VKM report 2022:29

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Scientific Opinion of the Panel on Biodiversity of the Norwegian Scientific Committee for Food and Environment

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Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the opinion. The project group consisted of Bjørnar Ytrehus, (VKM member), Katrine Eldegard (VKM member), Kyrre Kausrud (VKM member), Brett K. Sandercock (VKM member), Danica Grahek-Ogden (VKM staff), Dean Basic (VKM staff), Bård-Jørgen Bårdsen (external member), Jan Ove Bustnes (external member). Two referees commented on and reviewed the draft opinion. The Committee, by the Panel on Biodiversity and a member from the Panel on Animal Health and Welfare, assessed and approved the final opinion.

Authors of the opinion

The authors have contributed to the opinion in a way that fulfils the authorship principles of VKM (VKM, 2019). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group, and the VKM Panel on Biodiversity, supplemented with a member from the VKM Panel on Animal Health and Welfare, contributed as approval group.

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Project leader Danica Grahek-Ogden (VKM secretariat) is acknowledged for leading the project and coordinating the work on the opinion. Dean Basic (VKM secretariat) is acknowledged for information retrieval and general assistance on the opinion.

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

Key words: VKM, risk assessment, Norwegian Scientific Committee for Food and Environment, Norwegian Environment Agency, mallard (*Anas platyrhynchos*), tufted duck (*Aythya fuligula*), velvet scoter (*Melanitta fusca*), common scoter (*Melanitta nigra*), long-tailed duck (*Clangula hyemalis*), red-breasted merganser (*Mergus serrator*), spring hunting, Lodden

Background

Spring hunting for ducks (Lodden in Northern Sami) is part of the Sami hunting and trapping culture. In Norway, this traditional hunting has been permitted in Kautokeino Municipality in accordance with the exception provision in the Wildlife Act Section 15, with quotas for males of several duck species. However, hunting in the spring may be in conflict with the Nature Diversity Act's principle for species management, saying (quote from Section 15): “Unnecessary harm and suffering caused to animals occurring in the wild and their nests, lairs and burrows shall be avoided. Likewise, unnecessary pursuing of wildlife shall be avoided.” Furthermore, in accordance with international legislation and agreements, the Wildlife Act (Section 9) states that the hunting season should not be set to the nesting and breeding season for the species in question.

The Norwegian Environment Agency (NEA) asked VKM to (1) assess risk and risk-reducing measures on biodiversity and animal welfare when conducting spring hunting of ducks. The terms of reference were additionally clarified by the NEA to include assessments of the risks associated with hunting quotas of up to 150, 300, and 500 male individuals, on the populations of mallard (*Anas platyrhynchos*), tufted duck (*Aythya fuligula*), velvet scoter (*Melanitta fusca*), common scoter (*Melanitta nigra*), long-tailed duck (*Clangula hyemalis*), and red-breasted merganser (*Mergus serrator*). VKM was furthermore asked to (2) point out risk-reducing measures in scenarios with hunting bags corresponding to the mentioned quotas of all the six species.

Method

VKM appointed a project group to answer the request from NEA and assess the risks to biodiversity and animal welfare posed by spring hunting for adult male ducks. The project group narrowed down the scope of the biodiversity risk assessment to encompass risks for local populations of six target species: mallard, tufted duck, velvet scoter, common scoter, long-tailed duck, and red-breasted merganser, and non-target migratory waterbirds. Negative impacts on biodiversity was defined as negative effects on population viability.

The VKM project group gathered data from publications retrieved from literature searches and reports from Kautokeino municipality to the Finnmark Estate (Finnmarkseiendommen), which were made available to the group by the Norwegian Environment Agency. Hunting statistics were acquired from Statistics Norway (Statistisk sentralbyrå; SSB).

During the assessment, several critical knowledge gaps and uncertainties were identified. The main obstacle for assessment of the impact of spring hunting on viability of local populations in Kautokeino, is the lack of data on relevant population sizes and demographic rates for the six target species. The available population estimates are partly based on almost 30-year-old bird counts. In addition, knowledge about spatial and temporal distributions of each species, combined with local or remote-sensed data on ice breakup, is needed to estimate the proportion of the population being effectively hunted in early spring when ducks are congregating on available ice-free waters. Such knowledge, combined with information about where, when, how and by how many hunters the hunting is performed, is also critical for sound assessments of risk to biodiversity and harm to bird welfare. Improved data on hunting bags (reliable, spatially explicit, and detailed) and frequency of wounding and crippling is also needed to provide accurate assessments.

The project group performed modelling of harvest scenarios for a range of conditions (e.g., number of birds harvested, reduced breeding success caused by indirect effects of disturbance, environmental stochasticity, and spatial variation in habitat) to assess how sensitive the populations are to different parameters and model assumptions. The modelling provides improved insights into what type of data managers will need to quantify the effects of spring hunting and decide on quotas (see below).

The project group conducted qualitative assessments of the likelihood of negative impacts and the consequences of potential negative effects by considering the combined information about national red list status and population trends, species ecology, evidence of population impacts of spring hunting, and insights from the modelling.

We assessed the risks to the local target populations of each species, focusing on qualitatively assuming quotas of 150, 300, and 500 male ducks were fulfilled (while using a continuous range of quotas in the model).

The risk of harm to animal welfare from spring hunting was compared to the risk of harm to animal welfare caused by hunting in the autumn.

In our assessments, we defined likelihood as:

- Low: <10% probability of the exposure/consequence occurring
- Moderate: 10–50 % probability of the exposure/consequence occurring
- High: >50% probability of the exposure/consequence occurring

Consequence, i.e., the magnitude of the effects of spring hunting, was defined as:

- Low: Limited or no consequences for biodiversity/animal welfare
- Moderate: Short-term or reversible consequences for biodiversity/animal welfare
- Serious: Long-term consequences for biodiversity/animal welfare

Risk from spring hunting for adult male ducks on biodiversity/animal welfare was assessed as Low, Moderate, or High based on the combined scores for likelihood and consequence.

Results

Impacts on the viability of target and non-target waterbird populations

Our population model suggests that increasing human disturbance and between-year variation in survival, also in the time period outside the spring hunting, would make populations more at risk of local extirpation and less able to tolerate harvesting pressure. Consequently, future and/or on-going changes in human behavior, increased environmental variability from climate change and land use impacting survival would greatly affect the sustainability of hunting.

Based on insights from the population model and our qualitative assessments of the likelihood and consequences of potential negative effects, we assess with medium confidence that for the velvet scoter, common scoter, and long-tailed duck, any spring hunting poses a high risk to the viability of the local populations for these species. Based on the presumably small sizes of the local populations of mallards and red-breasted mergansers, we assess with low confidence that spring hunting of 150, 300 or 500 males poses a high risk to the viability of these local populations. Hunting of 300 or 500 tufted ducks is also, with low confidence, assessed to constitute a moderate to high risk to population viability. In contrast, hunting 150 tufted duck males are considered to constitute a low to moderate risk, also with low confidence. For non-target waterbirds, we assess with low confidence that spring hunting for target species poses a moderate risk to species that are spatially associated with the target species during the spring hunt, and a low risk to species that are not present in the same habitat during this period. The risk to non-target species depends on population size and the magnitude and temporal/spatial extent of the hunting disturbance.

Impacts on animal welfare

Hunting implies a risk of harm to animal welfare through disturbance, loss of individuals to which the remaining animals have a social relationship, and wounding/crippling. Spring hunting occurs in intermittent periods over a limited period, with a limited number of people involved and is only allowed on a small proportion of the total area of Kautokeino municipality. This indicates that individual birds experience only short and intermittent periods of disturbance in a limited number of places. However, if the hunting area includes a large proportion of available open water lanes in Kautokeino, the hunting may expose a large proportion of the population to serious harm to animal welfare. The area of hunting in proportion to the area of open water lanes is a major uncertainty in the assessment.

The assessment of welfare is hampered by lack of accessible observational studies of both the spring- and autumn hunting in Kautokeino and a lack of knowledge about the species- and site-specific impact of hunting on the welfare of the focal duck species. The spring hunt is otherwise not assessed to represent a higher risk of harm to animal welfare than the autumn hunt. Still, if hunting occurs in spring and autumn, the cumulative harm to animal welfare will increase.

Conclusions

Target and non-target waterbird populations

- We have insufficient data on local and regional population sizes, population trends, survival rates, and hunting bags to make quantitative assessments of risks to the viability of local populations of the target species. Still, larger quotas will entail increased risks of decreased population viability.

- Combining qualitative assessments and insights from the population modelling with the precautionary principle, we conclude that the risk to local population viability from spring hunting for male ducks is as follows:
  - Harvesting any quota of **common scoter**, **velvet scoter** and **long-tailed duck** poses a high risk, as these species are vulnerable or near threatened according to the Norwegian red list, have negative national (and global) population trends, and occurred in low numbers in Kautokeino during the surveys done in the 1990s.
  - Harvesting 150, 300, or 500 **mallards** and **red-breasted mergansers** pose a high risk, since bird counts from the 1990s found low local abundances of these species during the spring hunting season.
  - Harvesting 150 **tufted ducks** constitutes a low to moderate risk, while harvesting 300 or 500 tufted ducks poses a moderate to high risk.
  - New data on the target species' local abundances and spatial and temporal distributions are needed and may change the risk assessments for mallards, red-breasted mergansers, and tufted ducks.
  - For **non-target waterbirds**, spring hunting for target species poses a moderate risk to species that are spatially associated with the target species during the spring hunt, and a low risk to species that are not present in the same habitat during this period.

Animal welfare

- The cumulative risk of harm to animal welfare is greater if hunting occurs in both spring and autumn than if hunting only occurs in one season.
- We have not identified factors indicating that spring hunting constitutes a higher risk to the animal welfare of the target species than hunting in the autumn, as long as spring hunting does not occur on the majority of the open lanes of water in the area. If the latter is the case, spring hunting will most likely constitute a serious disturbance to a proportionally high number of ducks and hence a high risk to welfare.

Risk-reducing measures

Potential measures to reduce risks to **viability of waterbird populations**

- A management programme, which can be updated – for example, by adjusting quotas or restricting/prohibiting hunting – as new evidence becomes available.
- Designating waterbird refuges without hunting in preferred and easily available habitats.
- Improve data on hunting bags and hunting efforts, for example, by making hunting permits contingent on submitting an adequate report.
- Training in species identification and control by field inspectors.

Potential measures to reduce risks to **animal welfare**:

- Improving hunter training to minimize disturbance and wounding.
- Ensuring that some areas with open water are available where the birds are allowed to rest without disturbance (i.e., to define some non-hunting refuges).
- Decrease the number of hunters allowed to participate, the length of the hunting season (i.e., to reduce the number of days), or reduce the quotas – to lower disturbance and likelihood of wounding.
- To stop the hunt when the ducks start to show mating behaviour.
- Compensate increased disturbance during the spring with decreased disturbance during the autumn.

Due to a lack of data, we could not provide quota- or species-specific risk-reducing measures.

Sammendrag på norsk

Stikkord: VKM, risikovurdering, Vitenskapskomiteen for mat og miljø, Miljødirektoratet, stokkand (*Anas platyrynchos*), toppand (*Aythya fuligula*), sjøorre (*Melanitta fusca*), svartand (*Melanitta nigra*), havelle (*Clangula hyemalis*), siland (*Mergus serrator*), vårjakt, Lodden

Bakgrunn

Vårjakt på ender (Lodden på nordsamisk) er en del av den samiske jakt- og fangsttradisjonen. I Norge har denne tradisjonelle jakten vært tillatt i Kautokeino kommune med hjemmel i unntaksbestemmelsen i viltlovens § 15, og det har blitt tildelt jaktkvoter for hanner av flere andearter. Vårjakt kan imidlertid være i konflikt med naturmangfoldlovens forvaltningsprinsipp slik det uttrykkes i § 15: «Ved enhver aktivitet skal unødig skade og lidelse på viltlevende dyr og deres reir, bo eller hi unngås. Likeledes skal unødig jaging av viltlevende dyr unngås». Viltlovens § 9 uttrykker videre, i overensstemmelse med internasjonal lovgivning og internasjonale avtaler, at jakttiden ikke bør fastsettes i hekke- og yngletiden for vedkommende art.

Miljødirektoratet ba VKM om å vurdere (1) risiko og risikoreduserende tiltak for biologisk mangfold og dyrevelferd ved utførelsen av vårjakt på ender. Oppgaven ble ytterligere klargjort av Miljødirektoratet til å omfatte vurdering av risikoen ved jaktkvoter på 150, 300 og 500 hanner for bestandene av stokkand (*Anas platyrynchos*), toppand (*Aythya fuligula*), sjøorre (*Melanitta fusca*), svartand (*Melanitta nigra*), havelle (*Clangula hyemalis*) og siland (*Mergus serrator*). VKM ble videre bedt om å (2) peke på risikoreduserende tiltak ved scenarioer hvor jaktuttaket er like stort som de nevnte kvotene for alle de seks artene.

Metode

VKM oppnevnte en prosjektgruppe som skulle besvare forespørselen fra Miljødirektoratet og vurdere risikoen for biologisk mangfold og dyrevelferd ved vårjakt på voksne hannender. Prosjektgruppen definerte målet om å vurdere risiko for biologisk mangfold til å omfatte risiko for de lokale bestandene av de seks aktuelle artene: stokkand, toppand, sjøorre, svartand, havelle og siland og andre trekkende vannfugler. Negativ påvirkning av biologisk mangfold ble definert som negativ påvirkning av bestandenes livskraftighet (overlevelsesevne, levedyktighet).

Prosjektgruppen samlet data fra publiserte artikler funnet ved litteratursøk og rapporter fra Kautokeino kommune til Finnmarkseiendommen, som Miljødirektoratet hadde gjort tilgjengelig for gruppen. Jaktstatistikk ble hentet fra Statistisk sentralbyrå.

I arbeidet ble det identifisert flere kritiske kunnskapsmangler og usikkerheter. Det viktigste hinderet for vurdering av effekten av vårjakt på lokale bestander i Kautokeino, er mangelen på data om relevante bestandsstørrelser og demografiske rater for de seks ulike artene. De bestandsestimatene som er tilgjengelige, baserer seg delvis på fugletellinger som ble gjort for nesten 30 år siden. I tillegg trengs det kunnskap om bevegelsesmønsteret over tid for de ulike artene, kombinert med kunnskap om når isen går, slik at en kan estimere hvor stor andel av bestandene som faktisk kan jaktes på tidlig i jakttiden, når endene samler seg i åpne råker i isen. Denne kunnskapen, kombinert med informasjon om hvor, når og hvordan jakten utøves og hvor mange jegere som deltar, er også nødvendig for å kunne gjøre fornuftige vurderinger av risikoen for biologisk mangfold og dårlig dyrevelferd. Bedre data på jaktuttak (pålitelige, stedsfestede og detaljerte) og forekomst av skadeskyting og varig fysisk mén hos fuglene, er også nødvendig for å kunne gi korrekte vurderinger.

Prosjektgruppen utførte modellering av høstingsscenarioer for en rekke forhold (f.eks. kvoter/jaktuttak, redusert hekkesuksess forårsaket av indirekte effekter av forstyrrelser, miljøvariasjon og romlig variasjon i habitat) for å vurdere hvor følsomme populasjonene er for ulike parametere og modellantagelser. Modelleringen ga bedre innsikt i hvilke opplysninger forvaltningen trenger for å kvantifisere effekten av vårjakt på bestandene, for å kunne ta avgjørelser om jaktkvoter.

Vi vurderte risikoen for de lokale bestandene av hver art ved uttak av henholdsvis 150, 300 og 500 hanner.

Risikoen for dyrevelferd som følge av vårjakt, ble sammenliknet med tilsvarende risiko ved andejakt på høsten.

I våre vurderinger definerte vi sannsynlighet som følger:

- Lav: <10 % sannsynlighet for at eksponeringen/konsekvensen opptrer
- Middels: 10–50 % sannsynlighet for at eksponeringen/konsekvensen opptrer
- Høy: >50 % sannsynlighet for at eksponeringen/konsekvensen opptrer

Konsekvens, dvs. graden av påvirkning av vårjakten, ble definert som følger:

- Liten: Ingen eller få konsekvenser for biologisk mangfold/dyrevelferd
- Moderat: Kortvarige eller reversible konsekvenser for biologisk mangfold/dyrevelferd
- Alvorlig: Langvarige konsekvenser for biologisk mangfold/dyrevelferd.

Risikoen for negativ påvirkning av biologisk mangfold/dyrevelferd ved vårjakt på voksne hannender ble vurdert som lav, middels eller høy basert på kombinasjonen av vurderingen av sannsynlighet og konsekvens.

Resultater

Påvirkning av livskraftigheten til bestander av vannfugl potensielt omfattet av og ikke omfattet av vårjakten

Bestandsmodellen antyder at økende forstyrrelser fra mennesker og mellomårlig variasjon i overlevelse, også i tiden utenom vårjakten, vil gjøre bestandene mer sårbare for lokal utryddelse og mindre i stand til å tåle beskatning. Framtidige og pågående endringer i folks atferd, økt miljømessig variasjon som følge av klimaendring, og endringer i arealbruk vil dermed i høy grad påvirke hvor bærekraftig jakten vil være.

Basert på innsikten fra bestandsmodellen og våre kvalitative vurderinger av sannsynligheten for og konsekvensene av potensielle negative effekter, vurderer vi med middels sikkerhet at enhver jakt på de lokale bestandene av sjøorre, svartand og havelle vil medføre høy risiko for overlevelsesevnen. Basert på de antatt små størrelsene på de lokale bestandene av stokkand og siland, vurderer vi med lav sikkerhet at vårjakt med et uttak på 150, 300 eller 500 hanner vil innebære høy risiko for livskraftigheten til disse. Uttak av 300 eller 500 toppender vurderer vi, med lav sikkerhet, til å medføre middels til høy risiko for bestandens overlevelsesevne. Uttak av 150 toppandhanner vurderes til å medføre lav til middels risiko, også det med lav sikkerhet. For arter som ikke omfattes av vårjakten, vurderer vi med lav sikkerhet at vårjakt på de omtalte andeartene vil utgjøre en middels risiko for de artene som oppholder seg nær dem, mens risikoen er lav for arter som ikke finnes i samme habitat i vårjaktperioden. Risikoen for arter som ikke er omfattet av vårjakten, vil avhenge av deres bestandsstørrelse, graden av forstyrrelsen jakten medfører og omfanget/utbredelsen av den.

Påvirkning på dyrevelferd

Jakt innebærer en risiko for dyrevelferd ved at den medfører forstyrrelser, gjennom tapet av individer som de gjenværende fuglene har en relasjon til, og ved skadeskyting og varig fysisk skade. Vårjakten skjer i avbrutte perioder i et avgrenset tidsrom, den utføres av et begrenset antall jegere, og den er bare tillatt på en liten andel av totalarealet av Kautokeino kommune. Dette tilsier at den enkelte fugl bare opplever korte og avbrutte perioder med forstyrrelser på et begrenset antall plasser. Men – om det er slik at jaktområdet omfatter en stor andel av de isfrie områdene i Kautokeino, så kan jakten medføre at en stor andel av fuglebestanden utsettes for alvorlig nedsatt dyrevelferd. Hvor stor andel av tilgjengelig åpent vann som er omfattet av jaktområdet, er dermed en vesentlig usikkerhet i vurderingen.

Vurderingen av dyrevelferd vanskeliggjøres av mangel på tilgjengelige observasjonsstudier av både vår- og høstjakta i Kautokeino, og mangel på spesifikk kunnskap om hvordan dyrevelferden til de aktuelle andeartene vil påvirkes. Vårjakten vurderes ellers ikke til å medføre en høyere risiko for dårlig dyrevelferd enn høstjakten, men om det foregår jakt både vår og høst, så vil den sammenlagte belastningen på dyrevelferden øke.

