5.1-1 depicts a simplified food web, with interactions of wild mallards with other organisms. However, quantitative data are missing and the composition of the ecosystems where mallards are released will vary according to location.

Studies on density dependency of duck populations have provided different outcomes. However, as density-dependence patterns vary both temporally and spatially, it is difficult to determine some general reference values that are relevant to the Norwegian situation.

There is considerable uncertainty in regard to competition between farmed mallards and wild mallards and/or other animal species. The uncertainties are particularly related to the duration of artificial feeding of the hand-reared ducklings and on the specific communities of fish feeding on invertebrates, both of which will determine the characteristics of the competition.

There is particularly high uncertainty around assessing the risk for negative effects on biodiversity from a 50-year perspective. This is due to variations in the number of individuals released, their survival in each particular case, and the uncertainty associated with future climate projections.

Nutrient status

We estimate that the confidence in the assessment of potential eutrophication caused by hand-reared mallards is 80 % for scenario I, 50 % for scenario II, and 80 % for the scenario III. There is a high level of uncertainty because only two studies were identified that could act as references for comparison, and because site-specific factors must be considered when predicting eutrophication. Information from the reference studies increased the confidence of the low-density and high-density scenarios. Uncertainties arise because: (1) The effect will vary according to the density of mallards. (2) The current nutrient status of a site may have an impact. (3) Eutrophication depends on the terrestrial vegetation density and the proportion of bogs. (4) The food chain of the ecosystem can influence the effects of increased nutrient input. (5) Site-specific morphological characteristics of a lake and climate are important. (6) Future climates may influence the responsiveness to nutrients. In sum, the actual impact can perhaps only be assessed by monitoring of the water subsequent to the release of birds.

Climate projections

Several factors create uncertainties in climate projections based on different CO_2-increase scenarios. First, there is a lack of knowledge about the sensitivity of the climate system on Earth. Second, the general circulation models used to model future climates have limitations (ICPP, 2013). Projections that follow scenarios with a low CO_2 emission, such as RCP4.5, are in general more certain than projections that follow scenarios with a high CO_2 emission, such as RCP8.5. Also, the upper boundary of the climate projections is beset with larger uncertainties than the lower boundary. In attempting to cancel out uncertainties in the general circulation models, many researchers have chosen to base climate projections on an ensemble of models. VKM has adopted projections made by the Norwegian Centre for Climate Services (Norsk klimaservicesenter) that are based on an ensemble of ten different climate models (Hanssen-Bauer et al., 2015).

The projected annual mean temperature for Norway in 2067 under scenario RCP8.5 is 3.3 °C with an upper boundary (90th percentile) of 4.6 °C and a lower boundary (10th percentile) of 2.8 °C (Hanssen-Bauer et al., 2015). Under RCP2.5, the projected temperature is 2.2 °C with an upper boundary (90th percentile) of 3.2 °C and a lower boundary (10th percentile) of 1.6 °C. The uncertainties of the modelled winter temperatures and summer temperatures are similar to the uncertainties for annual temperature.

Animal health and welfare

There are considerable data gaps, especially regarding the mortality rate of released mallards in Norway and the causes of mortality. Observations from people involved in the release of mallards for hunting purposes in Norway are that mallard populations seem to be stable and not significantly increasing from year to year. Although it is known that 2-3 individuals die during transport (out of 600-4000), and that 25-50 % of released birds are shot during the hunting season, the fate of the other birds is highly uncertain; possible outcomes include death from factors such as predation or starvation before the hunting season, death later in the year, or moving to another location.

10 Conclusions (with answers to the terms of reference)

10.1 Interbreeding between released and wild mallards and the potential for genetic impact on native populations.

The probability of hybridization between released farmed mallards and wild mallards or other dabbling ducks will be related to the number of released birds. The consequence of interspecific hybridization will depend on the status of the resident population. The effects of on-going hybridization and introgression will accumulate over generations. Due to a projected climate changes, the population densities of mallards and other dabbling ducks in Norway are expected to increase in the next 50 years.

Interbreeding between farmed mallards and other duck species

Common duck species: For the common dabbling duck species teal (krikkand) and wigeon (brunnakke), the risk of negative effects from interbreeding and hybridization with released farmed mallards is assessed as being **Low** for all scenarios. From a 50-year perspective and given Scenario III (release of 100,000 mallards annually), the risk of negative effects from teal and wigeon crossbreeding with released farmed mallards is assessed as being **Medium risk**.