Konklusjoner

Bestander av vannfugler potensielt omfattet av og ikke omfattet av vårjakten

- Vi har utilstrekkelig kunnskap om lokale og regionale bestandsstørrelser, bestandsutvikling, overlevelse og jaktuttak til å gjøre kvantitative vurderinger av risikoen for levedyktigheten til bestandene av de aktuelle andeartene. Likevel kan vi si at større jaktkvoter innebærer økt risiko for livskraftigheten til bestandene.
- Ved å kombinere kvalitative vurderinger og innsikt fra bestandsmodelleringen med føre-var-prinsippet, konkluderer vi med at vårjakten innebærer følgende risiko for livskraftigheten til de lokale bestandene:
    - Ethvert jaktuttak av svartand, sjøorre og havelle utgjør en høy risiko, siden disse artene er sårbare eller nær truet ifølge den norske Rødlista, har negativ

nasjonal (og global) bestandsutvikling, og bare ble observert i små antall i Kautokeino ved tellingene på nittitallet.
    - Uttak av 150, 300 eller 500 stokkender eller silender utgjør en høy risiko, siden fugletellingene fra 1990-tallet viste lav forekomst av disse artene i vårjaktperioden.
    - Uttak av 150 toppender utgjør en lav til middels risiko, mens uttak av 300 eller 500 toppender utgjør en middels til høy risiko.
    - Ny kunnskap om den lokale forekomsten av de aktuelle artene og hvordan de forflytter seg over tid, er nødvendig og kan endre risikovurderingen for stokkand, siland og toppand.
    - For arter som ikke omfattes av jakten, vil eventuell vårjakt medføre en middels risiko for arter som befinner seg på samme sted som artene det jaktes på i jaktperioden, mens arter som ikke befinner seg i samme habitat i denne perioden, vil være utsatt for lav risiko.

Dyrevelferd

- Den sammenlagte risikoen for dyrevelferden er større hvis det jaktes både vår og høst, enn om jakten bare foregår i én sesong.
- Vi har ikke påvist faktorer som indikerer at vårjakten medfører en høyere risiko for dyrevelferden til de aktuelle artene enn jakt som utføres om høsten, så lenge vårjakten ikke skjer på størstedelen av de åpne råkene i vassdragene i området. Hvis det sistnevnte er tilfellet, vil vårjakten med høy sannsynlighet innebære en alvorligforstyrrelse for et forholdsmessig høyt antall ender og dermed en risiko for dyrevelferden.

Risikoreduserende tiltak

Mulige tiltak som kan redusere risikoen for livskraftigheten til bestandene av vannfugl:

- en forvaltningsplan som kan oppdateres, for eksempel ved å justere kvotene eller begrense/forby jakt, ettersom ny kunnskap blir tilgjengelig
- opprette områder, som omfatter attraktive og lett tilgjengelige habitater, hvor vannfuglene kan søke tilflukt uten å bli jaktet på
- framskaffe bedre data på jaktuttak og jaktinnsats, for eksempel ved å gjøre innrapportering til en betingelse for utstedelse av nytt jaktkort
- opptrening på artsbestemmelse og kontroll av feltinspektører

Mulige tiltak for å redusere risikoen for dyrevelferden:

- forbedre opplæringen av jegere med henblikk på å minimere forstyrrelsen av fuglene og skadeskyting
- sikre at noen områder med åpent vann hvor fuglene kan hvile uten forstyrrelser er tilgjengelige (dvs. opprette noen områder hvor det ikke er tillatt å drive jakt)

- redusere antall jegere som har lov til å delta på jakten, lengden på jaktsesongen (dvs. redusere antallet dager) eller redusere kvotene, slik at det blir mindre forstyrrelser og mindre sannsynlighet for skadeskyting
- å stanse jakten når endene begynner å vise parringsatferd
- å kompensere økt forstyrrelse om våren ved å redusere forstyrrelsen om høsten

På grunn av mangel på data kan vi ikke gi kvote- og artsspesifikke risikoreduserende tiltak.

Background as provided by the Norwegian Environment Agency

The Norwegian Environment Agency (NEA) refers to the collaboration agreement signed between NEA and the Norwegian Scientific Committee for Food and Environment (VKM) on 31 January 2019, and hereby asks VKM to assess risk and risk reduction measures on biodiversity due to spring duck hunting.

Spring hunting of ducks is part of the Sami hunting and trapping culture with traditions far back in time. However, traditional practices, including practices native to the Sami culture, is not in accordance with modern wildlife management principles. Spring hunting is contrary to the Wildlife Act's principle stating that hunting should not occur during the breeding season. This is a principle that is recognized internationally – this is, e.g., described in the Bern Convention and the EU's Birds Directive.

Nevertheless, hunting times have been set on several occasions with quotas for several species, as part of the Sami tradition and hunting practice. The hunt is authorized in the Wildlife Act §15 as an exception provision. As a temporary trial scheme, spring hunting has been implemented since 1994, but various adjustments to species and numbers have occurred over time.

In 1995 and 1996, the Norwegian Institute for Nature Research (NINA) submitted reports that assessed the population ecological effects of spring hunting and summarized, the first of a three-year study on the impact of spring hunting on several duck species. This study concluded that the vulnerability to hunting varied considerably between species. Indirect effects on hunting were that many ducks left the hunting area and that grazing females became more stressed. The nesting success in the local populations[1] was lower than in the surrounding areas. Increased disturbance and stress can contribute to spring hunting being an unfavourable hunting strategy compared to autumn hunting.

After being banned for a few years, spring hunting was reintroduced in 1999 and has since been carried out with multi-year permits. The last permit was valid from 2013-2022, with a quota of a maximum of 150 individuals per year and for three species: mallard, red-breasted merganser, and tufted duck.

The NEA has, on several occasions, put forward arguments against continuing spring hunting in our professional assessments in advance of new hunting periods determined by the Ministry of Climate and the Environment. Our assessments have been that spring hunting is an additional mortality factor for the birds being hunted. In the spring, the birds will nest to

[1] The populations hunted during Lodden (working group clarification)

produce new offspring that can be hunted sustainably within the limit of the population size. The fact that the stocks produce a hunting-worthy surplus of offspring is the mainstay of wildlife management. Moreover, the general disturbance and potential shooting of non-target species during the nesting season are of concern. The results from this assignment to VKM will be used together with an overall assessment of the Sami cultural traditions and the significance of spring hunting for the practice of Sami culture in light of international obligations of indigenous peoples' rights.

Terms of reference as provided by the Norwegian Environment Agency

1. The NEA asks VKM to assess risk and risk-reducing measures on biodiversity and animal welfare when conducting spring hunting of ducks.

2. In this assessment, VKM shall point out risk-reducing measures in different scenarios for offtake, both species selection and the number of individuals allowed to be shot[2].

[2] Further clarifications from the Norwegian Environment Agency: We request VKM to assess the risk from offtake, with quotas up to 150, 300 and 500 male individuals, on populations of mallard, tufted duck, and red-breasted merganser. In addition, we ask VKM to assess the risk from offtake, with the same quotas for males, on populations of long-tailed duck, velvet scoter and common scoter, as potentially huntable new species.

Introduction

Sami traditional hunting of ducks during spring

Spring hunting (Northern Sami: "Lodden") is the hunting of ducks during the period when winter turns to spring (the term "spring winter hunting" is used locally). The term "spring hunting" is commonly used in the scientific literature and will be used in this report. Spring hunting has long traditions in the Sami areas of Finnmark. Spring migrating ducks is an important food source as they provided fresh meat in a period that traditionally was characterized by scarcity and little variation in the diet. This tradition has survived as a recreational hunt, notably in the Kautokeino area (Buljo et al., 2021).

The most valued species during the spring hunt have traditionally been diving ducks, especially large sea ducks, such as the common scoter (*Melanitta nigra*), velvet scoter (*Melanitta fusca*), and long-tailed duck (*Clangula hyemalis*) (Buljo et al., 2021). In addition, the Sami people hunted other diving ducks, such as tufted ducks (*Aythya fuligula*), red-breasted mergansers (*Mergus serrator*), and goldeneyes (*Bucephala clangula*). Dabbling ducks were traditionally not highly valued and hunted to a lesser extent.

According to the most recent regulations on quota-regulated spring hunting of ducks from 2013 to 2022 for Kautokeino/Guovdageainnu municipality, Finnmark county, it was permitted to hunt male birds of three species: mallard (*Anas platyrhynchos*), tufted duck, and red-breasted merganser. It was permitted to kill up to 150 ducks per year, and of this total quota, the number of tufted ducks could not exceed 100 individuals (Table 1) (Lovdata, 2013). The hunting period was up to 10 days within the period 15 May to 10 June. Finnmarkseiendommen/Finnmàrkkuopmodat in collaboration with Kautokeino municipality, determines the final hunting period. Finnmarkseiendommen grants hunting licenses, and licenses can be granted to persons who have paid the hunter's fee, and who for the past five years have been and are still residents of Kautokeino municipality.

Traditional hunting of ducks during spring in other countries

In most European countries, spring hunting is no longer permitted. EU's Birds Directive (Directive 2009/147/EC - https://eur-lex.europa.eu/eli/dir/2009/147/oj), which is the oldest piece of EU legislation on the environment and one of its cornerstones, recognises hunting as a legitimate activity under specific conditions to ensure that this practice is sustainable. Birds may not be hunted during the various stages of reproduction or their return to rearing grounds unless certain conditions are fulfilled, for instance, that there is no other alternative to the hunting, that it takes place to prevent serious damage to crops, for research, or that it is selective, and the quota limited to small numbers.

Hunting in Sweden and Finland

Spring hunting is not allowed, nor has this been a tradition, in Sweden (Per Risberg, Swedish Environmental Protection Agency, personal communication). Finland used to have a long-lasting tradition of hunting of adult male ducks (also called drakes) in the spring. This ceased when Finland joined the European Union in 1996 and harmonized its legislation with EU (Merkel and Barry, 2008). Hunting of male common eider (*Somateria mollissima*) is allowed in designated areas of the outer part of The Archipelago Sea (Finnish: Saaristomeri, Swedish: Skärgårdshavet) in southwestern Finland (east of Åland) during the first two weeks of June, which is regarded as summer hunting taking place on the autumn migrating males (Mikko Alhainen, Finnish Wildlife Agency, personal communication).

Spring hunting on waterfowl has been a long cultural tradition in Åland (an autonomous region in Finland), and hunting was allowed on males of several waterfowl species. Following a decision in the EU court in 2005, hunting was only permitted on long-tailed ducks for a few years. Hunting was significantly reduced after Åland joined the EU, with various quotas, personalized permits, and shortened hunting season to fulfil EU's Birds Directive (Directive 2009/147/EC). Since 2020, spring hunting was no longer allowed in Åland (Robin Juslin, Government of Åland, personal communication).

Hunting among indigenous people in other arctic areas:

In Russia, traditional subsistence hunting by indigenous people does not require a hunting permit and is allowed all seasons (Klokov and Syroechkovskiy, 2018). Hunting ducks in spring seems to be common, but it is only allowed to shoot males (Kostin, 1996; Merkel and Barry, 2008).

In Greenland, like in Norway, Sweden and Finland, all birds are protected, but hunting is allowed during specified seasons. The indigenous people of Greenland do not have special rights to hunt ducks outside this season. For mallards and long-tailed duck, the regular hunting season starts September 1st and lasts until the end of February (https://www.sullissivik.gl/-/media/sullissivik/blanketter-og-pdf/jagt_fangst_og_fiskeri/piniarneq-2021-da.pdf?la=da-dk). Red-breasted merganser is not hunted. Velvet scoter, common scoter, and tufted duck are rarely found on Greenland (Boertmann, 1994).

In USA and Canada, the Migratory Birds Convention from 1916 is implemented in the current federal Migratory Bird Treaty Act and Migratory Birds Convention Act, respectively. This prohibits the hunting of ducks during spring. However, after an amendment in the treaty between the nations in 1995, subsistence hunting in the spring by Indigenous people may still be allowed (see below).

In Canada, the Migratory Birds Regulations have just been comprehensively updated and revised (Migratory Birds Regulations, 2022: SOR/2022-105 - https://www.gazette.gc.ca/rp-pr/p2/2022/2022-06-08/html/sor-dors105-eng.html). The new regulations came into force on July 30, 2022. Inclusion of the recognition of the existing Indigenous and treaty harvesting rights of individuals recognized and affirmed under section 35 of the Canadian Constitution

Act, 1982 was among the main objectives of this modernization (see the Regulatory Impact Analysis statement on the website: https://www.gazette.gc.ca/rp-pr/p2/2022/2022-06-08/html/sor-dors105-eng.html).

In Canada, Indigenous peoples may hunt migratory birds and harvest their eggs without a permit and without being subject to a limit as to open seasons, a daily bag limit or a possession limit (Migratory Birds Regulations, 21(1)).

In the USA, apart from Alaska, special regulations apply to hunting for "Indian Tribes on reservations and ceded lands" (Federal Register, 2022). However, the hunting regulations are still consistent with the closed season between March 10th and through September.

In Alaska, the mentioned amendment in the treaty between USA and Canada, allowed the reintroduction of traditional subsistence hunting and harvest of eggs during spring and summer for permanent residents of local villages, regardless of ethnicity (https://www.fws.gov/subsistence-springsummer-bird-harvest-2022-alaska). A large number of species, among them several relevant for this report (i.e., mallard, ring-necked duck (*Aythya collaris*), greater scaup (*Aythya marila*), lesser scaup (*Aythya affinis*), red-breasted merganser, surf scoter (*Melanitta perspicillata*), white-winged scoter (*Melanitta deglandi*), black scoter (*Melanitta americana*), and long-tailed duck are open for hunting. The Alaska Migratory Bird Co-Management Council manage the harvest and consists of representatives from the U.S. Fish & Wildlife Service, Alaska Department of Fish & Game, and Alaska Native representatives from each of the ten subsistence regions in Alaska. The role of the Council is to (quote from bulletpoint 5) "develop recommendations for, among other things: seasons and bag limits, methods and means of take, law enforcement policies, population and harvest monitoring, education programs, research into, and use of, traditional knowledge, and habitat protection." (https://www.fws.gov/node/269356).

Methodology and Data

Narrowing the scope of the biodiversity assessment

The project group narrowed down the task from assessing risks to biodiversity in general to assessing risk to target (the six duck species) and non-target wildlife species (i.e., other migratory waterbirds). For both target and non-target species, the assessment of potential indirect (non-lethal) impacts of hunting activity is based on general scientific knowledge about the impacts of human disturbance on wildlife, in particular on waterbirds.

We assess consequences of spring hunting on the local populations of target and non-target species – either by killing or through increased disturbance – and define negative consequences as either the situation where i) hunting mortality rates exceed net population growth rates over time, which will cause population decline, i.e., the hunting is unsustainable or ii) hunting disturbance is so severe that it could potentially cause population declines.

Data and information gathering

The project group gathered data from articles from literature searches and reports from Kautokeino municipality to Finnmarkseiendommen, which were made available to the committee by The Norwegian Environment Agency. We acquired hunting statistics from Statistics Norway (Statistisk sentralbyrå, SSB).

Literature search and selection

We performed literature searches for each of the six target species, combined with its scientific name, using the Advanced Search Builder provided by Web of Science (WoS). We did not restrict article language or temporal coverage in our search, and the search strings applied are specified in Appendix I. Finally, the involved experts used their own databases of relevant scientific literature.

Relevance screening

Articles were included or excluded based on:

Inclusion criteria: Studies that were within the mandate (i.e., biodiversity, animal welfare, hunting, species biology, brood, conspecific parasitism, sex ratios, population ecology, or ecological consequences) were included.

Exclusion criteria: Studies addressing the following topics were omitted: Diseases, ecotoxicology, pesticides, phylogenetics, antimicrobial resistance, and studies addressing ethical or socio-economic aspects of hunting, marking, and tracing methods.

Initial relevance screening was performed by VKM staff with the titles and abstracts of all hits in searches were scanned. The remaining abstracts were retained for further relevance screening by the rest of the project group (Appendix I).

- Literature search for tufted duck retrieved 319 hits, of which 50 were found relevant.
- Literature search for red-breasted merganser retrieved 72 hits, of which 20 were found relevant.
- Literature search for long-tailed duck retrieved 140 hits, of which 44 were found relevant.
- Literature search for common scoter retrieved 109 hits, of which eight were found relevant.
- Literature search for velvet scoter retrieved 98 hits, of which 23 were found relevant.

For mallards, a literature search was not performed, but literature used in a recent VKM report on the animal welfare of mallard was used (VKM, 2017).

Risk assessment approach

Our initial ambition was to assess the risks to target and non-target wildlife (migratory waterbirds) using a semi-quantitative risk assessment approach, where the outcome of the risk assessments (low, moderate, or high risk) is determined by the score along two axes in a matrix: 1) the overall likelihood of impact; and 2) the magnitude of the potential impact on biodiversity, and finally displayed in a risk matrix diagramme (e.g., VKM 2017).

However, because of the lack of data on local and regional population sizes and trends for the six target species; their distribution in space and time; critical life history parameters for these populations; and discrepancies between quotas and offtake (number of birds harvested) for the different species, the outcomes (risk assessments) were not presented in risk matrix diagrams. The same applies to non-target wildlife species, for which information was even more limited.

In our qualitative assessments, we defined likelihood as:

- Low: <10 % probability of the exposure/consequence occurring
- Moderate: 10 – 50 % probability of the exposure/consequence occurring
- High: >50 % probability of the exposure/consequence occurring

Consequence, i.e., the magnitude of the effects of spring hunting, was defined as:

- Low: Limited or no consequences from spring hunting on biodiversity[1] or animal welfare
- Moderate: Short-term or reversible consequences from spring hunting on biodiversity[1] or animal welfare
- Serious: Long-term consequences from spring hunting on biodiversity[1] or animal welfare

[1]See section "Narrowing the scope of the biodiversity assessment" for definition of biodiversity.

Risk was determined by the combined scores for likelihood (L) and consequence (C):

- Low risk: L(low)+C(low) or L(low)+C(moderate) or L(moderate)+C(low)
- Moderate risk: L(moderate)+C(moderate) or L(low)+C(high) or L(high)+C(low)
- Major risk: L(high)+C(high) or L(high)+C(moderate) or L(moderate)+C(high)

Confidence of the assessments was graded based on amount of accessible information:

- Low: No or only limited data; data of poor quality and/or old data were available; or only general publications or publications concerning other bird populations were available, and the assessment relied heavily on expert judgements.
- Medium: Some relevant data and published information exists on the topic, but expert judgements were still used.
- High: There was sufficient data and/or published information available, and expert judgements were in concurrence.

Notably, uncertainty about the outcome due to lack of knowledge about current and local circumstances is one of the reasons for the low confidence levels of this assessment, for example when we do not know the current size of the local populations of ducks, or to what degree increased mortality will be compensated by migration from other areas.

We assessed the risks to local target populations, assuming that quotas of 150, 300, and 500 male duck are filled, because we lack knowledge about any discrepancies between quotas and offtake (number of birds harvested) for the target species.

The assessment of the direct effects (mortality) of spring hunting for males on target and non-target waterbirds was based on the Norwegian red list of species classification (Artsdatabanken, 2021) and available information of population trends and hunting statistics, scientific knowledge about the ecology of the species, as well as scientific studies of the impacts (timing of) hunting on wildlife (waterbird) populations, and insight from our modelling exercise. For indirect effects of hunting on target and non-target species, we could only make a very general assessment based on the scientific literature on the effects of human disturbance, including hunting disturbance, on wildlife behaviour and populations.

In the absence of data on local population sizes for all six target species, the project group carried out a population modelling exercise (See Appendix II and III), in an attempt to gain more insight into the potential effects of harvesting on population abundance and growth, and to improve our understanding of what type of empirical information managers need to be able to quantify the effects of spring hunting, and to make informed decisions about quotas.

Ecology and status of the target species, harvest, and landscape context

Ecology and conservation status of the target species

Mallard (*Anas platyrhynchos*) [Norwegian: stokkand, Northern Sami: duoršu]

The mallard (Figure 1) is the most common dabbling duck in Norway. According to recent hunting statistics (SSB), about 10,000 individuals are shot annually during the autumn hunt, mainly in Trøndelag County and further north (Pedersen et al., 2021). The mallard is one of the largest dabbling ducks and can weigh up to 1.3 kg.

Figure 1. Male (in front) and female (behind) mallard (Photo: Doug Olson, Mostphotos.com).

Population development: In Norway, winter censuses carried out in 1979-1993 indicate an increasing population, but the recent population development is poorly known (Pedersen et al., 2021). The Norwegian breeding population was estimated to be somewhere between 43,000 and 75,000 pairs 2005-2014 (Shimmings and Øien, 2015) (Pedersen et al., 2021). Worldwide, the population of mallards seems to be increasing in size (Birdlife International, 2019).

Habitat: Inhabits diverse habitats. Nests are usually near calm, freshwater, often in wetlands, but can also be found close to rivers and brackish water, sometimes in marine environments (Cramp and Simmons, 1977).

Migration: Most populations migrate, but some are resident (Bakken et al., 2003; Cramp and Simmons, 1977). Birds from inland areas, also in Finnmark, most commonly move to coastal waters in during winter (Bakken et al., 2003).

Behaviour and social patterns: Breeding starts from the end of April to the beginning of June, depending on local conditions. Mallards are usually seasonally monogamous (forming new pairs each year). Pair formation usually takes place in the autumn but can also occur in late winter. Most populations have a surplus of males (Cramp and Simmons, 1977; Pattenden and Boag, 1989), and the species is known for promiscuous behaviour where the males mate with several females, also by forced mating (Cramp and Simmons, 1977). The male defends an area around the female in the time before and during egg-laying. It normally takes 50-60 days before the young fledges, and sexual maturity occurs at the age of 1 year (Drilling et al., 2020).

Conservation and management: The mallard is a Least Concern (LC) species both in the Norwegian Red List for Species (Stokke et al., 2021a) and in the IUCN Red List of Threatened Species, where a trend of increasing population size is reported (Birdlife International, 2019). The legal hunting period for mallard in Norway is August 21 – December 23 (Lovdata, 2022). According to the most recent regulations on quota-regulated spring hunting of ducks from 2013 to 2022 for Kautokeino, it was permitted to hunt male mallards for up to 10 days within the period 15 May to 10 June (see Lovdata, 2013 for details and quotas).

Tufted duck (*Aythya fuligula*) [Norwegian: toppand, Northern Sami: diehpefiehta]

The tufted duck (Figure 2) is one of Norway's most common freshwater diving ducks and weighs up to one kg. There has been, and still is, some autumn hunting for the species, especially in Viken and Rogaland (Pedersen et al., 2021).

Figure 2. Male (right) and female (left) tufted duck (Photo: Dmytro Pylypenko, Colourbox.com).

Population development: The Norwegian breeding population of tufted ducks increased in southern Norway in the period leading up to the 1990s (Nygård, 1994), and was estimated at 6500-9000 pairs in 2005-2014 (Shimmings and Øien, 2015), but little is known about the population development in the rest of the country in recent years (Pedersen et al., 2021). Worldwide the number of tufted ducks seems stable (BirdLife International, 2016).

Habitat: Prefers small and medium-sized lakes where the water is shallower than 15 m. During the breeding season, the species uses ponds and lakes with moderate depths (3-5 m).

Migration: The Norwegian population overwinters mainly in the North Sea area, in Germany, Denmark, and United Kingdom.

Behaviour and social patterns: Tufted ducks start breeding at the beginning of June, depending on local conditions. It is seasonally monogamous, and the pair formation occurs in March and April, sometimes females may not mate until the end of May, and most populations have a surplus of males (Cramp and Simmons, 1977; Poysä et al., 2019). The pair bonds do not appear to be particularly strong, and examples of bigamy have been observed (Cramp and Simmons, 1977). There is very little information about tufted ducks being territorial before egg-laying, but anecdotal evidence of this exists. It takes 45-50 days before the young fledge. Sexual maturity occurs at one year of age, but more usually at two years (Carboneras and Kirwan, 2020a; Cramp and Simmons, 1977).

Conservation and management: Both the Norwegian Red List for Species and the IUCN Red List of Threatened Species classifies tufted ducks as Least Concern (LC: Stokke 2021b, Birdlife International, 2016). A stable population size trend for this species is reported in the IUCN Red List (Birdlife International, 2016). The legal hunting season for tufted ducks in Norway is September 10 – December 23 (Lovdata, 2022). According to the most recent regulations on quota-regulated spring hunting of ducks from 2013 to 2022 for Kautokeino, it was permitted to hunt male tufted ducks for up to 10 days from 15 May to 10 June (see Lovdata, 2013 for details and quotas.

Velvet scoter (*Melanitta fusca*) [Norwegian: sjøorre, Northen Sami: skoarra]

The velvet scoter (Figure 3) is a large sea duck (1.5-2 kg), and there is no legal spring hunt for this species in Norway, although birds have been shot in the past in the Kautokeino area, during the traditional spring hunt (Jaren, 1983).

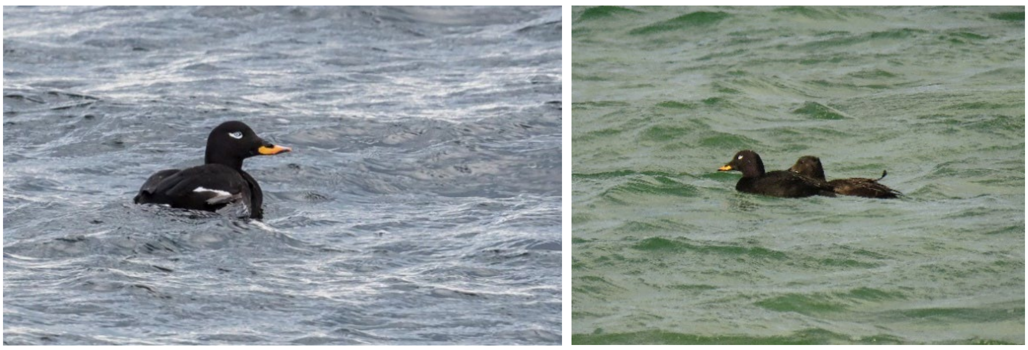

Figure 3. Male (left) and female (right) velvet scoter (Photos: John Haugen CC BY 4.0 and Donald Hoburn CC 2.0).

Population development: The Norwegian breeding population is small and was estimated at 400-650 pairs 2005-2015. The population had then declined by around 30% in Norway since the early 1990s (Shimmings and Øien, 2015).

Habitat: The velvet scoter nests close to freshwater ponds, mainly inland, but it may also breed near brackish water. During winter, the velvet scoter mostly stays in marine habitats close to the shore, with sandy bottom, but may also be found in lakes.

Migration: The migrations of the Norwegian population are largely unknown.

Behaviour and Social Patterns: Egg laying starts around mid-June. Velvet scoters are seasonally monogamous, and pair bonds may form in winter flocks, although most pairs seem to develop during the spring migration. The young fledge at the age of 45-50 days and sexual maturity occurs at the age of 2–3 years (Carboneras et al., 2020; Cramp and Simmons, 1977).

Conservation and management: The velvet scoter is assessed as vulnerable (VU) on the Norwegian Red List for Species (Stokke et al., 2021c). The species is listed as vulnerable (VU) with a decreasing population size trend on the IUCN Red List of Threatened Species (Birdlife International, 2020). Under the convention of migratory species (CMS), the parties under African Eurasian waterbird Agreement (AEWA) have implemented an International Single Species Action Plan for Velvet Scooter, which should be implemented in Norway and other party countries (Dagys et al., 2015). According to the current national regulations on hunting and hunting times (Lovdata, 2022), hunting for velvet scoter is not allowed in Norway.

Common scoter (*Melanitta nigra)* [Norwegian: svartand, Northern Sami: njurgu]

The common scoter (Figure 4) is a large sea duck (1.5-2 kg), and relatively rare duck species in Norway. The common scoter is currently not legally hunted in Kautokeino during spring, but it has been shot in Kautokeino in the past (Jaren, 1983), and hunters express preferences for it as a game species.

Figure 4. Male (left) and females (right) common scoter (Photos: Svein-Håkon Lorentsen and Jan Ove Gjershaug, CC BY 4.0).

Population development: The breeding populations in northern Fennoscandia declined over the past century (Haapanen and Nilsson, 1979), and the Norwegian breeding population (635-1255 pairs 2005-2014) has declined since the early 1990s (Shimmings and Øien, 2015).

Habitat: Common scoters breed in freshwater, often in mountainous regions, and sometimes in forested areas. During winter, the common scoter mostly stays in marine habitats close to the shore.

Migration: The migration pattern of the Norwegian population is poorly known.

Behaviour and Social Patterns: Egg laying occurs around mid-June. Common scoters are seasonally monogamous, and promiscuous behaviour with forced mating occurs (Cramp and Simmons, 1977). While mating begins in the winter flocks, most pairs form during the spring migration. Little is known about the male's territorial behaviour except that the males defend the female against other males before and during egg laying. The young fledge at the age of 45-50 days, and sexual maturity occurs at 2–3 years of age (Carboneras and Kirwan, 2020b; Cramp and Simmons, 1977).

Conservation and management: The common scoter is assessed as vulnerable (VU) on the Norwegian Red List for Species (Stokke et al., 2021d). The species is listed as vulnerable (VU) with a decreasing population size trend on the IUCN Red List of Threatened Species (Birdlife International, 2018a). Some autumn hunting of common scoters has taken place in Norway, especially in Viken and Agder, numbering about 1500 birds per year (Pedersen et al., 2021). According to the current national regulations on hunting and hunting times (Lovdata, 2022), hunting for common scoter is allowed in Norway only in former Østfold county from 10 September to 23 December.

Long-tailed duck (*Clangula hyemalis)* [Norwegian: havelle, Northern Sami: haŋŋá]

The long-tailed duck (Figure 5) is a common sea duck on most of the Norwegian coast in winter. It is also a relatively common breeder in Norwegian high mountain areas. Individuals of this species are relatively small and usually weigh between 600g and 800g (up to 1 kg).

Figure 5. Male (left) and female (right) long-tailed duck (Photos: Judy Gallagher and Ron Knight, CC BY 4.0).

Population development: The Norwegian breeding population was estimated at 3,000-7,000 pairs 2005-2014 (Shimmings and Øien, 2015), but the population in Scandinavia has declined considerably over the last decades (Stokke et al., 2021e).

Habitat: Long-tailed duck breed in mountainous regions, up to the willow and dwarf-birch belt, and avoids the forested tundra. It prefers calm water and is often seen on small lakes.

Migration: Much of the Scandinavian breeding population (3,000-7,000 pairs) seems to winter along the Norwegian coast together with birds from north-western Russia (Bustnes and Bianki, 2000).

Behaviour and Social Patterns: Breeding starts at the beginning of June. Strong monogamous pair bonds may span several years in some pairs (Alison, 1975). The birds arrive in the nesting area in pairs. Mating occurs from November, and most birds stay in pairs from January to February. Populations often have an excess of males (Cramp and Simmons, 1977). The male fiercely defends the female during the time before the incubation begins. Promiscuous behaviour is rarely detected. Alison (1975) found that the females did not form new pairs if the male was removed just before breeding, and apparently did not produce offspring. The young fledge after 35-40 days, and sexual maturity occurs from the age of 2 years (Robertson and Savard, 2020).

Conservation and management: The long-tailed duck is categorised as Near Threatened (NT) in the Norwegian Red List for Species (Stokke et al., 2021e) and as Vulnerable (VU) in the IUCN Red List of Threatened Species (Birdlife International, 2018b). BirdLife International's (2018) definition was due to a decreasing trend in population size. Harvest of long-tailed ducks was allowed until 2017 (Lovdata, 2012), and harvested numbers are in the data from Kautokeino (Table 1). Under the convention of migratory species (CMS), the parties under African Eurasian waterbird Agreement (AEWA) have implemented an International Single Species Action Plan for Long-tailed Duck, which should be implemented in Norway and other party countries (Hearn et al., 2015). According to the current national regulations on hunting and hunting seasons, hunting for long-tailed duck is not allowed in Norway (Lovdata, 2022).

Red-breasted merganser (*Mergus serrator*) [Norwegian: siland, Northern Sami: vuoktagoalsi]

The red-breasted merganser (Figure 6) is a common duck in Norway, both during the breeding and winter season. It is fish-eating and weighs up to 1.4 kg. At present, about 1500 red-breasted mergansers are shot annually in Norway during the autumn hunt. Most birds are shot in Vestland and Agder counties.

Figure 6. Male (left) and female (right) red-breasted merganser (Photo: Sten-Åke Stenberg, Mostphotos.com).

Population development: The breeding population in Norway 2005-2014 was estimated at 10 000-30 000 birds (Shimmings and Øien, 2015). There are some indications that this species has increased somewhat in number in Norway over the past decade (Pedersen et al., 2021), with relatively large flocks becoming more abundant along the coast in the non-breeding season. Worldwide, the population size of red-breasted mergansers has seemed stable, although probably decreasing in some parts of Europe (BirdLife International, 2018c).

Habitat: Nests in both marine environments and freshwater. Also found near rivers with moderate currents and deep waters.

Migration: Red-breasted merganser typically migrates from the inland to winter in coastal waters (Craik et al., 2020). The Norwegian breeding population seems to winter mainly off the coast of Norway (Bakken et al., 2003), but there is no information about the wintering areas of birds in Finnmark.

Behaviour and social patterns: The red-breasted merganser begins to lay eggs during the second half of May. It is seasonally monogamous. Polygyny (one male mate with several females) and polyandry (one female mate with several males) have been observed (Cramp and Simmons, 1977). This could indicate relatively weak pair bonds. Pair formation is observed from November, but most pairs are formed in late winter and during spring migration. The pairs are, unlike other species, social in the time before laying eggs and are often found in flocks on the water or in resting sites on land. The young fledge after 60 to 65 days and most females start breeding at the age of two years (Cramp and Simmons, 1977; Craik et al., 2020).

Conservation and management: The red-breasted merganser is classified as Least Concern (LC) in the Norwegian Red List for Species (Stokke et al., 2021f) and in the IUCN Red List of Threatened Species, where stable population size is reported (Birdlife International, 2018c). The legal hunting period for red-breasted merganser in Norway is September 10 – December 23 (Lovdata, 2022). According to the most recent regulations on quota-regulated spring hunting of ducks from 2013 to 2022 for Kautokeino, it was permitted to hunt male red-breasted mergansers for up to ten days within the period 15 May to 10 June (see Lovdata, 2013 for details and quotas).

Information on local populations sizes of target species

Scarce data on population sizes are available for ducks in Kautokeino, but limited information is available from aerial counts done in 1996 (Bustnes and Nilsen, 1996). The tufted duck was the most common species on the Katuokeino river in the spring of 1996 and the most common breeding duck in the municipality. The estimated number of tufted ducks was between 620 and 1030 pairs, depending on how much of the population had started breeding at the time of the aerial count.

Only scattered individuals of common scoter and velvet scoter were observed in- and around Kautokeino before- and during the hunt. Nevertheless, there were relatively many birds during the aerial count. These species are clearly visible from aircrafts because they are large and arrive late. Bustnes & Nilsen (1996) estimated that the number of these two species in the whole of Kautokeino municipality (9707 square kilometres) was just over 500 birds (200-250 pairs). This figure is well in line with the estimates for northern Fennoscandia in the early 1970's (Haapanen and Nilsson, 1979).

However, nothing is known about the present population sizes and trends for the duck species hunted in Kautokeino as no data, to our knowledge, have been collected since the mid-1990s. Large changes may have occurred in the populations in the almost 30 years that have passed since the last census. Moreover, the breeding range of the ducks shot during the spring hunt is not known; i.e., whether they are local breeders or disperse over large areas in western Finnmark.

Areas in Kautokeino where spring hunting takes place

The spring hunting for ducks in Kautokeino traditionally started as the ice broke up on rivers, ponds, and lakes (see Buljo et al. 2021 for a detailed description). At this time, the ducks aggregate in the open waters and hence the habitat available to the ducks is limited, and they are most accessible to the hunters. The legal hunting in recent years has been restricted between 15 May and 10 June, over a period when most of the ice melts, providing more feeding habitats for the ducks and thus more spacing out.

When the ducks are on the staging-areas on the open waters in spring, the daily number at specific location varies greatly, and the onset of hunting seemed to increase such spatial movements (Bustnes and Nilsen 1995; 1996). Moreover, the breeding grounds of the hunted ducks are found in a much larger area than just the hunting areas. As the ice on the lakes and ponds breaks up, the birds move from the staging areas to their breeding habitats. However, it is not known what proportion of the ducks that aggregate on open waters in

Kautokeino in spring are just using Kautokeino as stop-over site, and what proportion of the birds actually breed in the vicinity of Kautokeino.

After 2013, the spring hunting has been limited to the following lakes and river stretches in Kautokeino municipality (typonomy according to the regulation): 1. Calbmejavri, Luovosjavri, Luovosluoppal, Aidejavri and Lahppojavri. The Kautokeino river on the stretch from the bridge at Økseidet to the Suophatjohka confluence, from Labbesuolo north of Kautokeino church site to the Kautokeino river Lahppojohka confluence (except Mieronjavvi), from Habatguoika to the Mazejohka confluence and from Cievramielli in the lower Maze to Heastanjarga in Latnetjavri; and 2. Sihccasaiva, Roggeluoppal at Galaniito and Raggesluoppa (Lovdata, 2013) (Figure 7).

Figure 7. Map showing the lakes and river stretches where lodden, i.e., the spring hunting on ducks, was allowed 2013-2022 (dark blue). (1a) Čalbmejávri, Luovosjávri, Luovosluoppal and Aidejávri, (1b) Láhpojávri; (1c) Kautokeino river (Guovdageaineatnu) from Økseidet (Ákšomuotki) to Suohpatjohka confluence, (1d) Kautokeino river from Láppessuolo north of Kautokeino church site to the Láhpojohka confluence (excl. Mierojávri), (1e) Kautokeino river from Hábatguoika to Mázejohka confluence, (1f) Kautokeino river from Čievramielli to Heastanjárga in Latnetjávri, (2a) Šihččasáiva, (2b) Roggeluoppal at Gálaniitu and (2c) Rágesluobbalat. Modified from a map provided by the Norwegian Nature Inspectorate (SNO). Toponomy in legend adjusted from the regulation (Lovdata, 2013) to be in accordance with the toponomy in the Norwegian Place Name Register (SSR) by comparing the map from SNO with maps from the Norwegian Mapping Authority (Kartverket) at www.norgeskart.no.

Hunting statistics 2007-2022

We found information about the number of male ducks shot in the spring in reports from Kautokeino municipality to Finnmarkseiendommen for the years 2007-2012, 2014-2017, and 2019-2022 (Finnmarkseiendommen, 2020; Finnmarkseiendommen, 2021; Finnmarkseiendommen, 2022; Kautokeino Kommune and Finnmarkseiendommen, 2007; 2008; 2009; 2011; 2012; 2014; 2015; 2016; 2017; 2019). Species-specific counts of the number of individuals shot are based on reports from hunters (Figure 8).

Both quotas, hunting effort, the proportion of quota reported shot, the proportion of hunters submitting hunting reports, and the amount of information included in the annual reports from Kautokeino Municipality, vary among years (Table 1). Consequently, it is difficult to assess whether the apparent declines in the number of hunted individuals, e.g., for tufted ducks (Figure 8 and Figure 9), reflect actual population declines (see also Ericsson and Wallin, 1999; Pedersen and Pedersen, 2012; Cattadori et al., 2003 for a discussion of the usefulness of hunting statistics as a proxy for populations status and trends).

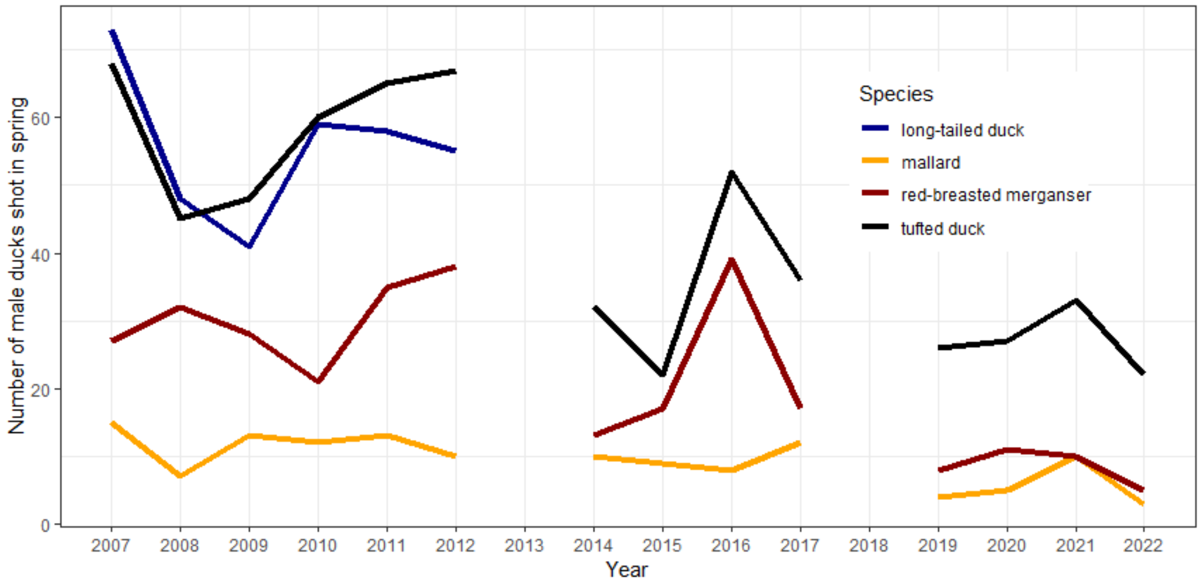

Figure 8. Reported offtake (number of birds harvested) during spring hunting in Kautokeino Municipality. The number of male ducks reported shot during spring hunting in 2007-2022. No hunting licenses were issued for spring hunting in 2013. Data from 2018 are missing. For data on licenses, quotas, and reporting, see Table 1.