Red Listed duck species: For the less abundant and redlisted species gadwall (snadderand), garganey (knekkand), pintail (stjertand), and shoveller (skjeand), the risk of negative effects from interbreeding and hybridization with released farmed mallards is considered as **Medium risk** for Scenario III. For a 50-year perspective, Scenario I (release of 10,000 mallards annually) results in **Medium Risk**, whereas for Scenario II (release of 100,000 mallards annually), the risk is assessed as **High**.

Conclusion: Red Listed dabbling ducks will be particularly vulnerable to negative effects from interbreeding with mallards. Information about presence of gadwall (snadderand), garganey (knekkand), pintail (stjertand), and shoveller (skjeand) in specific areas (e.g., obtained from NBIC distribution maps) could be consulted prior to release of farmed mallards in order to reduce the risk of hybridization.

Interbreeding between native and hand-reared mallards

For Scenarios I and II, the probability of negative effects from interbreeding between released farmed mallards and native mallards is considered as **Low Risk.** Increasing the number of released individuals ten times compared with today's level (Scenario III) will increase the risk to **Medium.** For a 50-year perspective, with farmed mallards released over consecutive generations, Scenario I (release of 10,000 farmed mallards annually) is assessed as being **Medium Risk**. Scenario III (release of 100,000 farmed mallards annually) increases the risk from **Medium** to **High Risk**.

Conclusion: If a large proportion of the Norwegian mallard population is non-migratory, extensive interbreeding with farmed mallards could have considerable genetic consequences. Genetic monitoring of both released and resident populations and collection of recovery data for ringed birds would provide more information about survival and migratory patterns of released birds.

10.2 Ecological interactions between released and resident mallards

Competition for resources with native mallards
A rapid increase in population density may result in density-dependent effects. The intensity of those effects will depend upon the number of individuals released compared to the size of the local population. The importance of the various impacts will differ through the various phases, from release and until next year's breeding season.

In the first few weeks after release, there is a risk that native mallards may have restricted access to food, due to the competition with a large number of released mallards. Considering a Scenario II (release 50-150% of local population), the risk of increased competition is considered as **Medium Risk.** Increasing the number of released mallards to more than 150% of the local population, Scenario III, will increase the risk to **Medium** to **High.**

The effect of competition for food resources and nesting areas after the hunting season and during the first winter is assessed as **Low Risk** for all scenarios due to the anticipated low survival of hand-reared mallards.

From a 50-year perspective, the effects will accumulate, assuming a continuous release of individuals and the expected effects of climate change, which will probably contribute to an increased survival of released farmed mallards.

10.3 The impact of duck release on local fauna, including the potential for increased abundance of small and medium-sized predators

Potential for increased abundance of small and medium-sized predators
Several predators are considered to pose a threat to mallards, and an increase in the mallard population may result in an increase in predator numbers in the area of release.

The risk of an increase in the population of pike in the water body where mallards are released is considered **Low**, both Scenario I and II. For the Scenario III (release > 150% of local population), the risk is assessed as **Medium**, due to an increased likelihood of the event occurring.

A local increase in fox and/or mink populations in the area of release and in the surroundings is considered as a risk for all scenarios, with the risk increasing from **Medium** (Scenario I) to **High** (Scenario II and III).

A local increase in avian predator populations, such as various raptors, is considered to be a risk when the number of birds released exceeds 50% of the local populations, Scenario II and III. The risks are assessed as being **Medium Risk** and **High Risk,** respectively.

There is also the possibility of an increase in predators populations caused by heterospecific attraction (i.e., other duck species being attracted to the area after the release and could further contribute to increasing the predator numbers). The risk of such an event is assessed as **Medium** (for Scenario I and II) and **High** (for Scenario III).

Conclusions: The distribution of mammalian predators, such as mink and fox, and avian predators should be taken into account on the areas where releases are planned; a high prevalence of these predators is to be expected. However, it should be noted that there is high uncertainty attached to this assessment, particularly for avian predators. First, this is because of the different species that can potentially predate on ducklings, and, second, because the distribution of these species and the ranges that they are capable of covering might be difficult to determine.

Competition for resources and habitat with other species
Fish feeding on invertebrates and other species of ducks and geese may be affected by an increase in the local mallard population. However, because the released farmed mallards are fed for a period between a few weeks and several months after release, the consequence is not considered to be severe. Thus, for Scenario I and II, the risk is assessed as being **Low**. However, raising the number of individuals released will increase the probability of such competition occurring, and thus the risk for the Scenario III is assessed as **Medium**.

Feeding (predation) by ducklings on lower levels of the food web
Ducklings feed primarily on newly hatched invertebrates, and although their feeding habits change as they grow older, invertebrates and plants comprise a major part of their diet. The risk of the population of invertebrates and macrophytes decreasing due to ducklings feeding on them is considered **Low** for the Scenario I and II. The risk increases with the number of ducks released, and the risk assessed as **Medium** for Scenario III.