In Statistics Norway's (SSB) hunting statistics for Kautokeino (2009-2022), all the target species except velvet scoters were represented (Figure 9).

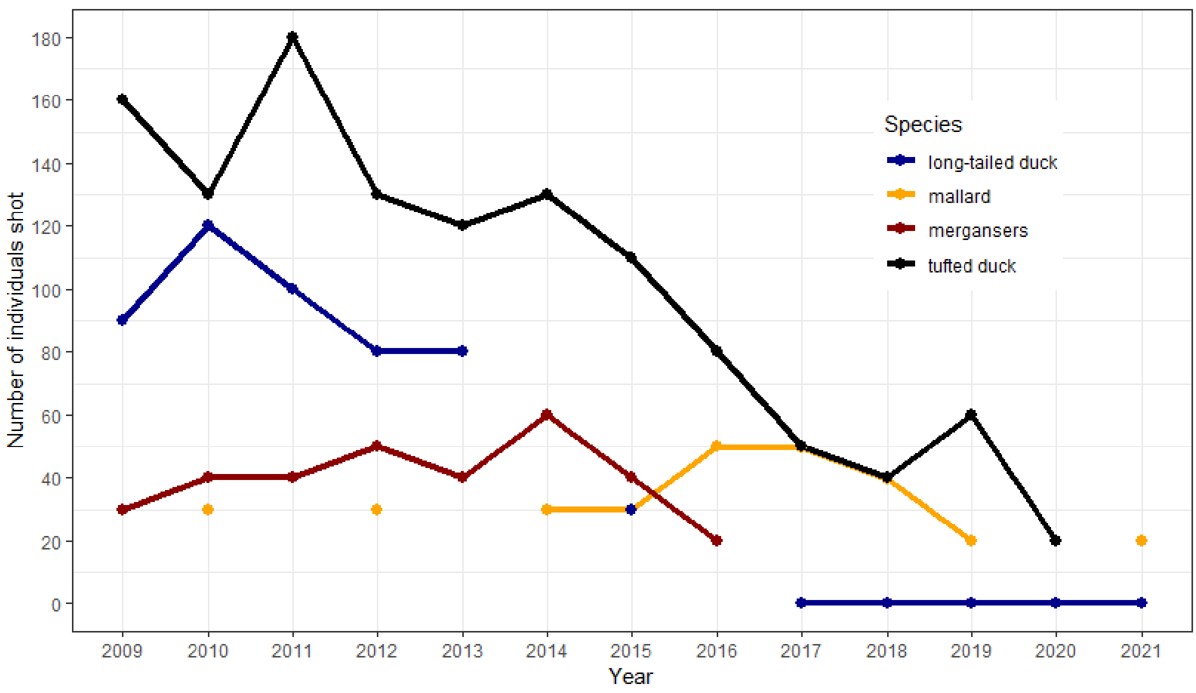

Figure 9. The number of ducks shot per "hunting year" in Kautokeino Municipality. A "hunting year" is from 1 April to 31 March (e.g., 2010 is from 1 April 2010 to 31 March 2011). Data on the number of individuals shot are from Statistics Norway's hunting statistics (SSB; downloaded in October 2022, see details in Hagesæther and Rundtom, 2010). In addition to the data in the diagramme, the hunting statistics includes some information on number of shot common scoters: 30 in 2011; 50 in 2013, 0 in 2016-18 and 2021, while there was no information about velvet scoters from Kautokeino. Gaps in the data series mean missing data. The mergansers are pooled data for red-breasted merganser (*Mergus serrator*) and goosander (*M. merganser*; the underlying data do not differentiate between red-breasted merganser and goosander). According to the new regulations on hunting and hunting times (Lovdata, 2022), hunting for long-tailed ducks, is no longer permitted.

Table 1. Key figures relating to hunting effort, quotas, and reporting of ducks shot in the spring hunting in Kautokeino Municipality in 2007-2022. Appl. = number of hunters who applied for a spring hunting license; Licenses = number of licenses (NO: jaktkort) issued; (Un)Claimed = number of licenses (not) collected; Quotas (number of male ducks): Total = all species; TD = tufted duck; LTD = long-tailed duck; No. reported = number of ducks shot, according to reports from hunters, % of quota reported shot = percentage of quota shot; Reports: Count = number of individual reports from hunters, % of licenses = percentage of reports relative to total number of issued licenses, % of claimed = percentage of reports relative to the number of claimed licenses. Source: Annual reports from Kautokeino Municipality to Finnmarkseiendommen. In 2013, no spring hunting licenses were issued. Reports from 2020, 2021, and 2022 do not include information about claimed and unclaimed licences, or number of reports (*). Data from 2018 are missing.

					Quotas			No. reported shot			% of quota reported shot			Reports		
Year	**Appl.**	**Licences**	**Claimed**	**Unclaimed**	**Total**	**TD**	**LTD**	**Total**	**TD**	**LTD**	**Total**	**TD**	**LTD**	**Count**	**% of licences**	**% of claimed**
2007	122	122	113	9	300	100	100	183	68	73	61	68	73	97	86	80
2008	138	138	115	23	300	100	100	132	45	48	44	45	48	74	64	54
2009	114	114	92	22	300	100	100	130	48	41	43	48	41	65	71	57
2010	123	123	107	16	300	100	100	152	60	59	51	60	59	82	77	67
2011	131	129	120	9	300	100	100	171	65	58	57	65	58	87	73	67
2012	131	127	119	8	300	100	100	170	67	55	57	67	55	89	75	70
2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2014	110	108	94	14	150	100	0	55	32	—	37	32	—	63	67	58
2015	123	121	115	6	150	100	0	48	22	—	32	22	—	63	55	52
2016	103	99	94	5	150	100	0	99	52	—	66	52	—	90	96	91
2017	101	101	93	8	150	100	0	65	36	—	43	36	—	56	60	55
2018	-	-	-	-	-	-	-	-	-	-	-	-	-—	-	-	-
2019	107	87	67	20	150	100	0	46	26	—	31	26	—	36	54	41
2020	-	137*	-	-	150	100	0	43	27	—	29	27	—	-	-	-
2021	-	117*	-	-	150	100	0	53	33	—	35	33	—	-	-	-
2022	-	93*	-	-	150	100	0	30	22	—	20	22	—	-	-	-
Median	122	119	107	9				82	41	57	43	41	57	74	71	58
Min	101	87	67	5				30	22	41	20	22	41	36	54	41
Max	138	138	120	23				183	68	73	66	68	73	97	96	91

Impacts of spring hunting on wildlife

Impacts of hunting on waterbird populations

Hunting is historically an important driver of biodiversity loss (Maxwell et al., 2016). When unsustainable, hunting mortality can lead to population declines and, in the worst case, extinction. Infamous examples of bird extinctions where overharvest was a contributing factor to extinctions are the great auk *Pinguinus impennis* and the passenger pigeon *Ectopistes migratorius* (Bucher, 1992; Di Minin et al., 2021). Market hunting also contributed to the extinction of eskimo curlew *Numenius borealis* (Graves, 2010; Gill et al., 2020), and probably also Labrador ducks *Camptorhynchus labradorius* (Chilton, 2020). Sustainable use of wildlife resources is central to biodiversity conservation (Di Minin et al., 2021; Diaz et al., 2015; Diaz et al., 2018; Pascual et al., 2017). Any unsustainable impact of hunting on species, particularly those important for peoples' livelihoods, wellbeing, and cultural traditions, presents a threat to the species itself and the associated cultural traditions (McRae et al., 2022). For hunting to be sustainable, annual hunting mortality rates cannot be higher than net population growth rates over time (Boyce et al., 1999; Hilborn et al., 1995; Lande et al., 1995; Riecke et al., 2022).

Even without killing, disturbance from hunting activities can have negative impacts on wildlife. There is ample evidence of negative impacts of disturbance from hunting on waterfowl behaviour and distribution (see reviews by Davidson and Rothwell, 1993; Madsen and Fox, 1995). Hunting disturbance can affect both target and non-target species (Martinez-Abrain et al., 2013), and non-target individuals within the target species if the hunting permit is limited to certain sex- and age-groups. In the scientific literature on human disturbance effects, effects on birds have received much attention, and many studies have documented negative effects on metabolism, behaviour, and breeding success (e.g., Bolduc and Guillemette, 2003; Beale and Monaghan, 2004 and references therein). Irrespective of whether humans are hunters or recreationists, wild animals are likely to perceive humans as predators and change their behaviours accordingly (Beale and Monaghan, 2004; Frid and Dill, 2002; Gaynor et al., 2021). Many human activities can affect the behaviour of wildlife (Peckarsky et al., 2008; Preisser et al., 2005) and ultimately lead to population-level consequences (Baudains and Lloyd, 2007; Ellenberg et al., 2006).

Hazard identification - Impacts of spring hunting on waterbirds

We have identified two main hazards of spring hunting for male ducks: 1) over-hunting of target species populations, leading to population decline; and 2) potential negative effects on non-target waterbird species. The latter includes: i) direct effects in the form of species identification errors leading to killing non-target species; and ii) indirect effects caused by disturbance of non-target species. Regarding point 1), there is also a risk of misidentification, unintentional disturbance, and killing of females.

Over-hunting of target populations

Many bird populations are declining worldwide (Birdlife International, 2022; IPBES, 2019; Johnson et al., 2017; Rosenberg et al., 2019). Seabirds are more threatened than comparable groups of birds (Croxall et al., 2012). A recent global assessment found that more than 30% of the sea ducks are negatively affected by marine (fisheries bycatch and pollution) and terrestrial (alien species and hunting/trapping) threats (Dias et al., 2019). All the sea duck species in this risk assessment, i.e., long-tailed duck, common scoter, and velvet scoter, are categorized as threatened or near threatened on the Norwegian Red List for Species (Artsdatabanken, 2021) because of decreasing population size trends. Their life history parameters, long generation times and low reproduction rates (Johnson et al., 1992) make it hard for these species to recover. Ecological theory, therefore, suggests that hunting these species can potentially have strong negative impacts.

In hunted populations, a key question is whether hunting mortality is additive to natural mortality rates (Burnham and Anderson, 1984; Conroy and Krementz, 1990; Cooch et al., 2014; Nichols et al., 1984; Sandercock et al., 2011; Sedinger and Herzog, 2012). Negative density dependence may affect the relationship between survival and hunting-induced mortally, making it challenging to estimate these effects separately (Riecke et al., 2022). Hunting mortality is more likely to be additive to natural mortality in wildlife species with high survival and low fecundity because of their lower ability to compensate for losses to hunting and other forms of mortality through density-dependent changes in recruitment, age at maturity, survival, or movements (Hamel et al., 2006; Reese and Connelly, 2011; Sandercock et al., 2011; Sedinger et al., 2007). Cooch et al. (2014) reviewed the evidence of the effects of hunting on waterfowl populations and concluded that results for duck species vary too much to allow for generalizations across species. In addition to direct hunting mortality there is also the issue of crippling losses, i.e., all other deaths attributable to hunting activity, but not counted as hunting mortality (e.g., wounds and lead poisoning; Schulz et al., 2006; Guillemain et al., 2007). As pointed out by Péron (2013) "crippling losses are a source of concern for the estimation of compensation-additivity rate because the impacted animals are classified as dying from natural causes".

Population viability for long-lived species is sensitive to changes in two parameters: adult survival and recruitment (e.g., Stearns, 1992). Based on numerous empirical and theoretical studies, it is a robust generalization that decreases in adult survival are of far greater importance for long-lived species than decreases of the same magnitude in juveniles (Croxall and Rothery, 1991; Gaillard et al., 1998; Gaillard et al., 2000) and even a small increase in adult mortality can lead to rapid population declines (Saether and Bakke, 2000; Stearns, 1992). In a comparative study, Péron (2013) concluded that long-lived species compensate less than short-lived species for human-caused mortality. Sea ducks, such as long-tailed ducks, red-breasted merganser, common scoter, and velvet scoter, are considered to be long-lived (Mallory, 2015).

Within wildlife ecology and management, hunting before or during the breeding season is widely considered a breach of sound management practice because it involves deducting from the capital of breeding adult individuals (Kokko, 2001). For wildlife species that live in seasonal environments, reproduction and (most of) mortality do not coincide in time; therefore, population sizes fluctuate annually (Kokko, 2001). Killing an individual just before reproduction (spring hunting) leads to a more considerable reduction in the population than if the killing occurred earlier (autumn hunting) (Brøseth et al., 2012; Kokko et al., 1998). This is because an individual shot in autumn could have died of other reasons before reproducing, and thus its expected contribution to population growth is lower. The effect of timing of hunting can also vary between populations that differ in critical life history parameters, such as annual survival (Brøseth et al., 2012). Spring hunting has proven to be an efficient conservation measure to reduce the population growth of overabundant species, i.e., the greater snow goose (*Anser caerulescens atlanticus*) in North America, primarily by causing decreased adult survival (Calvert and Gauthier, 2005).

Because male ducks do not provide parental care and leave their incubating mates upon clutch completion, there has traditionally been a widely accepted view that males can be removed without compromising female reproductive success (Kokko et al., 2001). However, as pointed out by Kokko (2001), the empirical evidence for this assumption is lacking. Studies of ducks do suggest that males play an important role in protecting the females, allowing undisturbed feeding in the critical time prior to egg laying (Christensen, 2000, Squires et al., 2007). Knowing how much one can reduce the proportion of males without reducing the capacity to fertilise the female population would require information about the breeding system at extremely biased and not naturally occurring sex ratios (Kokko et al., 2001). In a rare experimental study mimicking spring hunting of male common eiders in the Gulf of Finland, Hario et al. (2002) demonstrated that shooting males while attending females during the pre-laying and laying period lowered the fecundity of eider females reduced nesting success by 35% of long-term averages. To our knowledge, the only other male removal experiment on sea ducks was carried out by Alison (1975), who found that long-tailed duck females did not remate if the male was removed prior to egg-laying (Alison 1975). Manlove and Hepp (1998), however, found few effects to incubating females when they removed male wood ducks (*Aix sponsa*) during incubation, but paired females tended to produce second broods more often than widowed females. In other waterfowl, such as geese, the results of male removal experiments are equivocal. LeSchack et al. (1998) concluded that male removal in two arctic goose species had few effects on female nesting success and incubation behavior, but that males in arctic-nesting geese may be more critical during egg laying and the post-hatch period than during incubation. Martin et al. (1985) was also unable to conclude firmly about the impact of removing male lesser snow goose (*Anser caerulescens*) during incubation.

Even if un-paired male ducks are available, we do not know to what degree they can replace and compensate for the breeding contribution of shot males, which had already paired up with a female. In territorial birds like ptarmigan (*Lagopus* spp.), findings from experimental studies differ. Pedersen et al. (2014) found that territory-holding males shot in spring were replaced, and Martin and Cooke (1987) found few effects on the reproductive performance of willow ptarmigan (*Lagopus lagopus*) females when males were removed during incubation. In contrast, Watson and Jenkins (1968) found that territorial red grouse males (*L. lagopus scoticus*) that were removed in spring were not replaced, even though non-territorial males were present, while territorial males removed during winter or the previous autumn were replaced (Watson and Jenkins, 1968; see also Pedersen, 1988). In ducks, an experimental study by Hario et al. (1995) did show that several common eider females were able to replace the shot male, but with great reductions in reproductive output compared to other females.

In general, most male removal experiments have been carried out after egg laying, so it is difficult to compare these results to impacts of shooting males prior to egg laying as happens in Kautokeino.

Finally, a potentially important factor for determining the impact of the spring hunt is whether the males are paired or not. The killing of a non-paired male probably has less impact on the population in terms of reduced reproduction, compared to killing a paired male. However, if a pair in which a male is shot already have mated, the female may store sperm and may be able to lay viable eggs. Hence, the impact will depend on 1) whether the pair has mated before the male is shot, and 2) how much time and energy the female will lose if she has to find a new male and build bonds. Many of these birds have been in pairs for months and remating is probably a considerable disturbance affecting reproductive performance. Nevertheless, the status of the males is unknown for the spring hunt in Kautokeino, so it cannot be adequately addressed in this risk assessment.

Impacts on other species and non-target individuals

Direct effects – mortality

Spring hunting might entail intentional or unintentional (due to species identification errors) illegal shooting of non-target waterbirds in a critical stage of their annual cycle. According to articles in the news media, illegal killings of non-target species have taken place in Finnmark and within Kautokeino (NRK, 2016a,b). However, the extent of such illegal killings is unknown.

Three threatened goose species occur in Finnmark in spring; the critically threatened (Stokke et al., 2021g) lesser white-fronted goose (*Anser erythropus*) [Norwegian: dverggås, Northern Sami: giljobaš]; the endangered (Stokke et al., 2021h) taiga bean goose (*A. fabalis*) [Norwegian: taigasædgås, Northern Sami: čuonjá]; and the vulnerable (Stokke et al., 2021i) tundra bean goose (*A. serrirostris*) [Norwegian: tundrasædgås, Northern Sami: tundračuonjá]. Almost the entire Fennoscandian breeding population of lesser white-fronted goose breeds in Norway, but even so, the Norwegian breeding population is less than 50 reproducing individuals (Stokke et al., 2021g). Lesser white-fronted goose breeds in Finnmark in undisturbed areas in the low and mid-alpine zone with willow thickets, preferably near water or rivers, but currently use less than 1% of their original range in Fennoscandia (Direktoratet for naturforvaltning, 2009). Birds that breed in Norway stop-over to feed and rest at Valdakmyra in Indre Porsangerfjord but have in recent years also been observed in the Alta river estuary, after being absent for many years (Ken Gøran Uglebakken, SNO, pers. comm). Most of the Norwegian population of 60-120 individuals of taiga bean goose breed in East Finnmark/Troms and Finnmark is also the core breeding area for tundra bean goose (Stokke et al., 2021h; i). For species with very low population sizes, loss of even just one individual can have a negative impact on population viability (Townsend, 2008; Primack, 2014;).

There are several other duck species that may be considered non-target species, some of which were included in the spring hunt in Kautokeino in the 1990s. Non-target species include goldeneye, wigeon (*Anas penelope*), and teal (*Anas crecca*) (Bustnes and Nilsen 1995; 1996). These species are hunted in Norway during autumn. In addition, the goosander (*Mergus merganser*) is a species that may killed accidentally, possibly due to its resemblance to red-breasted merganser. All these seem to be relatively common in Finnmark and are considered of least concern (LC) in Norway, although population trends are uncertain (Shimmings and Øien, 2015; Pedersen et al., 2021).

Hunting for adult males may also increase the risk of killing non-target individuals within the target species (i.e., the females). The target species differ with respect to sexual dimorphism in plumage colouration (see photos in section Ecology and conservation status of the target species) and secondary sex characters (e.g., extended tail feathers in male long-tailed ducks; (Figure 5) in the breeding season. However, even though the sexes may be easy to tell apart under good conditions, this may be difficult under natural environmental conditions. For example, environments with ice and water surfaces can create challenging light- and optical conditions, which makes species and sex identification harder. This will increase the chances of shooting a female by mistake. If an adult female is killed shortly before egg-laying, the expected impact on the population is much larger than if a male is killed; the killed female's contribution to the population in terms of production of new recruits cannot be replaced by another female, whereas a killed male's contribution (mating and fertilizing eggs) can at least partly be replaced by another male.

Indirect effects – disturbance

Both target and non-target wildlife species likely perceive human hunters as predators and respond accordingly (Madsen, 1998a; Madsen and Fox, 1995; Mayhew, 1988). It is well-documented that hunting can have a disturbing effect on waterfowl (Davidson and Rothwell, 1993; Madsen and Fox, 1995; Väänänen, 2001b). Hunting disturbance increases escape flight distances (Madsen and Fox, 1995). Hunting activity can also cause changes in foraging behaviour, such as reductions in the amount of time the birds spend foraging, and shifts in their diel activity patterns, with more daytime foraging in refuge areas without hunting and more night-time foraging outside refuges (Madsen, 1998a; Madsen and Fox, 1995; Mayhew, 1988). Hunting disturbance can cause a spatial redistribution of waterfowl in the landscape with an aggregation of birds seeking shelter in refuge areas (Madsen, 1998b; Väänänen, 2001a). Behavioral responses to disturbance can entail increased energy expenditure and reduce energy intake before the energetically demanding breeding period (Väänänen, 2001a). Whether disturbance effects ultimately result in population-level effects, will depend on the extent of disturbance (Gaynor et al., 2021).

Eggs and chicks are vulnerable to human disturbance because their survival depends on intensive parental care (Bolduc and Guillemette, 2003; Clutton-Brock, 1991). Disturbing incubating and brooding parents in the breeding season is likely to increase the risk of nest failure, either through predation if the parents are scared away from the nest and leave the eggs and chicks unattended, or permanent nest desertion (Bolduc and Guillemette, 2003).

Consequence characterization for waterbird populations

The main challenge with assessing the true impact of the spring hunting in Kautokeino is the lack of data on local population sizes of the species recently hunted (mallard, red-breasted merganser, and tufted duck), and the species that are desired hunting game (common scoter, velvet scoter, and long-tailed duck). This lack of data on population sizes from Kautokeino makes it impossible to make firm quantitative conclusions about the likelihood of negative impacts and the magnitude of the potential consequences of spring hunting.

The lack of data is at several levels: 1) the size of the populations of each duck species is unknown; 2) the size of the male surplus in the populations is unknown; 3) the arrival times of the different species into the hunting grounds are largely unknown; 4) the extent to which the ducks killed during the hunt are replaced by individuals from other areas in the subsequent years is unknown; 5) it is largely unknown to what extent hunted ducks are in established pairs or not, which potentially would greatly influence the impact of hunting. Due to the lack of data, it is not possible to reach firm conclusions in the risk assessment. Nevertheless, based on available information about conservation status and population trends, ecology of the species (see section Ecology and conservation status of the target species), scientific evidence on impacts of (timing of) harvest and hunting disturbance on waterbird populations, as well as insight from our modeling exercise (see Modelling scenarios for impact of spring hunting (below) and Appendix III, we have qualitatively assessed the expected impacts of spring hunting on the local populations of the target species, assuming that quotas of 150, 300, and 500 males, respectively, are filled. Yet, we acknowledge that there is often a discrepancy between quotas and offtake (number of birds harvested; see Table 1 and Uncertainties and data gaps).

The **long-tailed duck**, legally hunted in the 1990s, is categorized as near threatened (NT) on a national level, and the population of this species was relatively small compared to the tufted duck back in the 1990s (Bustnes and Nilsen 1996). Aerial counts at that time suggested that the population of long-tailed ducks was less than 300 pairs, suggesting that shooting 150 males could have serious consequences, and shooting of 300 or 500 will likely lead to temporary local extinction. We assess the likelihood of serious consequences to be high for all quota levels. This assessment is made with medium confidence.

Hunting is expected to have considerable negative impacts on **common scoter** and **velvet scoter**. These species are threatened and have experienced declining population trends both nationally and globally. Bustnes and Nilsen (1996) estimated that the combined total population of velvet- and common scoter was 200-250 pairs in the Kautokeino area (based on aerial counts). Although there could be regional increases (Nilsson and Nilsson, 2012), there is no reason to believe that the national populations of these species have increased, and based on national and international trends, there is reason to suspect they have declined. Hence, killing 150 males of any of these species will likely have serious consequences, and shooting 300 or 500 will most certainly lead to local extinction. We assess the likelihood of serious consequences to be high for all quota levels. This assessment is made with medium confidence.

The **mallard** is a widespread and common duck species in Norway. However, it was not commonly observed in spring in the Kautokeino area in the 1990s- (Bustnes and Nilsen, 1995; 1996). If the current local population size is similar to the status almost 30 years ago, shooting hundreds of mallards in Kautokeino (150-500 males) seems impossible without (at least temporarily) eradicating the local population. Consequently, we assess that the consequences will be serious, with high likelihood. This assessment is made with low confidence.

Although the **red-breasted merganser** seems to have increased in coastal Norway, it was, as the mallard, relatively rare in Kautokeino during the spring in the 1990s (Bustnes and Nilsen 1995; 1996). Hence, hunting this species in large numbers (150-500 males) also seems highly likely to have serious consequences for the local population. This assessment is made with low confidence.

In the 1990s, the **tufted duck** was the most common duck in Kautokeino in spring. Bustnes and Nilsen (1995; 1996) concluded that a limited hunt on males of this species might be sustainable, given the sex ratio in the population at the time. We cannot make a quantitative assessment of the impact of increasing the quotas. Still, our model (see Modelling scenarios for impact of spring hunting and Appendix III) shows that increased hunting pressure and disturbance, combined with climate change, may substantially decrease the ability of the local population to sustain even modest hunting pressure without becoming a population sink. Yet, under the assumption that the current population status (and sex ratio) for tufted ducks in the area is similar to the assessments made >25 years ago (Bustnes and Nilsen, 1995; 1996), we assess that with moderate likelihood, an offtake of 150 males will have low to moderate consequences for the viability of the local population, whereas an offtake of 300 or 500 will have moderate to serious consequences. However, the fact that we lack monitoring data implies that we have no information about current population status (or sex ratios), and hence cannot conclude if increased hunting pressure will have an accelerating negative impact on population viability. These assessments are made with low confidence.

We assess with low confidence that it is moderately likely that spring hunting (for target species) can have moderate negative consequences for **non-target waterbirds** that are associated with the target species during the spring hunting period. For species that are not present during the spring hunting period, we assess that the likelihood and consequences are low, with low confidence. The risk to non-target species depends on population size and the magnitude and spatial extent of the hunting disturbance. Species with critically low population sizes, such as the lesser white-fronted goose, are particularly vulnerable.

We lack recent empirical evidence of the current effects of hunting disturbance on waterbirds – both target and non-target species – in the Kautokeino area. Still, Bustnes and Nilssen (1995; 1996) found that the initiation of hunting in Kautokeino resulted in a reduction in the numbers of ducks in the hunting areas compared to control areas without hunting, and reduced feeding efficiency among female ducks. Hence, it is reasonable to believe that target and non-target species are affected by the spring hunt through disturbance. However, we do not have empirical data to assess whether the magnitude of hunting disturbance is large enough to cause negative consequences in terms of local or regional population declines.

Modelling scenarios for the impact of spring hunting

Model description

The model is based on a simple age-structured model, where a population consists of two age classes: juveniles (<1 years old) and male and female adults (1+ years old). The birth ratio of females to males is estimated from the literature found to be just above half for tufted ducks. The population dynamics are determined by three core demographic rates: The number of offspring produced per female per year, the probability of surviving the first year from birth to adulthood, and the annual survival of the adults.

Each year, we also remove a number of males depending on a quota (offtake) through spring hunting (before breeding) and also apply a reduction in breeding success caused by indirect effects of disturbance. Environmental stochasticity was applied as variable but zero-centered variation in survival both between years and between different sites (habitat patches). Spatial variation was included as a number (usually 100) "habitat patches" representing waterways or lakes, each containing a finite number of nesting sites. The number of habitat patches affected by hunting thus represent how widely hunting occurs in the landscape. After hunting, some of the remaining ducks are re-distributed according to free available nest space and mates to represent ducks moving around optimizing their chance of success.

We wanted to (1) assess the effect of hunting a certain number of males in the spring before breeding, and (2) assess the sensitivity of our predictions to underlying assumptions. In the absence of good population estimates or accurate information about breeding areas and hunting impact we cannot make predictive models. Therefore, we use a simulation approach where we run the model for thousands of combinations of random parameter values drawn from plausible ranges of values. This lets us map the predictions conditional on what may be the case and assess what sort of parameters has the largest influences on the outcome. The parameters with the largest effects on the outcome represent critical knowledge gaps and factors for which the populations are most sensitive to change.

Thus, the simulation model is designed to include many of the important aspects of the study system including the underlying demographic rates of waterfowl populations, environmental conditions, and the effects of harvest. The model is relatively simple but still contains enough biological complexity that we can use simulations to evaluate the key model assumptions.

Model assumptions

The model also still contains some simplifying assumptions that could be relaxed with additional effort if knowledge was available:

- Population structure. Spatial population structure is homogenous enough not matter beyond the effects on survival and local population size encapsulated in the model.
- Senescence. Age-dependent declines in reproductive performance and survival are minor, and age structure of the population is stable enough that transient population dynamics are unimportant.
- Environmental variation. Clutch size and reproductive effort are not expected to vary much from year to year and environmental stochasticity is likely to only affect juvenile and adult survival.
- Carrying capacity. Population density is regulated by the number of nesting sites acting as a cut-off. Overabundant numbers of waterfowl are assumed to not have long-term effect on food resources, and the average quality of nesting sites is independent of population density.
- Disturbance. The effects of disturbance from exposure to harvest might have a separate relationship with quotas and the hunting efficiency.
- Climate. Between-year variation in weather conditions as well as climate change probably influences population dynamics both in winter and summer, as well as during hunting when the availability of open water may influence overlap between population and hunters.
- Trends. Land-use, hunting, predation, and other factors change, as well as climate and species compositions in wintering and migration areas, this may be behind population trends operating independently of the spring hunt but influencing how resilient the populations are to hunting and disturbance.

Model results

This **approach** enables the exploration of the sensitivity of our population models to different assumptions and parameters. Such an exploration of different scenarios is the only quantitative assessment we can do, as long as sufficiently good population surveillance data and accurate natural history knowledge on the vital rates of the species and habitats in question are not available. Note that the models were run over the full range of offtake from 0 to 1000 (and can be easily run for higher numbers, just by replacing the upper limit, but this was enough to show the principle).

For 3000 iterations of the model, we see that the introduction of a spatial element makes the predictions a lot more stable and less sensitive to hunting than a non-spatial model, as long as hunting only happens in parts of the range (i.e., the collection of all modeled habitats). Appendix III - Modelling of hunting scenarios, Figure 12 displays the effects of the different terms on the expected proportion of habitat patches having >2 birds in them on average for the last 10 years of a 100-year simulation.

Looking at populations in the absence of hunting, we see strong positive effects from juvenile survival (S0) and adult survival (S1) as expected, and a strong negative effect of environmental temporal stochasticity. Spatial environmental variation on the other hand tends to have a positive effect on population viability (see Appendix III - Modelling of hunting scenarios, Figure 12 and Figure 14).

Incorporating hunting into the model (see Appendix III - Modelling of hunting scenarios, Figure 13 and Figure 15) allows for assessment of the effect of the different parameters on the outcomes for a hunted population. We see that a harvest of males is sustainable under a range of circumstances, but this depends heavily on 1) how common the species is in the first place, and 2) the ability of this species to tolerate a given hunting quota (offtake). These factors are clearly negatively affected by:

(1) increased temporal variance in survival (a predicted outcome of climate change),

(2) decreased average juvenile and adult survival (as would happen through poorer migration survival from land use changes, habitat destruction, hunting and similar in the migration paths and wintering ranges), and

(3) increased disturbance per hunter.

As shown in Appendix III - Modelling of hunting scenarios, we may assess the predicted stability of populations for different combinations of factors. We see that such a system is robust to considerable hunting of males as long as the habitat is common, survival is high, and disturbance per hunter is low. On the other hand, even systems that have been sustainable for a very long time may become vulnerable to even low levels of hunting if between-year environmental stochasticity increases, mean annual survival decreases, disturbance increases, and a larger part of the habitat is affected by hunting or disturbance, or is less productive.

Risk characterisation for target and non-target species

The risk of an adverse event is defined as the probability that a hazard will cause any given event, multiplied by the degree of the negative consequence of this event.

The aim of this section is to characterize the risk of adverse effects to the viability of local populations caused by offtake (i.e., assuming quotas are filled) of 150, 300, and 500 males for each species that were legally hunted during spring in the period from 2013 to 2022, i.e., mallard, red-breasted merganser, and tufted duck. In addition, a similar assessment of the potential risk of allowing spring hunting for male common scoters, velvet scoters, and long-tailed ducks, which not have been legal to hunt the last decade, is performed as a response to supplementary requests and clarifications (see footnote in Terms of reference as provided by the Norwegian Environment Agency).

Various scientific approaches have different strengths and weaknesses. Scientific questions should therefore be answered through a combination of statistical analyses of observational data, experimental protocols, and various modelling tools (e.g., Turchin, 1995). For instance, empirical studies inherently involve unknown variables that can be challenging or even impossible to control or quantify. Observational data alone may thus not be sufficient to improve our understanding of complex relationships because of 1) confounding factors (e.g., Smith and Ebrahim, 2002; Zuur et al., 2009) and 2) the limited spatiotemporal extent to which we are able to collect empirical data (e.g. Bårdsen, 2017). In the context of this shortfall, statistical models can help us to gain knowledge about mechanisms or patterns that might occur in the real world. Our use of population models (see Appendix II – Data availability and knowledge gaps for quantitative assessment and Appendix III - Modelling of hunting scenarios) may be viewed as an attempt to elucidate the logic and assumptions behind arguments and hypotheses (see reviews: Grainger et al., 2022; Servedio, 2020; Servedio et al, 2014). It is important to remember that this not only allows testing various scenarios of the spring hunt with regard to risk to population viability, but that the modelling also may identify knowledge gaps. These gaps represent mechanisms, or patterns, where we currently have insufficient information (e.g., the shape of relationships), unknown parameters or empirical estimates with poor precision or biases (for example, because we lack information about the size of the duck populations inhabiting the hunting area in Kautokeino during the spring hunting season).

The spring hunt for ducks takes place in a relatively small proportion of the water bodies in Kautokeino municipality, mainly along the Kautokeino River (Figure 7), and is said to occur before the start of the breeding season (Buljo et al. 2021; see also Bustnes and Nilsen 1995; 1996). In contrast, in the model the hunt is performed in a variable proportion of the breeding habitats, to assess the effect of hunting (and disturbances) in a smaller or larger part of the distribution of the species. This discrepancy between the model and the actual world is due to a lack of information about several vital parameters. First, we lack knowledge about the proportion of hunting grounds relative to waterbodies where hunting is not allowed during the season defined in the model (or the proportion of ducks inhabiting these two habitats). Second, we know that many ducks fly out of the area when the hunting starts (Bustnes and Nilsen 1995:12). Nonetheless, we do not know the proportion of birds that move, the distance they travel, and if (or when) they come back. Disturbances may also affect the behaviour of birds within the hunted area: birds in the hunting area spend less time feeding and are more vigilant than individuals elsewhere (Bustnes and Nilsen 1995: Fig.5). In the model, displacement, vigilance behaviour, stress and similar responses are all summed up as one parameter for the net effect of disturbance on reproductive success, but its magnitude and relationship to hunting efforts (quotas) are a matter of guesswork based on literature in the absence of observational studies from the area.

In conclusion, a better understanding of the identified knowledge gaps, preferably based on empirical data from Kautokeino, would have enabled us to produce a more realistic and accurate assessment of the risks of adverse effects of spring hunting on the population viability of the target species.

Currently, based on the national population trends of the **long-tailed duck**, **common scoter**, and **velvet scoter**, and almost 30-year-old bird counts from Kautokeino, we assess with medium confidence that any level of spring hunting poses a high risk to the viability of the local populations for these species. Based on the presumably small sizes of the local populations of **mallards** and **red-breasted mergansers**, we assess with low confidence that spring hunting of 150, 300, or 500 males poses a high risk to the viability of these local populations. Hunting 300 or 500 **tufted ducks** are also, with low confidence, assessed to constitute a moderate to high risk to population viability, while hunting of 150 tufted duck males may be assessed to constitute a low to moderate risk to population viability, with similarly low confidence.

For **non-target waterbirds**, we assess with low confidence that spring hunting for target species poses a moderate risk to species that are associated with the target species during the spring hunt, and a low risk to species that are not present during this period. The risk to non-target species depends on population size, and the magnitude and spatial extent of the hunting disturbance.

Animal welfare impacts of spring hunting

Principles for assessment of animal welfare in wild birds

There are multiple definitions of animal welfare. However, many of the definitions are best suited for animal production and are not easily applied to wildlife. One definition that may be applied also to wild animals is based on an assessment of the individual animal's perception of its ability to in a natural way adjust to the circumstances it is exposed to: i.e., "The welfare of an individual is its state as regards its attempts to cope with its environment" (quote from (Broom, 1986) and EFSA Guidance on Risk Assessment for Animal Welfare (EFSA, 2012). (Broom, 1996) lists four measures of good welfare:

1) A variety of normal behaviours to show
2) The extent to which strongly preferred behaviours can be shown
3) Physiological indicators of pleasure
4) Behavioural indicators of pleasure

On the other hand, the same author characterizes poor welfare as:

1. Reduced life expectancy
2. Reduced ability to grow or breed.
3. Body damage
4. Disease
5. Immunosuppression
6. Physiological attempts to cope
7. Behavioural attempts to cope
8. Behaviour pathology
9. Self-narcotization
10. Extent of behavioural aversion shown
11. Extent of suppression of normal behaviour
12. Extent to which normal physiological processes and anatomical development are prevented

Broom furthermore advocates that (quote) "the subjective feelings of an animal are an essential part of its welfare" (Broom, 1996).

EFSA has developed guidance on risk assessment of animal welfare (EFSA, 2012). The guidance divides the assessment into steps of problem formulation (comprising an identification of the risk question, the target population, factors of animal welfare concern, exposure scenarios, known animal welfare consequences and their measurement and building of a conceptual model), exposure assessment, consequence- and risk-characterization.

The guidance defines the welfare of an animal as good if (quote), "as indicated by scientific evidence, it is healthy, comfortable, well-nourished, safe, able to express key aspects of behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress." (EFSA, 2012)

Broom's criteria may, however, be complicated to measure in a wildlife setting. Furthermore, it is questionable if EFSA's definition of good welfare applies to wild animals, as being at least temporally uncomfortable, unsafe and suffering from pain and fear may be regarded as natural parts of life as a free-ranging animal. (Kirkwood et al., 1994) suggested that the scale and severity of harm to the welfare of free-living wild animals at the simplest level could be assessed by considering:

1) The number of animals affected
2) The cause and the nature of the harm
3) The duration of the harm
4) The capacity of the animal to suffer

It is most difficult to assess the last factor since we can never experience, and it is difficult to measure, the feelings of a given species. Sainsbury et al. (1995) claim that without knowledge that clearly shows differences in the suffering capacity of wild mammals and birds, we should assume that this suffering capacity is similar in all species. It becomes even more complicated when we discuss different animals' ability to have emotions, like grief when they experience loss of individuals that they have social relations to. In a review, Brooks Pribac (2013) concludes (quote): "The neural substrates for conscious and affective states humans share with other species, the shared physical and mental significance of attachment relationships, the complex social structures and interpersonal relationships many animals construct and nurture, suggest that grief might be a constituent part of nonhuman animals' lives just as it is of humans'." (Brooks Pribac, 2013).

The Norwegian Animal Welfare Act does not differentiate between domestic and wild animals but applies to all mammals, birds, reptiles, amphibians, fish, decapods, squid, octopuses and honeybees (https://www.regjeringen.no/en/dokumenter/animal-welfare-act/id571188/). Consequently, wild ducks have an intrinsic value irrespective of their usable value for man, and shall be treated well and protected from the danger of unnecessary stress and strains (§ 3, Animal Welfare Act).