10.4 Mallard release and water eutrophication, including potential for downstream effects on local ecosystems.

The risk of water eutrophication caused by the release of farmed mallards is considered to be **Low** for Scenario I (1 mallard per 300 m^2 open water surface area*).*

The risk is considered **Low** for the Scenario II (1 mallard per 150 m^2 open water surface area)*,* for a period of up to 6 years of annual release, followed by 6 years of fallowing of the area. Given a consecutive release for 6-12 years, followed by a 6-year fallowing period, the risk is assessed as being **Medium**, increasing to **High** risk if there is more than 12 years of release.

Based on Scenario III (1 mallard per 50 m^2 open water surface area), the WFD ecological status is likely to deteriorate and be below good. The risk after 6 years of release and 6 years of fallowing is considered to be **Medium**, increasing to a **High** risk if there is more than 6 consecutive years of release in the same lake.

The probability that release of hand-reared mallards will cause eutrophication will likely increase over the next 50 years due to climate change factors.

10.5 The risk of introducing new diseases when introducing and releasing mallards from Sweden

The risk of introducing notifiable diseases through legal import of mallards from Sweden is considered **Medium** with regard to HPAI H5N8 and Newcastle disease.

The risk of introducing the zoonotic notifiable diseases avian chlamydiosis or salmonellosis through legal import of mallards from Sweden is considered **Low.**

The risk of introducing the notifiable diseases duck virus hepatitis, duck virus enteritis, avian tuberculosis, and fowl cholera through legal import of mallards from Sweden is considered **Low.**

10.6 The risk of reduced animal welfare as a result of the current routines for releasing farmed mallards in the wild

The expected mortality rate during the first year of release farmed mallards will exceed 75%, which is considered significantly higher than the mortality of wild mallards. The risk of a high mortality rate is assessed as **High**.

The likelihood of wounding and crippling during hunting is estimated to 0.5 wounded or crippled mallards per harvested bird. As the likelihood of wounding and crippling is considered to be high and the consequences for the birds are serious, the risk of wounding and crippling is assessed as being **High**.

10.7 Science-based tools and methods to reduce knowledge gaps

The NEA requested VKM to provide a scientific evaluation of which science-based tools and methods could be applied to increase our knowledge concerning the potential impacts on biodiversity stemming from the release of mallards. VKM was also asked to state if there are specific measures or limitations that may affect the risks.

Despite the fact that a significant number of mallards are released in Europe every year, very few systematic studies have been published on the subject. Thus, provision of evidence-based, risk-reduction measures is difficult. Nevertheless, the methods described in the sections below could contribute to decreasing some of the risk factors described in this report.

10.7.1 Genetic effects on native mallards and other dabbling ducks

- The ultimate measure to avoid negative genetic effects would be sterilization of all hand-reared ducks prior to release. Some attempts have been made to develop non-toxic sterilizing agents for birds, but none are currently available that would be suitable for hand-reared mallards.
- To avoid loss of genetic variability, the breeding regimes for farmed ducks should be designed so that genetic variability is maximised in mallards used for restocking.
- Statistical modelling (as proposed in Appendix III) could be of importance for evaluation the genetic effects arising from release of captive mallards with low effective population size into the wild population.
- Continuous sampling of DNA from wild mallards and other dabbling ducks and from hand-reared mallards would be useful for a hybridization assessment programme that could be used to map the distribution of non-introgressed natural populations, and to support their conservation in the wild.

- Numerous SNP-markers to distinguish wild mallards from farmed mallards already exist and the development of standardized SNP-chips would lower costs and make admixture analyses more accessible and comparable.
- Directs studies of pair formations between released and native birds in the wild could be enabled by marking released mallards with nasal saddles. However, it should be noted that VKM has previously assessed that there is a medium risk of impaired welfare in waterfowls carrying nasal saddles (VKM, 2013).