Hazard identification - formulation of the assessed welfare problem

The welfare problem assessed in the current report is whether an open spring season for traditional Sami hunting of males has negative consequences on the welfare of wild ducks. The focal duck species consists of mallards, tufted ducks, red-breasted mergansers, common scoters, velvet scoters and long-tailed ducks, of which only the first three species have been hunted during the last decade in Kautokeino. It is our understanding that the eventual negative consequences on welfare associated with spring hunting, must be compared to the welfare of wild ducks in a situation where duck hunting only occurs in the autumn, as it is evident that any hunting increases risk of harm to welfare.

The welfare consequences considered are fear, flight and distress, and disruption of normal behaviour that are due to disturbance associated with the hunting. We also discuss wounding and crippling.

The conceptual model is that opening a season for hunting ducks in the spring may increase the risk of harm to duck welfare.

Due to a lack of quantitative knowledge, the risk assessment will be conducted with a qualitative approach.

Exposure assessment

Based on the available data, 67 to 120 hunters participate in the spring hunt. Hunters were only allowed to shoot two ducks each from 2013-2022, meaning that each hunter probably caused a moderate amount of disturbance to the ducks. In Kautokeino, the only municipality where spring hunting has been allowed during the last decade, the area where the legal hunting takes place is reckoned to constitute 2% of the total area of the municipality (Buljo and et al., 2021). This may be interpreted to indicate that the birds only were disturbed in a limited number of available places, i.e., a *low* or *moderate* exposure to disturbance. However, the exposure to disturbance to the birds will be *high* if these sites constitute a major proportion (>50%) of lakes and rivers with open lanes. The 2% area of hunting can be significant part of the habitat for the ducks if the area forms the only available habitat for the species in the relevant time period. The exposure to disturbance can consequently not be properly assessed without better knowledge about 1) where the birds actually are during the period, i.e. which number of birds are present in which habitats 2) which water lanes that are open, i.e. which alternative habitats they have, and 3) where, when and how the hunting is performed, i.e. how many hunters are present and how to which degree do they disturb the birds.

When the spring hunt traditionally takes place, people also fish pike (*Esox lucius*). The pike is most often caught with fishing nets, but some are shot with a shotgun (Buljo et al., 2021), causing much of the same disturbance to the birds, as hunting, i.e., disturbance caused by people and sounds of shots. We do not know how common this fishing activity is in the areas and the period when spring hunting takes place.

According to the temporary regulation, the spring hunting season lasts ten days and starts between the 15th of May and the 10th of June. The starting date is decided by local authorities for each year. According to current descriptions of the tradition (Buljo et al., 2021), hunting started when the ice began to break up and the formation of open lanes in the ice. Goldeneye, tufted duck and red-breasted merganser usually arrived first (10th to 15th of May) and were hunted by Sami youth, while experienced hunters waited until black scoter, velvet scoter, and long-tailed duck arrived (23rd-25th of May) (Buljo et al., 2021). Mallards were traditionally not hunted because it is regarded as too lean in the spring. However, hunting was and is only performed when the weather is relatively mild with southern winds, as cold weather and northern winds result in low activity among the ducks. Furthermore, flooding may force the ducks to spread from the hunting grounds. According to current descriptions of the tradition (Buljo et al., 2021), the hunters used to stop hunting the small diving ducks when mating behaviour was observed. As a rule, the hunting season ended on the 6th of June. If the birch leaves reached the size of a fingernail before this date, the hunting was stopped (Buljo et al., 2021).

This implies that active hunting may occur only in a proportion of the days of the hunting season and that the actual number of days suitable for hunting may vary yearly. Hence, the individual birds may experience only short and intermittent periods of disturbance over a limited period, indicating a *low* to *moderate* exposure to disturbance.

When assessing if exposure to factors affecting animal welfare increases if spring hunting is allowed, it is essential to know if the increase in the number of hunting days in the spring will be added to the hunting days in the autumn, or if the opening of a spring season will result in the closing of the season in the autumn.

Consequence characterization for welfare

To be hunted, i.e., to be shot at and consequently be disturbed by loud noises, and to be disturbed by human activity, cause a flight response that probably indicates an experience of fear. Other behaviours, such as social interactions, foraging and resting, are then disrupted, and physical exertion is required. The fear and stress will most probably increase under repeated disturbances. If the birds are not allowed to land on open water but are chased from place to place, it can be presumed that there is *serious* harm to the welfare of the affected ducks. In addition, birds that are hit, but not lethally, will suffer from physical pain and experience fear and can subsequently become crippled. Crippling can have major effects on long term survival and fecundity and an individual's ability to cope with their environment, and constitute a *serious* harm to animal welfare of affected animals.

There are, however, only a few differences in the harm to welfare caused by spring compared to autumn hunting:

- It *may be* that the availability of open water is limited in the start of the spring hunting season, so that the ducks will experience a high exposure to disturbance and serious distress when they attempt to find lanes in the ice where they can land undisturbed after an initial disturbance event. However, the area where the hunting takes place is limited, suggesting that it is probable that the ducks find other lanes to land on if the availability of open water is not limited (see Chapter 9 Uncertainties and data gaps).
- The population size is much smaller in the spring than in the autumn, making it more probable that a given individual will be exposed to moderate to serious harm to welfare caused by hunting in the spring than in the autumn.
- The ducks are in a vulnerable phase during the spring hunt, trying to find and keep a mating partner in competition with other ducks, as well as building up resources for egg production. However, it is difficult to objectively assess whether disturbance in this situation will increase the individual's experience of suffering, or their physiological status would make them more resilient against disturbance.

There are very few studies of the effect of disturbance of ducks in the spring. A study of eider ducks by Hario et al. (2002) indicated that shooting males during the mating period reduced hatching success by widowed females by 40%. This was however caused by a 2,5 to 3-fold increase in the proportion of addled eggs and eggs with embryo death, either because other females laid parasitic unfertilized eggs in the nest or as a consequence of lower fertilization rate after the male was removed and repeated mating not was possible. Hario et al. (2002) described that five of the 16 studied eider widows did not breed, and only four of the 16 found new mates that year. However, whether these phenomena were caused by separation distress or grief in the widows, or merely a consequence of lack of access to males (since the hunting caused a female-biased sex ratio), is impossible to say.

It is, of course, debatable if adult ducks disturbed by the spring hunting are more or less susceptible to experience suffering than juveniles that proportionally constitute the largest part of the population during the hunting season in the autumn. It may be argued that the juveniles are stressed by migration and other changes occurring in the autumn, and hence are as vulnerable as the adults in the spring. The local tradition does, according to Buljo et al. (2021), regard it as ethically wrong to hunt juvenile ducks in the areas where the ducklings are hatched and grow up. It is claimed that this will cause the ducks to fear the areas (Buljo et al., 2021). It has also been claimed that the mother duck will feel grief over the loss of any of her ducklings and show behaviour (searching) that indicates fear or stress when they are shot. However, female ducks may have already abandoned their young once they are independent and fledged. Brood attendance is for example regarded to last 29-42 days for female Tufted Ducks (Carboneras and Kirwan, 2020a).

Risk characterisation for animal welfare

The probability of occurrence of harm to welfare for an individual duck depends on:

- Legislation: For example regulation of the cumulative length of the hunting season, hours of the day when hunting is allowed, how many ducks each hunter is allowed to shoot,

size and location of areas where hunting is permitted and which species that are allowed to shoot.
- Hunters: For example number of active hunters, their level of activity and how they perform the hunting concerning shooting accuracy and level of disturbance.
- Environmental conditions: For example number, distribution and size of ice lanes, water level and current, temperature and wind (influencing duck behaviour).
- Ducks: For example population sizes, inherent susceptibility to stress, individual experiences and predispositions and physiological status.

The magnitude of harm to welfare will be most *serious* for ducks that are wounded after being shot but do not die instantly. However, we lack data that allow assessment of the frequency and severity of wounding during the spring- and autumn hunt and can, hence, not compare the risk in the two hunting seasons.

There has been considerable debate about the emotions of animals, and it is beyond the scope of this assessment to go in depth in this field. Under the assumption that suffering capacity is similar in all species and that birds experience emotions after a loss (see Principles for assessment of animal welfare in wild birds), Bekoff (2009) and references therein or Brooks Pribac (2013) and references therein), individual ducks could be impacted if they have social bonds with partners or young that are killed during hunting (or die of other causes) or if they lose contact in other ways. We cannot, however, from a scientific background, say that ducks of various species grieve more or less if they lose adult companions during the spring hunt than if a female duck, for example, loses its offspring during the autumn hunt.

The risk of harm to the welfare of individual ducks due to disturbance can be *serious* if there are few ducks, few and small available lanes of open water, and many hunters spread over large areas, but will be *moderate* or even *low* if few hunters hunt in a minor proportion of available habitat during a limited period of time.

To our knowledge, no scientific reports compare animal welfare aspects of hunting adult individuals during the mating season in spring with the hunting of juveniles and adults in the autumn. In addition, we lack data that can support a case-specific comparison of the risk of harm to animal welfare between the spring- and autumn hunting.

A scientific characterization of risk for harm to duck welfare in the spring hunt compared to hunting in autumn is consequently challenging to perform objectively.

Uncertainties and data gaps

Waterbird populations

Knowledge about population size and trends, and yearly adult survival and recruitment is imperative to determine sustainable hunting quotas (e.g., Elmberg et al., 2006), which can be updated as new evidence becomes available within an adaptive management framework (McCarthy and Possingham, 2007). Already in the 1990s, Bustnes and Nilsen (1995; 1996) recommended monitoring duck populations in Kautokeino to evaluate the potential effects of the spring hunt. As this is still lacking, the empirical evidence to inform management decisions is weaker today than it was in the 1990s, when the last survey was carried out.

Before deciding on quotas and risk-reducing measures, it is crucial to know the size and trends in the local duck populations. Without such knowledge, it is unlikely that the measures will be effective. A monitoring programme, which starts with a thorough mapping of the duck populations in the Kautokeino area and includes spring, breeding, and moulting populations, would inform management. This may form the basis for annual monitoring that will document the long-term changes in the populations.

The number of ducks in Kautokeino varies greatly among years – and even among days within the same year – and among species (Bustnes and Nilsen 1995; 1996). Consequently, bird counts should span several days (e.g., 7-10 days) and should be repeated annually. For the duck species present in Kautokeino during the spring hunt, the relative proportion of resident breeders *versus* the proportion that are just stopping over before moving on to breeding grounds elsewhere, is unknown. Therefore, bird counts should be carried out in three main periods every year: 1) shortly before and under the spring hunt; 2) in the breeding season, on the breeding grounds, after the ducklings have left the nest (counting the number of broods); and 3) during the moulting period. During moulting, the birds often aggregate in flocks and are easier to detect, for example in aerial surveys, and bird counts in this period would give information about population size and reproduction. The first bird count period each year should be done both pre-hunting and during the hunt to enable assessment of hunting disturbance. For the same reason, counts should be made both in areas with hunting and in control areas without hunting. Because bird counts vary greatly with weather and ice conditions, relevant environmental conditions should be recorded in parallel with the bird counts. Long time series with individual data are needed to allow for the variance in population demography and environment (Lande et al., 2003).

A control area established sufficiently far from the hunting areas, to avoid interactions with the hunting, would provide evidence for whether the population densities in Kautokeino are lower than in similar areas, and whether the local population trends differ (i.e., using similar approaches as Bustnes and Nilsen, 1995; 1996). Population monitoring only where hunting is permitted can potentially mask adverse effects of hunting; a stable local population size will, for instance, be apparent if immigrants replace hunted individuals. Hunted areas could, however, act as ecological population sinks if the immigrants are not replaced in the source areas through density-dependent mechanisms. Knowing whether the local populations are sinks or sources is essential in decisions making. A population is a sink if mortality exceeds reproduction and immigration exceeds emigration. To direct hunting and other management actions to the right areas, the number of ducks an area produces and exports have to be estimated (e.g., (Williams et al., 2001).

The impacts of hunting disturbance on target and non-target species in Kautokeino are mainly unknown; i.e., we do not know whether the disturbance is severe enough to cause local population declines. To reduce the impact of disturbance, it is important to assess where the harvestable species overlap with the threatened ones, as hunting might be sustainable for target species, but still induce unsustainable disturbances on other waterbird species occurring in the designated hunting area. The impact of disturbance should be assessed independently.

There is also uncertainty about hunting effort, offtake, and unreported hunting, both legal and illegal (target and non-target species). Improved harvest data are needed, including reliable data on offtake (harvested individuals), hunting effort, and spatial distribution of the hunting. This applies to the reports compiled by Kautokeino municipality and the reports from the hunters. A substantial proportion of the hunters do not submit reports to Kautokeino municipality (Table 1).

The most significant data gaps and uncertainties stem from a lack of knowledge about the current and historical population size for the target species covered by this assessment, both at local, regional, and national levels.

There are also considerable knowledge gaps and uncertainty about important demographic and population parameters for the species under consideration, including:

- Distribution, range, and habitat use throughout the year, both for the hunted areas and the surrounding areas where hunting is prohibited
- Arrival time in the spring
- Recruitment and migration
- Survival rates
- Hunting mortality *versus* natural mortality
- Among-year variation in important life history parameters

There is also much uncertainty for all the species about sex ratios and whether the males have formed pairs with females in the spring hunting period; if they have, negative consequences of removing males on female breeding success are likely. During the spring hunt in Kautokeino, it is only allowed to shoot males, but the impact of this strategy is not fully understood. Although studies on male removal in waterfowl have shown moderate effects, they are not conclusive about long-term consequences for duck populations. Most male removal experiments have taken place after the eggs were laid, which is different from removing males pre-nesting, when a duck male actually may have a function (e.g., mate guarding securing undisturbed feeding for the females). Finally, the only experiment shooting duck males pre-nesting, did find considerable reductions in the reproductive output of females (Hario et al., 2002).

Population surveys and monitoring can also inform recovery plans if the monitoring reveals the status of the local populations is poor. Designing a scientifically rigorous monitoring program, including recommendations for spatial extent of the monitoring, is beyond the scope of this report.

Animal welfare

In the animal welfare field, there is uncertainty about:

- How the hunting (in both seasons) actually is performed and how the ducks respond to various aspects of this and other activities in the area, as we only have one source of information describing first and foremost the human aspects of the hunting (Buljo et al., 2021), and no observational studies are available.
- The proportion of suitable habitat (lakes and rivers with open lanes) that is open for spring hunting. It has been stated (Buljo et al., 2021) that the area where the legal hunting takes place constitute 2% of the total area of the municipality, indicating that the birds are disturbed in a limited number of places. However, we do not know if the hunting area in a given year may constitute a major proportion of lakes and rivers with open lanes, which would indicate that the actual degree of disturbance is much higher.
- Frequency of wounding.
- What the birds actually feel, i.e., to which degree they suffer (see Principles for assessment of animal welfare in wild birds) during both spring hunting and the hunting season in the autumn.

Risk-reducing measures

Measures for target and non-target waterbird populations

The risk of overharvesting could be reduced by implementation of an adaptive management approach (McCarthy and Possingham, 2007), which can be updated – for example by adjusting quotas – as new evidence (for example new data on relative abundance) becomes available, rather than setting fixed quotas for many years.

To reduce the uncertainty and increase knowledge about offtake (Table 1) and hunting efforts, one could make hunting permits contingent on submitting an adequate report.

Hunting in the spring and autumn should be considered together. Increased hunting in one season could, in theory, be compensated by a reduction in the other. However, hunting the same number of individuals in spring as in autumn will not have the same effect on the population (see Impacts of spring hunting on wildlife). An individual shot in autumn could have died in any case of other reasons, whereas shooting adults shortly before breeding is likely to deplete the reproductive capital (see Impacts of spring hunting on wildlife).

The measures listed above are aimed at reducing the risk of overharvesting target populations. As a general note, we expect that measures to reduce the level of human activity in the area in the sensitive pre-breeding and breeding periods for waterbirds, will reduce the potential negative effects of hunting disturbance.

The main disturbance is most likely the hunting activity (shooting) itself. Designating waterbird refuges without hunting within the defined spring hunting area – preferably in the areas with the earliest ice-break – could reduce the negative impacts of hunting disturbance on target and non-target species. An adaptive management programme would enable the implementation of other measures, if new data on hunting disturbance find that birds are negatively impacted by, e.g., noise and other human-caused disturbances.

To avoid shooting non-target species and individuals (females) by mistake, species identification skills are essential (Helgesen, 2017). Pre-hunting season information meetings and/or courses in species identification and reporting – for example in connection with the issuing of hunting licences – might reduce the chances of shooting non-target species/individuals by mistake and improve the quality of the hunting statistics.

Increased control, for example, by field inspectors, and collection of wings of shot birds for post hoc identification of species and sex/age ratios in the bag, could also reduce the risk of killing non-target birds.

Measures for animal welfare

Directed towards hunters

We lack information that indicates that spring hunting is a larger threat to animal welfare than hunting performed in the autumn. On a general basis, efforts that increase the knowledge level among hunters about how to perform the hunting to minimize disturbance, for example, information, voluntary courses and/or mandatory training, may improve welfare.

Likewise, shooting training can potentially increase shooting accuracy, so that wounding and unnecessary suffering is avoided as much as possible. This can be done by offering voluntary or demanding mandatory courses to hunters. Again, we do not have any knowledge that indicates whether shooting accuracy is higher or lower among the Lodden hunters than among those that hunt ducks in the autumn season.

Management measures

Management measures that can reduce risk of harm to welfare include:

- Ensure through local regulations that there always are well-suited areas where the birds can escape hunting and recover from stress, i.e., that spring hunting is not allowed in all or most of the lakes with open water, especially during the first phase of the hunting;
- Regulate the number of hunters allowed participation, number of hunting days or bird quotas to lower disturbance and risk of wounding;
- Ensure through local control that the hunt is stopped once the ducks start to show mating behaviour so that disruption during mating period is minimized; and
- Compensate increased disturbance during the spring with decreased disturbance during the autumn by reduced hunting to reduce the cumulative harm through the year

Conclusions (with answers to the terms of reference)

1. Assessment of risk to waterbird populations and animal welfare when conducting spring hunting of ducks

1.1. Waterbirds

- We have insufficient data on local and regional population sizes and trends to make quantitative assessments of risks to the viability of local populations of the target species. Still, larger quotas will entail increased risks of decreased population viability.
- Our population model suggests that increasing disturbance and between-year variation in survival would make populations more at risk of local extirpation and less able to tolerate harvesting pressure. Consequently, changes in hunter behavior, climate change and land use impacting winter survival would greatly affect the sustainability of hunting. But reliable data on population size, distribution, and survival rates would be needed to implement an informed management strategy.
- Combining qualitative assessments and insights from population modelling, and applying the precautionary principle, we conclude that the risk to local population viability from spring hunting is as follows:
    - Harvesting of any quota of male **common scoter**, **velvet scoter,** and **long-tailed duck** poses a high risk, with medium confidence, as these species are vulnerable or near threatened in the Norwegian red list, have negative national and global population trends, and occurred in low numbers in Kautokeino in the 1990s.
    - Harvesting of 150, 300, or 500 male **mallards** and **red-breasted mergansers** pose a high risk, with low confidence, since bird counts from the 1990s found low local abundance of these species during the spring hunting season. However, new data on local abundances is needed.
    - Harvesting of 300 or 500 male **tufted ducks** poses a moderate to high risk, while hunting of 150 tufted duck males constitutes a low to moderate risk. These assessments are made with low confidence, and new data on local abundances is needed.
    - For **non-target waterbirds**, spring hunting for target species poses a moderate risk to species that are associated with the target species during the spring hunt, and a low risk to species that are not present during this period. These assessments are made with low confidence.

1.2. Animal welfare

- Hunting implies a risk of harm to animal welfare through disturbance, loss of individuals to which remaining animals have a relationship, and wounding. Hunting in the spring is in general not assessed to represent a more considerable risk of harm to animal welfare than hunting in the autumn. However, the cumulative load will increase if hunting is performed in both the spring and the autumn.

- If spring hunting is performed so that mating behaviour is suppressed by fear and stress, this can be regarded as an increase in harm to animal welfare. There are, however, not studies available that support or invalidate this.
- If spring hunting is performed in a large proportion of available open water, so that the birds experience being chased from place to place without finding rest, this can be regarded as a significant increase in harm to animal welfare compared with hunting in the autumn, where there probably are ample opportunities to find areas without hunters. We do, however, lack knowledge about the distribution of ducks, hunters and ice-free lanes during the hunting period and can hence not assess if this is the case.