10.7.2 Ecological interactions between released and resident mallards.

- Ringing of all released hand-reared mallards would provide useful data on the proportion of released mallards in hunting bags, sex ratios, age ratios, survival, migration, local dispersal etc. For comparison, ringing of naturally wild mallards in Norway is desirable. Carrying a leg ring has previously been assessed to present a low risk of impaired welfare (VKM, 2013).
- Individual markings (additional to ringing) that can be observed from distance, e.g., nasal saddles, will enhance the likelihood of sightings and recognition and enable robust estimates to be made of survival of released mallards, including monthly survival outside the hunting season (Champagnon et al., 2016b). These robust estimates will provide information on the contribution of hand-reared mallards to the wild population. VKM has previously assessed that there is a medium risk of impaired welfare in waterfowls carrying nasal saddles (VKM, 2013).
- GPS loggers or satellite transmitters can provide a better understanding of local movements, dispersal, and migration patterns, which, in turn, will help us to understand the differences and similarities between wild and hand-reared mallards, and how released mallards may interact with, and affect, their environments. Knowledge about both local movements and migration is important for understanding the mallards' role in dispersal of organisms and spreading of pathogens such as avian influenza viruses.
- Continuous gathering of data is desirable, including DNA samples, but also biometric data such as bill morphology (height) etc.
- Common garden experiments to answer questions such as regarding the plasticity of bill morphology could provide useful information: experiments could explore effects of same genotypes (siblings, half-sibling designs) reared in natural-like conditions (sieving) and in farm-like conditions (eating bigger particles) to investigate which phenotypes develop.
- Other questions to address would include whether the "goose-like" bill has negative consequences for individual fitness, most likely reducing survival? Here the recapture / recovery (hunters reporting?) of ringed birds could provide information on survival in relation to bill morphology. Such investigations would probably be very difficult to implement logistically.

10.7.3 The impact of duck release on local fauna

- Repeated censuses of organisms (plants, birds, invertebrates, mammals) connected to the release sites would provide useful data on the long-term effects of mallard releases. The first censuses should be made prior to commencement of mallard releases.
- The distributions of each of the actors in the ecosystem should be investigated in locations where mallard releases are proposed, to investigate the probable extent of distribution overlapping.
- For the species considered at the different trophic levels, data on their diets, life histories, and phenologies should be gathered, to add a temporal dimension to the spatial distribution information, and to determine which life history stages are most vulnerable.
- Some of the involved species might be considered as threatened and/or included on the Red List. This information is important when assessing potential impacts that may result from mallard releases. Information from NEA on threatened species should be consulted.

10.7.4 Mallard release and water eutrophication, including potential for downstream effects on local ecosystems

Prior to introducing hand-reared mallards to a site, the baseline water quality should be assessed following guidelines in the water framework directive (Iversen and Sandøy, 2013). In the directive, water quality is measured as ecological status using biological quality elements. Hydro- morphological and physicochemical quality elements may be used as a measure of water quality to supplement the biological assessment. The biota is preferred as a measure of water quality as it incorporates potential changes that occur over time, whereas other measurements may fluctuate on a daily basis. Zoobenthos, zooplankton, macrophytes, fish and periphyton are used as indicators of water quality. The choice of indicator organism and its index depends on the site and is described in detail in Iversen and Sandøy (2013 – updated guidelines to be published in 2017). As a supplement to the biological quality elements, water samples and subsequent analyses of total nitrogen and total phosphorus may be taken. The ecological status as monitored over the autumn may be used to guide the decision on the number of mallards to be released during the subsequent year. The aim of such monitoring would be to prevent a reduction in water quality. A fallowing period may be needed if the status has deteriorated compared with the baseline.

10.8 Measures for reducing risks to animal welfare

The high risk of reduced welfare, as illustrated by the high probability of a high mortality rate of released mallards and the high probability of wounding and crippling of all mallards during hunting, indicates the need for risk reduction measures.

Farmed and released mallards may experience extensive suffering before death. Reducing the probability of the risk factors causing mortality (e.g., starvation) could reduce mortality rate and thus the risk.

The following measures for risk reduction regarding animal welfare of imported farmed mallards from Sweden for release in Norway are suggested:

- Release the birds during a dry, warm period. Wet ducklings are likely to freeze to death.
- Release the mallards at a location where it is easy to feed them in accordance with current regulations.
- Release the birds at a location where there is sufficient available nutrition until the hunting season.
- Performing predator control in accordance with the Norwegian Wildlife Act
- Conducting hunting such that stress of the hunted birds is reduced to a minimum.
- To decrease wounding and crippling, hunting can be organised such that the distance between the hunters and the flying prey is reduced to a minimum, and is no longer than 25 m.
- Test shooting abilities of all small game hunters annually during a mandatory training programme and follow up with an exam that includes hitting moving targets (clay pigeons before hunting of live game is permitted.

Ensuring that dogs used for retrieving downed ducks are available during the entire hunting period. Also, check the hunting ground for crippled birds as soon as possible after the hunt is terminated to reduce possible suffering. Document all released birds shot during the hunting season.

11 Potential impacts on ecosystem services

Freshwaters provide a range of ecosystem functions that can be translated into provisioning, cultural, regulatory, and supporting ecosystem services (MEA, 2005). Examples of ecosystem services provided by freshwater bodies include supply of water for consumption and irrigation, power production, nutrient cycling, decomposition of organic matter, and opportunities for fishing, recreation, and tourism.

Human influences, such as the introduction of organisms to a freshwater system, may have negative impacts on ecosystem functions and services. The release of a large number of hand-reared mallards may contribute to increased competition with resident ducks, or cause increased predation by facilitating an increase in various predator populations. These will, in turn, contribute to alterations in predator-prey relationships, and thus may affect the resilience of the ecosystem (a supporting service).

Eutrophication as a consequence of an increased number of mallards, and also from heterospecific attraction of other duck species, may result in an increase in primary production. This may have cascading effects on the ecosystem and its chemical and physical characteristics, and subsequent negative effects on nutrient cycling and water quality. Moreover, anthropogenic actions, such as the removal of predators prior to the release of mallards and feeding of mallards, will further contribute to altering the ecosystem from its original state.

Based on the various ecological risk factors presented in this report, VKM conclude that there could be significant impacts on ecosystem services from the release of farmed mallards.

12 Data gaps

The data available are insufficient for the assessors to conduct a full quantitative risk assessment of the impact of release of mallards on the environment, animal health, and animal welfare.

Biodiversity

In order to improve hazard characterization, data on both short-term and long-term survival of released mallards are required. Estimates of the breeding success of hand-reared mallards are lacking; such data are necessary to assess the risk of genetic impact on native populations. The potential negative effects on the fitness caused by breeding with farmed mallards need to be quantified. Furthermore, detailed distribution maps for mallards, other dabbling ducks, and other relevant species in the ecosystem where mallards are released (Figure 5.1-1) are required, especially for Red-Listed species. Data on ecological interactions between mallards and the same species (Figure 5.1-1) would further improve the predictability of the possible effects of mallard release on biodiversity.

Nutrient status

Studies on the effects caused by hand-reared mallards on the nutrient status of freshwaters are largely lacking. This is somewhat surprising, given the number of hand-reared mallards that are released each year in countries such as Sweden, Denmark, and France (see table 1). In order to gain knowledge on such effects, the ecological status of the waters should be monitored. In addition, such monitoring should also document those properties of the waterbody that may potentially influence its sensitivity to eutrophication. Factors that may be included are point-source input of nutrients, the density of terrestrial vegetation and the proportion of bogs, information on the food chain of the ecosystem, morphological characteristics of the lake basin, temperature stratification, water residence time, content of particles, light regimes, and local climates. The aim of extensive monitoring is obtaining knowledge on the carrying capacity of lakes with respect to eutrophication caused by mallards. Predictions on eutrophication can then be made prior to the release of mallards at monitored sites.

Animal health and welfare

The following data gaps have been noted: lack of disease data from active surveillance of mallard populations; lack of data on normal summer survival rates of mallards released in Norway; lack of data on normal survival rate of released mallards in Norway that survive to breed during the following season; lack of data on the causes of mortality in the mallard population and the proportion of mallards that die from each of these causes; lack of data on how many of the released birds are crippled or wounded and not retrieved during the hunting season.

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Appendix I

Sammendrag fra høringsekspert Fredrik Aalerud. Representant for Astrup Fearnley.

Endene importeres fra Sverige, firmaet Perdix. Endene har en 48 timers veterinærgodkjenning fra Sverige og må fraktes i dette tidsrommet.

Endene fraktes i plastikk-kasser som er godkjent som fraktkasser. Det er ca 15-20 dyr i hver kasse. Det er vanligvis 3-4 dyr (av 600) som dør under transporten.

Stokkender settes vanligvis ut rundt 2 ukers alder. Dette forutsetter at det er fint vær, og at det er spådd fint vær en periode fremover i tiden etter utsettingen. Endene settes ut i slutten av mai. Som en følge av tidlig utsetting er endene atferdsmessig å betrakte som ville. For å unngå at endene skal bli vant med mennesker settes de ut i vann der det er lite ferdsel. Erfaring tilsier at dette er viktig. Grunnet at de er så små når de settes ut er det ikke mulig å ringmerke disse dyrene.

De utsatte endene får bløtlagt korn som havre og bygg, og fôringen skjer på grunt vann for å oppfordre til et tilnærmet naturlig næringssøk. Fôres inntil vannet har vokst til og det er nok mat å finne for endene på naturlig måte.