1.3. Risk-reducing measures when conducting spring hunting of ducks

1.3.1. For waterbird populations

- An adaptive management programme, which can be updated – for example by adjusting quotas or bans on hunting – as new evidence becomes available
- Designating waterbird refuges without hunting within the defined spring hunting area
- Improve data on harvesting (offtake) and hunting effort for example by making hunting permits contingent on submitting an adequate report
- Training in species identification and control by field inspectors

1.3.2. For animal welfare

- Improving hunter training to minimize disturbance and wounding
- Ensuring that there are some areas with open water where the birds are allowed to rest, i.e. non-hunting refuges
- Decrease the number of hunters allowed participation, number of hunting days or bird quotas to lower disturbance and risk of wounding
- Ensure that the hunt is stopped when the ducks start to show mating behaviour
- Compensate increased disturbance during the spring with decreased disturbance during the autumn

2. Risk-reducing measures, in different scenarios for offtake, both species selection and the number of individuals allowed to be shot.

Due to a lack of data on population status, trends, and essential life history parameters, we could not provide quota- or species-specific risk-reducing measures. The model framework does provide a way of estimating effects of various quotas/offtake, but only if reliable estimate of population sizes, survival rates, and distributions are available and combined with specific management goals.

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Zuur, A.F., Ieno, E.N., Walker, N., Saveliev, A.A., Smith, G.M. (2009). Mixed Effects Models and Extensions in Ecology with R. Statistics for Biology and Health (SBH), Springer

Appendix I - Literature search strings

Search strings for each species combined with the scientific name, using the Advanced Search Builder in Web of Science, were conducted on July 5th, 2022.

TS=((Common scoter) OR (Melanitta nigra)), 109 articles retrieved

https://www.webofscience.com/wos/woscc/summary/0f44c4c1-6acb-465b-b85f-efa6001711c3-46d261d0/relevance/1

TS=((Long tailed duck) OR (Clangula hyemalis)), 140 articles retrieved

https://www.webofscience.com/wos/woscc/summary/a09ff2c5-edbb-40ce-bf6f-c06091502255-46d094a6/relevance/1

TS=((Red breasted merganser) OR (Mergus serrator)), 72 articles retrieved

https://www.webofscience.com/wos/woscc/summary/e6440061-380e-405f-a8c0-d3a3ee894e43-46d269c7/relevance/1

TS=((Tufted duck) OR (Aythya fuligula)), 319 articles retrieved

https://www.webofscience.com/wos/woscc/summary/3ed56cab-b245-4c73-8b62-f3b14e1d1b41-46d2707c/relevance/1

TS=((Velvet scoter) OR (Melanitta fusca)), 98 articles retrieved

https://www.webofscience.com/wos/woscc/summary/dc0d50e2-b407-4b00-81b8-312d56b4892d-46d276ac/relevance/1

Search strings for the survival and reproduction of tufted duck:

"(TI=("Aythya fuligula" OR tufted duck) AND TI=(surv* OR reprod* OR fecundity)) OR

(AB=("Aythya fuligula" OR tufted duck) AND AB=(surv* OR reprod* OR fecundity)) OR

(TS=("Aythya fuligula" OR tufted duck) AND TS=(surv* OR reprod* OR fecundity)) OR

(AK=("Aythya fuligula" OR tufted duck) AND AK=(surv* OR reprod* OR fecundity))".

Appendix II – Data availability and knowledge gaps for quantitative assessment

Literature review

To assess data availability and knowledge gaps for future model development and quota determination, we did a specific literature search on the survival and reproduction of tufted duck, the most commonly hunted species in the 1990s and in 2007-2021 (Figure 8 and Figure 9), and 54% and 42% of the harvested individuals in 1995 and 1996, respectively (Bustnes and Nilsen, 1995; 1996). We conducted the literature search using the 'Advanced Search Query Builder' on Clarivate's Web of Science (https://www.webofscience.com; assessed 19-JUL-2022) using string as shown in Appendix I.

Our search gave 68 hits and resulted in 1) 19 and 20 estimates of juvenile and adult- and yearling-survival, respectively (Blums et al., 1996; Blums et al., 2003; Blums et al., 2002; Dugger and Blums, 2001); 2) ten separate estimates of clutch and brood size, respectively (Blums et al., 1997; Dugger and Blums, 2001; Giles, 1994; Neuzilova and Musil, 2010); 3) three estimates of number of fledglings (Gardarsson and Einarsson, 2004; Giles, 1994); and 4) five estimates of hatching and nesting success (Blums et al., 2002; Dugger and Blums, 2001; Liordos and Lauder, 2015; Neuzilova and Musil, 2010).

Survival and reproduction

Based on the data from literature search, we drew two essential conclusions relevant to how we specified our model below. First, adult- and yearling survival were similar (one study tested this and found no support for distinguishing between them: Blums et al., 1996; other studies merged these classes in their analyses: Blums et al., 2002). Second, one study found that inexperienced and experienced birds had different clutch and brood sizes and that older birds produced more offspring (Blums et al., 1997). Nonetheless, we did not separate between yearlings, young adults, and fully mature individuals, as only one study reported such a difference. Moreover, one Latvian population, the Engure Marsh in the Baltic Sea, was overrepresented in the resulting hits, meaning that some estimates (e.g., apparent survival) in practice represent this area.

Population numbers

The last estimates for population numbers for the six target species of waterfowl in Finnmark were from surveys conducted in the 1970's with estimates of ~450-2200 pairs per species (Table 2). Population numbers are thought to have declined for several of the species and current number of pairs are likely to be lower (Hjåland, 2012; 2014, Hartman et al., 2013, Stokke et al. 2021i). If waterfowl populations have a high degree of migratory connectivity with other regions of Norway or Fennoscandia, then the effective population numbers could be several orders of magnitude larger (Table 2).

Table 2. Population estimates for six species of migratory ducks in Finnmark, Norway and Fennoscandia. Note that our population model uses no specific population estimate but runs over a wide range of population sizes and maps an outcome space for all sorts of values, including those that determine average population size.

	Finnmark (1973-1975) 48,618 km^2		Norway (2005-2014) 385,207 km^2	Fennoscandia (2011-2015) 1,252,094 km^2
Species	**Density (pairs/km2)**	**No. pairs**	**No. pairs**	**No. pairs**
Mallard	0.011	521	43,000 – 72,500	288,250 – 446,000
Tufted Duck	0.045	2210	6,500 – 9,000	121,500 – 144,000
Velvet Scoter	0.007	351	400 – 650	16,500 – 18,750
Common Scoter	0.009	419	635 – 1,255	7,735 – 9,355
Long-tailed Duck	0.039	1904	3,000 – 7,000	8,900 – 16,400
Red-breasted Merganser	0.021	1043	10,000 – 30,000	56,000 – 86,000
Sources	1		2	3

Sources: 1 = Haapanen and Nilsson, 1979; 2 = Shimmings and Øien 2015; 3 = Stokke et al., 2021.

Demographic rates

Estimates of age at maturity, fecundity and survival are not available for waterfowl populations in Finnmark but have been estimated for populations breeding elsewhere in northern Europe and North America (Table 3). The population dynamics are determined by four demographic rates, including the number of offspring produced per female per year, the probability of surviving the first year from hatching until recruitment as a yearling, the proportion of females entering the population as recruits, and the annual survival of adults - see Appendix III. The number of offspring produced per female is a product of clutch size, nesting success and hatchability of eggs among successful nests (Table 3). Estimates of duckling survival from hatch to fledging are typically in the range of 0.3-0.40 (Table 3). Estimates of juvenile survival from fledgling to 1-year of age are unknown for most waterfowl populations but are likely around 0.40 (range ≈ 0.21-0.61, Flint, 2015). Sex ratios among juveniles can be consistent with a 1:1 sex ratio (p_f = 0.480 in Mallards) but are female-biased in some populations including Tufted Ducks (p_f = 0.557, Wood et al., 2021). The ecology of migratory waterfowl in Finnmark contains many knowledge gaps: the status and trends of the populations are unknown, the underlying demographic rates have not been estimated from focal population studies, and the patterns of population connectivity are unknown.

Our population model attempts to explore the possible effects of spring harvest on the population viability by simulating waterfowl populations under a range of different ecological conditions. The main goals are to (1) predict the effect of hunting a certain number of males in the spring before breeding, and (2) assess the sensitivity of our predictions to different estimates of demographic rates for waterfowl and the environmental conditions.

Table 3. Estimates of demographic rates for six species of migratory ducks from field studies in northern Europe and North America.

Species	Age at maturity (yrs)	Clutch size	Nest success	Egg hatchability	Duckling survival to fledging	Adult survival	Sources
Mallard	1	5.7-10.6	0.120-0.323	0.905	0.350-0.390	0.510-0.680	1
Tufted Duck[a)]	1-2	8.4-9.2	0.795-0.917	0.956	0.370	0.707	2
Velvet Scoter/White-winged Scoter	2-3	9.2-10.2	0.650-0.760	0.670-0.920	0.280	0.782	3
Common Scoter/Black Scoter	2-3	7.7-8.7	0.570-0.890	0.952	0.200-0.600	0.770-0.930	4
Long-tailed Duck	2	6.7-7.9	0.263-0.589	0.810	0.090-0.100	0.720-0.750	5
Red-breasted Merganser	2-3	9.2-11.5	0.581-0.856	0.887	0.320-0.380	0.810	6

Sources: 1 = Hoekman et al. 2002, Coluccy et al. 2008, Drilling et al. 2020; 2 = Blums et al. 1997, Dugger and Blums 2001, Blums et al. 2002, Liordos and Lander 2015, Roy et al. 2020; 3 = Brown and Frederickson 2020, Carboneras et al. 2020; 4 = Bordage and Savard 2020, Carboneras and Kirwan 2020; 5 = Schamber et al. 2009, Robertson and Savard 2020; 6 = Craik et al. 2020.

[a)]In addition, our detailed literature search on tufted ducks resulted in estimated of measures of reproduction that we did not include in the final model:

1) Brood size (number of chicks hatched): mean=8.200; median=8.050; SD=0.593; SE=0.243; min=7.300; max=9.300; n=10.
2) Fledglings: mean=2.873; median=3.000; SD=1.195; SE=0.631; min=1.620; max=4.000; n=3.

Appendix III - Modelling of hunting scenarios

Projection matrix

The population model for ducks is age-structured with two sexes where a population consists of three demographic classes: juveniles (**F_1**) that are <1 years old, and adult females and males (**N_F** and **N_M**) that are at least 1+ years old (Flint, 2015). The model assumes that females start breeding as yearlings. The population dynamics are determined by four demographic rates, including the number of offspring produced per female per year (**R**), the probability of surviving the first year (t) from hatching until recruitment as a yearling (**S_0**), the proportion of females entering the population as recruits (**p_f**), and the annual survival of adults (**S_1**). The number of offspring produced per female is a product of clutch size, nesting success and hatchability of eggs among successful nests. We then test the effects of removing a number of males depending on a fixed quota (**Q**) of 50 to 500 birds through spring hunting before breeding.

$$N_{F,t} = S_{1,t} N_{F,t-1} + p_f S_{0,t} F_1 \quad (1)$$

$$N_{M,t} = S_{1,t} (N_{M,t-1} - H_{t-1}) + (1-p_f) S_{0,t} F_1 \quad (2)$$

$$H_t = \min\{N_{M,h} , Q\} \quad (3)$$

$$F_{1,t} = R_t N_{Fb,t} \quad (4)$$

Carrying capacity and habitat heterogeneity

Population numbers of waterfowl are likely to be constrained by the availability of nesting sites and feeding areas with direct density-dependence acting on productivity (Gunnarsson et al., 2008, Murray et al., 2010). The demographic rates that are affected by direct density-dependence and the shape of the relationship are unknown. Here we modeled the upper carrying capacity by stating that each habitat patch has a finite number of nesting sites (**K**). Thus, no more than K females may nest in each habitat patch in a given season. The freshwater habitat patches are not of uniform size, and as we expect that there are more small ponds and lakes than large ones, so we drew sizes of habitat patches from an exponential distribution. So if we have *i* different habitat patches, the probability of each having *k* nesting spots is inversely proportional to the number of nesting spots.

$$P(K_i=k) = \frac{1}{k} \quad (5)$$

$N_{Fb,i,t} = \min\{ N_{F,i,t} , K_i\}$ (6)

Environmental stochasticity

Environmental variability has greater effects on population dynamics of waterfowl than density dependence, and also greater effects on diving ducks than dabbling ducks (Pöysä et al. 2016). Survival for juveniles and adults is expected to vary between habitat patches of different quality and among years due to variation in weather conditions, food availability, predation and disease. Environmental factors may act during the breeding season but also during migration and the nonbreeding period. To keep the effects of environmental variation separate from the demographic parameters, we used the following approach. We let the environmental impacts on survival be zero on average and instead looked at the effect of increasing the spatial and temporal variance to determine how resistant populations are to stochastic extirpation. We used the following expressions to take random draws and to obtain probabilities that were bounded from $\langle 0,\ 1\rangle$.

$$S_{0,i,t} = \text{logit}^{-1} (\ln(S_0/(1-S_0))+E_{Spat,i} + E_{Temp,t}) \quad (7)$$

$$S_{1,i,t} = \text{logit}^{-1} (\ln(S_1/(1-S_1))+a_1(E_{Spat,i} + E_{Temp,t})) \quad (8)$$

Here, $\mathbf{S_{0,i,t}}$ and $\mathbf{S_{1,i,t}}$ are the juvenile and adult survival rates for different habitat patches (i) and years (t). The logit^{-1} function is the inverse logit transformation where $\text{logit}^{-1}(x) = \frac{1}{1+e^{-x}}$ takes the linear components inside the parentheses and backtransforms them to probabilities $\langle 0,\ 1\rangle$. In many vertebrate populations, the effects of environmental stochasticity are greater on younger than older age classes. Here we assumed that adults were less impacted than juveniles. The differential effects of environmental variance on age ($\mathbf{a_0}$) were modeled as a reduction in variance of adult survival S_1 by a factor $0 < a_0 < 1$. The environmental stochasticity components themselves were random draws from normal distributions with separate standard deviations for the spatial ($\boldsymbol{\sigma_{spatial}}$) and temporal components ($\boldsymbol{\sigma_{temporal}}$).

$$E_{spatial} \sim N(0, \sigma_{spatial}) \quad (9)$$

$$E_{temporal} \sim N(0, \sigma_{temporal}) \quad (10)$$

Heterogeneity between habitat patches was combined with the spatial and temporal variance to create a dynamic landscape that simulates a variable environment that might be found in the taiga biome of Finnmark (Figure 10).

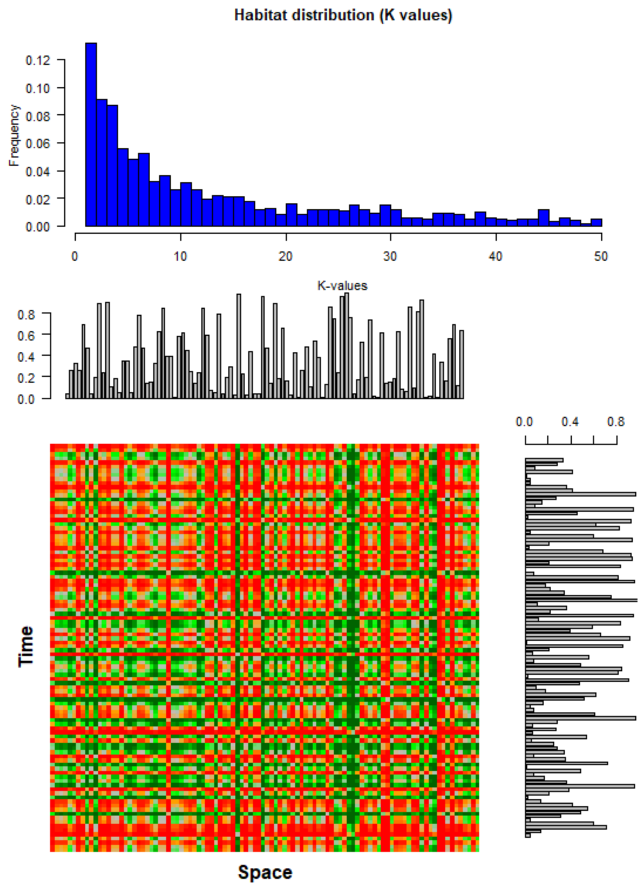

Figure 10. An example histogram of habitat patches with different numbers of nesting sites (K-values, blue, top), bar plots in grey displaying the potential spatial and temporal variation (middle and right) that are combined to form a matrix of environmental stochasticity over all habitat patches for all time steps (color plot, bottom).

Harvest quotas and hunter efficiency

Regional harvest quotas were set for the Kautokeino region of Finnmark and legal harvest was allowed in defined areas along major water courses. The total number of ducks that will be actually harvested will likely depend on hunter access to suitable habitats and their efficiency during the spring season. We divided the overall quota over all habitat patches available for hunting (**H_n**) according to prey availability, assuming that hunters will distribute themselves approximately optimally.

$$Q_i = min\left\{\frac{Q}{\sum_{i=1}^{i=H_n} N_{M,t,i}}\ ,\ 1\right\} \qquad (11)$$

Gamebirds often become more wary and more difficult to shoot at low population numbers. If population sizes were less than the harvest quota, we are likely to overestimate how vulnerable the system is to hunting if we assume that all remaining ducks can be shot. It is more likely that some birds will escape hunters by using refuges from hunting or if their seasonal phenology is outside of the spring harvest season. We created a model parameter to explore hunter efficiency (***h_0***) and to model how close to local extirpation a local population of ducks could be driven by spring harvest. We modeled annual harvest $\mathbf{H_t}$ as a binomial function of quotas (Q), hunter efficiency (*h_0*) and population size (N, Figure 11, panel a), scaled by a constant to mark the lowest probability when $h_0\, N_{M,t,i}$ is close to zero (*b*, here *b*=-5).

$$Q_i = min\left\{\frac{Q}{\sum_{i=1}^{i=H_n} N_{M,t,i}} \;,\; 1\right\} \tag{11}$$

$$H_{i,t} \sim Binom\left(N_{M,t,i}\,, \min\left\{Q_{t,i}\, logit^{-1}\left(b + \frac{h_0\, N_{M,t,i}}{K_i}\right) \;,\; 1\right\}\right) \tag{12}$$

Annual harvest of waterfowl in Troms and Finnmark during the three autumn hunting seasons of 2019-2022 included 160-180 Mallards, 20-60 Tufted Ducks, and 90-160 Red-breasted/Common Mergansers per year (SSB statistics for småvilt og rådyrjakt). We did not include separate harvest quotas for autumn harvest in the simulation model but consider them part of the losses that affect background survival (S_0 and S_1).

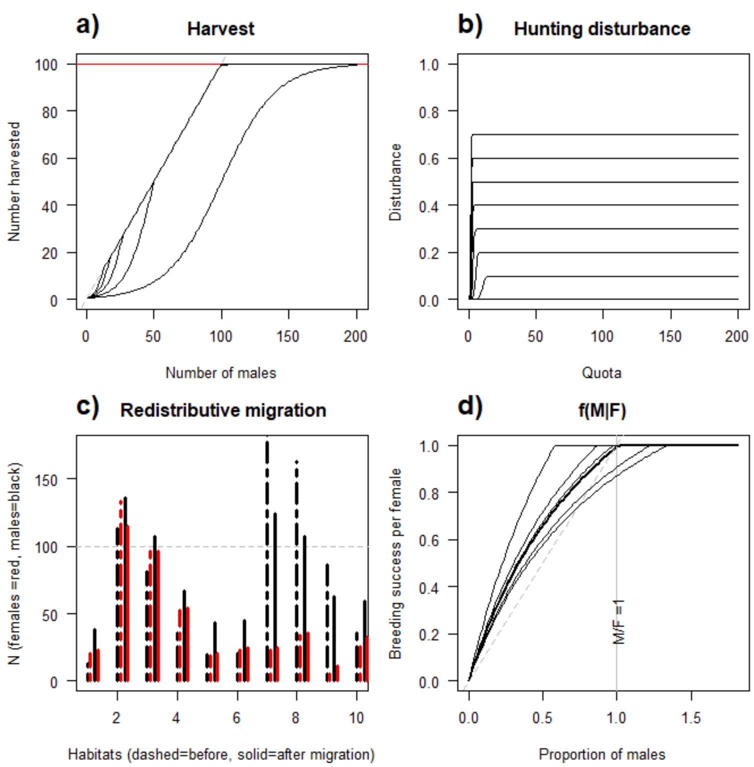

Figure 11. Showing examples of the functions regulated by; a): harvest efficiency (h0, eq.12), b): effects of hunting disturbance (d0, eq.13), c): movements leading to compensatory migration (m0, eqs.14-23), and d): effects of biased sex ratios on breeding performance (b0, eq.24). In a,b,c, and d the

different lines illustrate different values for the regulatory parameter in question (h0, d0 and m0 respectively). In c only one value of m0 is illustrated (m0=0.5) due to limited space.