Har satt ut ender siden 1979 og begynte med å sette ut 50-100 ender per år. Har lært mye underveis, siden 1979 og mener dagens praksis er optimal. Det har vært en økning i antall ender som settes ut, og nå settes det ut 600 hvert år. Endene settes ut i det samme vassdraget hvert år, men sprer seg etter hvert og blander seg med de ville endene. Området ligger i nærheten av Øyeren.

Det er uklart hvor mange villender som finnes i området, men det er kun snakk om noen få par med kull som vokser opp, grunnet predasjon fra mink og gjedde.

Når det gjelder predatorer i området rundt utslippsområdet så har det vært en økning i mink-bestanden. Det tas ut et stort antall mink hvert år. Det finnes også gjedde i vassdraget, men det er uklart om det har vært en økning i denne bestanden.

En rekke andre fuglearter holder til i utslippsområdet, som hegre, trane, bekkasin og kvinender. Utsatte ender tiltrekker seg ville ender og det er observert en økning i vadefugler.

Jakten begynner i august/september, og holder på frem til jul eller frem til det fryser på vannene. Antallet som skytes vil dermed avhenge av lengden på jaktsesongen. Mellom 25 og 50% av endene skytes (ikke mulig å si om andelen av disse som er tamme eller ville siden de ikke er ringmerket).

Jakten utføres kun av venner og bekjente. Jakten foregår ved hjelp av apporterende hund, noe som anses som viktig. Det er utføres ettersøk både etter jakt og om morgenen etter jakt-dagen for å plukke opp skadeskutte og døde ender.

Det er observert en positiv effekt på gjengroing i vassdraget, men mekanismen her er uklar.

Appendix II

Sammendrag fra samtale med høringsekspert Carl-Martin Nygren. Representant for Løvenskiold Fossum

Endene importeres i pappkasser på lastebil fra Sverige og leveres fra en fast leverandør. Får en kvittering som bekrefter helsekontroll av veterinær. I normale fall dør 1-2 kyllinger under transport.

Har importert ender de siste fire årene, økende antall med 8000 i fjor og søknad om 10000 i år. Leveres i to omganger (påfølgende dager). Vid varmt vær skjer transport om natten for å sikre kjølige forhold under transport og for å kunne sette ut endene tidlig om morgenen.

Endene settes ut når de er ca 3 uker gamle, eventuelt litt tidligere. Tidspunktet for utsettingen er avhengig av værvarsel og stabilt pent vær. De settes ut i slutten av mai eller i begynnelsen av juni. De er flyvedyktige fra midten av juli.

Endene blir først fôret med kraftfôr-pellets som er blandet med korn (hvete og bygg), siden de er vant til å få pellets. I perioden etter utsetting legges maten på landkanten, men etter hvert legges den på grunt vann. Endene fôres en gang i uken. De fores sjelden for å unngå at de blir vant til mennesker. Endene fores for primært for å holde seg ved vannene der de ble satt ut. Etter jaktsesongen fôres de kun i området rundt slottet.

Det er uklart hvor stor den ville stokkandbestanden er og hvor mange ville ender som bodde i området i forkant av utsettingene.

Det settes ut ender på flere vann, alle endene settes ikke ut på eksakt samme sted. Endene settes ut på relativt store vann, noen er naturlige men det også anlagte viltvann. En del ender kommer tilbake til vannet de ble satt ut på etter endt jaktsesong, men langt fra alle.

Det er nokså mye rev i området, og det jaktes på disse. Det ble før forrige utslipp av ender tatt ut 62 rev. Det finnes også en andre fuglearter i området, som for eksempel Kvinand og krikkand.

Jakten foregår fra august til medio oktober eller tidligere hvis det fryser på vannene. Det er kommersiell jakt og man kan kjøpe en engangslisens for å jakt. Det er grupper på 8-12 personer som jakter. Deltagerne har varierende jaktbakgrunn. Man betaler 295 NOK per 3 skudd, som er ment å representere en and. På denne måten unngår man noe bomskyting. Apportering av skutt fugl foregår ved hjelp av 10-15 personer med hund. Dagen etter jakt blir området patruljert av med apporterende hunder for å finne evt. skadeskutt fugl. Det anslås at ca 25% av de utsatte endene blir skutt. En del av jegerne vil ha med seg andekjøtt hjem.

Det er ikke lov å skyte ender på vannet, og alle skal skyte med større en 45°vinkel. Unntak gjelder for de jegerne som sammen med hund skal finne skadeskutte ender.

Endene brystes og brukes som livsmiddel for privat bruk. Restavfall behandles som vilt og graves ned.

Det har ikke kommet i gang med ringmerking enda men dette skal etter planen skje i år (etter påbud fra MD).

Appendix III

An evaluation of possible Ryman-Laikre effects from release of hand-reared mallards

The Ryman-Laikre-effect (Ryman and Laikre, 1991) is a reduction in total effective population size (and an increase in inbreeding) in a combined captive–wild system, which arises when a few captive parents produce large numbers of offspring. When organisms bred in captivity are released into wild populations, this effect can be estimated from estimates of the effective number of breeding animals in the wild, the effective number of captively bred animals, and the proportion captively bred animals in the wild breeding population. In regards to the release of hand-reared mallards, reliable estimates of these parameters do not exist, but are nevertheless crucial for an evaluation of the genetic effect arising from this practice (Laikre et al., 2010).

Applying a specified set of assumptions, we have tried to evaluate a possible Ryman-Laikre effect from existing knowledge of the number of released ducks and estimates of wild population size (N). The resulting estimates are uncertain, but demonstrates the need of documenting the number of brood ducks used for producing hand-reared offspring for releases, the effective number of breeders in the wild, and the proportion of released hand-reared ducks that contributes to reproduction in the wild.

Assumptions for estimating effective number of breeders in captivity

1. Equal number of males and females
2. Each female produces 10 offspring
3. The ratio between effective population size (N_{eC}) and census population size of captive breeders (N_C) is assumed to vary between 1:1 and 1:5 because of unequal number of offspring per family and because some brood ducks are held in captivity for more than one generation
4. We use 2%, 5%, and 10% of the number of released ducks to represent low, median, and high level of N_{eC} in the released ducks.

Assumptions for estimating effective number of breeders in wild populations

1. Estimates of the ratio between effective population size N_{eW} and census population size N_W in wild populations may range from 10% to 50% (Nunney,

1993; Frankham, 1995) with a point estimate at 34% for four bird species (Koenig, 1988).
2. In our estimates, we use 10% to represent a low level, 34% to represent a median, and 50% to represent a high level when estimating N_e in the wild from statistics of the actual number of wild ducks.
3. We assume that wild populations are numerically large and genetically homogeneous over long distances (Kraus et al., 2013, Söderquist, 2015).

Assumptions for estimating effective number of breeders in wild populations

1. The survival of hand-reared, released ducks until sexual maturity is set to 50% of that of the wild ducks (Champagnon et al., 2016b) with a range from 25% to 75% relative survival.

From official statistics of the number of released hand-reared ducks and wild population sizes in Europe and Norway (**Table 1**), the assumptions above about N_{eC} of the released ducks, N_{eW} of the wild populations, and the proportion of released ducks in wild breeding populations, the following set of calculations may be made for Europe, Norway, and the Østlandet region of Norway where the releases of hand-reared birds take place (**Table 1**). For the Østlandet region, we assume that the census population size of wild mallards is roughly one tenth of Norway's total, which represents a wild population number at the same level as the number of released hand-reared ducks.

Table 1 Number of wild (N_Wild), number of released (N_Released), estimates of effective number of wild (Ne_wild) and released (Ne_released) mallard in Europe, Norway and the Østlandet region in Norway, and the proportion of released ducks in these regions (X). * the ratio of effective number of released and wild ducks (NeC/NeW) is estimated for the purpose of obtaining the highest and lowest possible ratio, respectively.

	N_wild	N_released	Ne_wild	Ne_released	NeC/NeW *	Proportion (X)
Europe						
High	9220000		4610000	300000	0.013	0.283
Median	7460000	3000000	2536400	150000	0.059	0.167
Low	5700000		570000	60000	0.105	0.075
Norway						
High	150000		75000	1000	0.003	0.080
Median	100000	10000	34000	500	0.015	0.048
Low	86000		8600	200	0.116	0.016
Regional (Østlandet)						
High			5000	1000	0.040	0.429
Median	10000	10000	3400	500	0.147	0.333
Low			1000	200	1	0.200

The ratios of captive to wild effective population sizes N_{eC}/N_{eW} and the proportions of released ducks in the wild breeding population (Table 1) are plotted in Figure 1 to evaluate a possible Ryman-Laikre effect by using the methods of Karlsson et al. (2016) and Waples et al. (2016). The area above the red line in the figure represents a situation where a reduction in effective population size is expected (Ryman-Laikre effect). The green line represents the maximum total effective population size that can be obtained and the area below it represents a relatively low genetic contribution from the breeding of released hand-reared ducks. Between the green line and the red line, the total effective population size is gradually reduced from maximum to a total effective population size equal to that of the wild population without any contribution from hand-reared ducks (Karlsson et al., 2016, Waples et al., 2016).

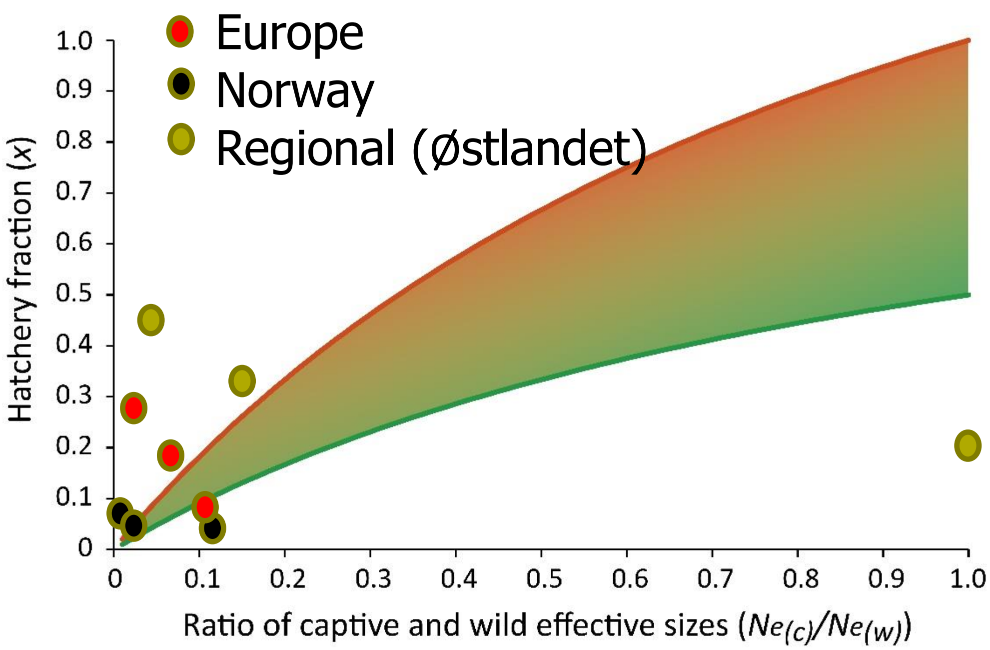

Figure 1 An evaluation of possible Ryman-Laikre effects from the release of hand-reared mallards on wild populations of mallards in Europe, Norway, and the Østlandet region of Norway. The area above the red line represents a reduction in total effective population size, the area below the green line represents a relatively low contribution from the release of mallards. From the green line towards the red line, total effective population size is gradually decreasing from a maximum level towards a level which is equal to the effective population size of the wild population alone.

The limited existing data does not allow us to give a precise estimate of a possible Ryman-Laikre effect in the calculations for releases of hand-reared ducks in Europe at large, Norway or a part of Norway (Figure 1). From the data at hand and the rough assumptions specified above, the effect of releases on total effective population size may be anything from severe (i.e. a reduction of total effective population size over large regions, which we consider to be RED zone (high risk)) to minor or non-existent genetic contribution of released mallards (which we consider to be in the GREEN zone (low risk)).

This variation in expected impact on total effective population size is produced for our calculations for Scenario I (releasing 10 000 hand-reared birds into a population ten times larger) in Norway, as well as for our calculations for Scenario III (releasing 10 000 hand-reared mallards into a wild population of the same size). Also, the calculations for Europe, which represent an intermediate situation (although not exactly Scenario II), suggest that anything from a reduction in total effective population size to no or limited genetic contribution, is possible.

Until reliable data exist, it is therefore not possible to define a safe level of this stocking activity to avoid negative genetic consequences on wild mallard populations.

Crucial knowledge gaps and concerns

There appears to be very little general or specific information on the rearing activities in terms of number of brood-ducks, their origin, crossing schemes, individual contribution to the next generation, or relatedness between captive individuals. Moreover, information seems to be lacking on how many generations brood-ducks have been kept in captivity, and if wild ducks used as brood-ducks are of pure wild or partly wild origin.

Molecular genetic analyses of mallard by Söderquist (paper IV referred to in 2015 Thesis) show a distinct genetic difference between farmed ducks and their wild conspecifics. This suggests a severe bottleneck and/or a subsequent large genetic drift due to low effective population size in the farmed stocks. It is therefore likely that the farmed ducks released in the wild have a much lower genetic variation than wild ducks (Söderquist, 2015: data from Paper IV), and potentially that the wild populations may be more impacted by interbreeding with captive-bred ducks than what is assumed for the calculations in Figure 1.

To what extent the genetic change in captive mallards relative to wild mallards reflects an inbreeding event, or whether it is due to genetic adaptation to captivity, is also of interest when assessing the genetic effects of releases on wild populations.