Disturbance

Spring hunting can have direct effects by increasing mortality rates of males but also indirect effects via disturbance and displacement of waterfowl from suitable habitats. Behavioral avoidance is a common response to disturbance from exposure to harvest in migratory waterfowl. Disturbance (D) can be caused by the presence of hunters and their dogs, including noise from motorized vehicles, and gunshots in the breeding areas during the spring hunt. Here, the effects of disturbance were modeled by adjusting a parameter for disturbance (**d_0**) that was applied to the subset of habitat patches designated for hunting ($Q_i > 0$). How patch - specific levels of disturbance **D_i** might scale with the harvest quotas Q_i is one of the major uncertainties of our model. In our current implementation, disturbance increased if quotas were adjusted from zero up to ca. 25 birds and were then unaffected by further increases in harvest quotas (Figure 11**,** panel b). To get a function that quickly increase from 0 to a given proportion we used:

$$D_i = d_0 \text{ logit}^{-1}(-10+10Qd_0) \qquad (13)$$

Compensatory immigration

Migratory populations of waterfowl are often panmictic with little genetic structure and tracking studies have shown that individual birds can move large distances in search of breeding opportunities. We opted to make our model spatially explicit and allowed individuals to re-distribute adaptively to compensate for hunting and environmental stochasticity. As it is costly to search for a suitable breeding site, we assumed that females that find themselves in habitat patches with no free nesting spaces (i.e., $N_{F,i,t} > K_i$) after the hunting season but before the nesting period redistribute to other habitat patches. Males then re-distribute according to the abundance of females. However, animals only have local information and limited time to search, so to allow for less-than-perfect distributions, we included an adjustable parameter for movements (**m_0**) that defines the proportion of surplus animals that succeed in redistributing themselves for each time step. In Figure 11, panel c, this is illustrated by showing ten example habitat patches with male (black) and female (red) populations before (solid line) vs. after (broken line) compensatory migration.

Movements and redistribution were modeled first for females (the G is a measure of attraction, giving how birds re-distribute over habitat patches):

$$N_{F,i,leave} \sim \text{Binom}(\max\{0 , N_{F,i,original} - K_i\}, m_0) \qquad (14)$$

$$N_{F,i,remain} = N_{F,i,original} - N_{F,i,leave} \qquad (15)$$

$G_F = (K_i - N_{F,i,remain}) - \min\{(K_i - N_{F,i,remain})\}$ (16)

$N_{F,i,arrive} = G_F \left(\sum_{i=1}^{i=\max(i)} G_{F,i}\right)^{-1}$ (17)

$N_{F,i,updated} = N_{F,i,original} - N_{F,i,leave} + N_{F,i,arrive}$ (18)

And then movements were modeled separately for males:

$N_{M,i,leave} \sim Binom(m_0, \max\{0, N_{M,i,original} - N_{F,i,updated}\})$ (19)

$N_{M,i,remain} = N_{M,i,original} - N_{M,i,remain}$ (20)

$G_M = (N_{F,i,updated} - N_{M,i,remain}) - \min\{(N_{F,i,updated} - N_{M,i,remain})\}$ (21)

$N_{M,i,arrive} = G_M \left(\sum_{i=1}^{i=\max(i)} G_{M,i}\right)^{-1}$
(22)

$N_{M,i,updated} = N_{M,i,original} - N_{M,i,leave} + N_{M,i,arrive}$ (23)

Skewed sex ratios

Waterfowl populations tend to have 1:1 sex ratios at hatching (Blums, 1996), female-biased sex ratios among recruits (Wood et al., 2021), and then male-biased sex ratios among adults (Christensen and Fox, 2014). Spring hunting could be sustainable if harvest removes only surplus males. However, skewed sex ratios could affect population dynamics via reductions in female reproductive success. Waterfowl are typically socially monogamous with pair bonds during the pre-laying period and female-only incubation. We assume that a M:F sex ratio ≥ 1:1 would allow all females to successfully mate and attempt nesting. On the other hand, a population where females have access to few males may lead to unmated females and low reproductive success. A stable pairbond during the prelaying period may allow females to feed without disturbance and gather enough resources for egg-laying. Mate removal experiments have generally shown that female waterfowl can incubate and raise young without any contributions from male parental care (Martin et al., 1985; LeSchack et al., 1998; Manlove and Hepp, 1998). However, spring harvest of males might lead to lower reproductive success among females if social structure is disrupted or if there is increased competition among females for nest sites (Hario et al., 2002). We modeled the potential impact (*B*) of spring harvest of males on female reproductive success with a parameter for behavior ($\mathbf{b_0}$) where relative reproductive success was zero for no males but asymptotically one for a population with a 1:1 sex ratio (Figure 11, panel d).

$B_{i,t} = b_0 N_{M,i,t} (1 + N_{M,i,t} + N_{F,i,t})^{-1}$ (24)

Thus, the number of offspring produced in a given season (eq.4) is determined by the adjusted reproductive rate (R_T) of offspring per nested bird.

$$R_{T,i} = R\ B_{i,t}\ D_i \qquad (25)$$

Simulation approach

The underlying assumptions include the largely unknown vital rates that could be used to parameterize the model. Instead of making one prediction based on what may or may not be a suitable set of model parameters, we make several thousand predictions based on different parameter combinations drawn randomly from intervals encompassing all values that make biological sense (and preferably a few more). This gives us essentially a multi-dimensional map of outcomes we can use to address our predictions depending on what assumptions we make and how sensitive they are to error.

In the simulation runs, the environmental conditions vary between habitat patches and years, but has no trend over time. We know that this is not the case due to, among other things, land use changes and climate change. However, since we do not know how the different aspects of climate change affect the demographic rates of the various duck species, we can at present not make predictive models projecting the demographic trajectories for climate change scenarios. Instead, we look at the demographic effects of environmental impacts on survival, and when further research allows us to make inference about what impact a specific climate change will have on survival (and other vital rates), the model can then predict the demographic consequences.

Model caveats

Our simulation model is designed to include many of the important aspects of the study system including the underlying demographic rates of waterfowl populations, variation in environmental conditions, and the effects of harvest. The model is relatively simple but still contains enough biological complexity that we can use simulations to evaluate the key model assumptions. The framework for a model that can be used to evaluate population dynamics if updated estimates of the input parameters become available. The model also has some simplifying assumptions that could be expanded with additional effort.

- Population structure. Spatial population structure is homogenous enough as to not matter beyond the effects on survival and local population size encapsulated in the model.
- Senescence. Age-dependent declines in reproductive performance and survival are minor, and age structure of the population is stable enough that transient population dynamics are unimportant.
- Environmental variation. Clutch size and reproductive effort are not expected to vary much from year to year and environmental stochasticity is likely to only affect juvenile and adult survival.

- Carrying capacity. Population density is regulated by the number of nesting sites acting as a cut-off. Overabundant numbers of waterfowl are assumed to not to have long-term effects on food resources, and the average quality of nesting sites is independent of population density.
- Disturbance. The effects of disturbance from exposure to harvest might have a different relationship with quotas and the hunting effort.

Results

This approach lets us examine the sensitivity of our population models to different assumptions and parameters, which is the only thing we can do in the absence of actual good population surveillance data and accurate natural history knowledge on the vital rates of the species and habitat distributions in question.

For 3000 iterations of the model, we see that the introduction of a spatial element makes the predictions a lot more stable and less sensitive to hunting than a non-spatial model, as long as hunting only happens in parts of the range (i.e., the collection of all modeled habitat patches). Figure 12 displays the effects of the different terms on the expected proportion of habitat patches having >2 birds in them on average for the last 10 years of a 100-year simulation (as a measure of extirpation).

Looking at populations in the absence of hunting, we see strong positive effects from S_0 and S_1 as expected, and a strong negative effect of environmental temporal stochasticity. Spatial environmental variation on the other hand tends to have a positive effect. See Figure 12 and Figure 14.

Incorporating hunting (1**Fel! Hittar inte referenskälla.**Figure 15) lets us assess the effect of the different parameters on the outcomes for a hunted population. We see that harvest of males is sustainable for many circumstances, but depends heavily on how common the species is in the first place, and its ability to tolerate a given hunting quota is negatively affected by:

1. increased temporal variance in survival (a predicted outcome of climate change),
2. decreased average juvenile and adult survival (as would happen through poorer migration survival from land use changes, habitat destruction, hunting and similar in the migration paths and wintering ranges), and
3. increased disturbance per hunter (as would happen from increased use of motorized vehicles and access to a larger part of the habitat from road building, boats and so on).

As shown in Figure 16, we may assess the predicted stability of populations for different combinations of factors. We see that such a system is robust to considerable hunting of males as long as habitat is common, survival is high and disturbance per hunter is low. On the other side, even systems that have been sustainable for a long time may become vulnerable to even low levels of hunting if between-year environmental stochasticity increases, disturbance increases and a larger part of the habitat is affected by hunting or disturbance or is less productive.

Since the model is stochastic, sensitivity analysis was conducted by regressing the output against the input variables using a set of generalized additive models with non-parametric constrained smoothing splines.

$$\text{logit}^{-1}(PN) \sim g_0 + f(S_0)+ f(S_1)+ f(a_0)+ f(K)+ f(R)+ f(E_{Temp})+ f(E_{Tspat})+ f(m_0)+ f(b_0)+ \text{error} \qquad (26)$$

Here, PN is the proportion of habitat patches having at least one breeding pair on average for the last ten years of simulation in the absence of hunting, and the explanatory variables are the model parameters explained above in equations 1-25. The term $f(x)$ denotes the non-parametric effects of each parameter on the outcome, shown in Figure 12.

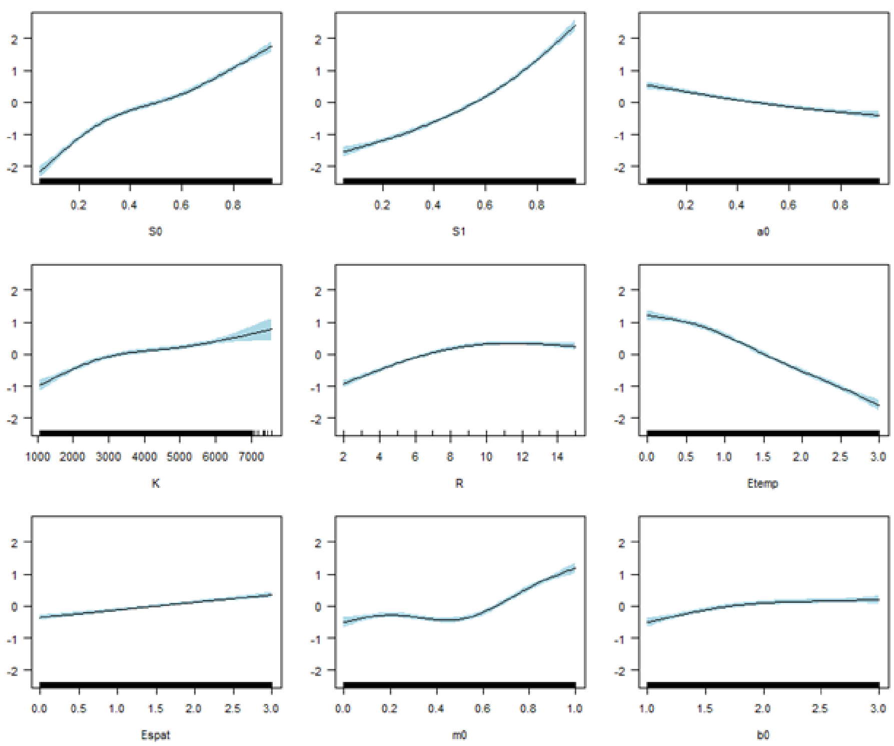

Figure 12. As the model is stochastic, sensitivity analysis is done with a generalized multiple regression (GAM) with non-parametric regression splines. Here we see the effect of the different terms in the model displayed on the same y-axis over the range for which each was drawn. The response here is the proportion of simulated habitat patches seeing on average at least 2 birds per year over a 10-year period. The x-axes are labelled by the respective input parameters, and the y-axes are simply how much each value of x contribute to the linear predicted value of equation 26.

$$\text{logit}^{-1}(PN)\sim g_0+ f(P_{F1})+f(S_0)+f(S_1)+ f(a_0)+ f(K)+f(R)+f(E_{Temp})+f(E_{Tspat})+f(H_nQ)+ f(H_nd_0)+f(m_0)+ f(b_0)+\text{error} \quad (27)$$

Next, we modified the model to consider the effects of spring hunting. Again, PN is the proportion of habitat patches having at least one breeding pair on average for the last ten years of simulation in the presence of hunting, and the explanatory variables are the model parameters explained above in equations 1-25. The effects of each parameter on the outcome are shown in Figure 13. $f(PF_1)$ denotes the predicted occurrence in the absence of hunting (i.e. expected value of PN from equation 26). Thus, the effects shown in Figure 13 are the effects of the different parameters on hunting that comes in addition to their contribution to PF1 in eq. 26. In other words, a widely occurring species is, unsurprisingly enough, predicted to be better able to withstand hunting than a rare species. This is shown by the strong positive effect of PF1 in Figure 13. Everything that contribute to a high PF1 (as shown in Figure 12 previously), therefore also contribute to robustness against hunting simply by making the total population abundant and widespread. Beyond that are the effects the different parameters have on the population's ability to withstand hunting (in this case measured as it is remaining in as many habitat patches as it was in the absence of hunting).

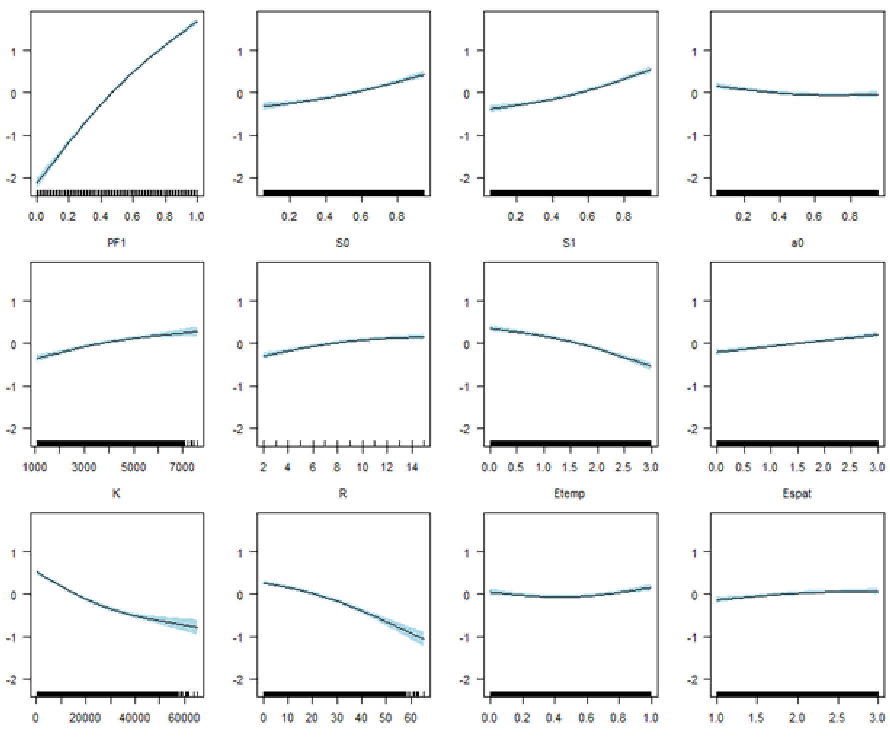

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Figure 13. As the model is stochastic, sensitivity analysis is done with a generalized multiple regression (GAM) with non-parametric regression splines. Here we see the effect of the different terms in the model displayed on the same y-axis over the range for which each was drawn. The response here is the occurrence of breeding couples, i.e. the proportion of simulated habitat patches seeing on average at least one breeding couple per year. As opposed to Figure 12, this model takes into account hunting as well as the occurrence in the absence of hunting.

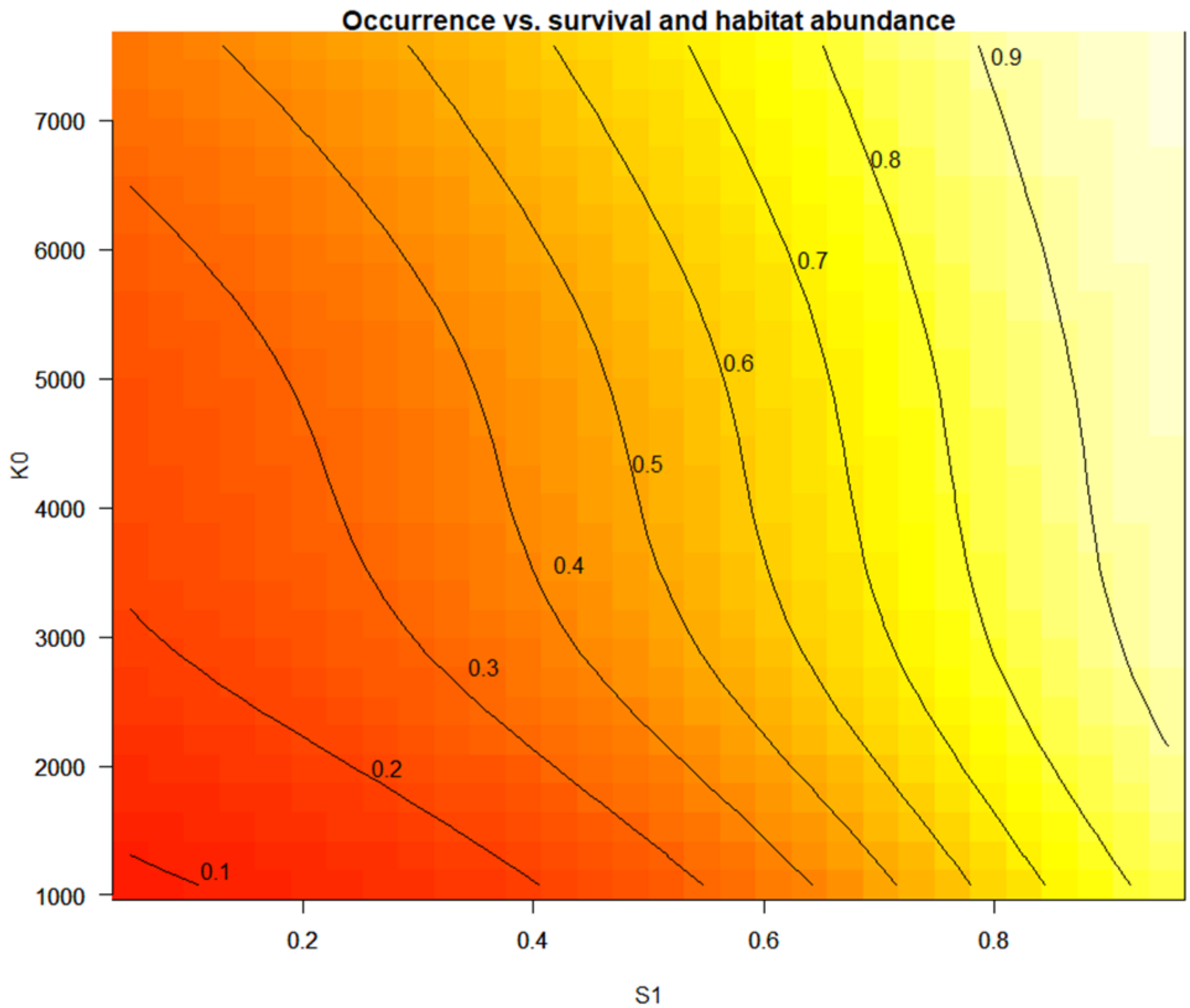

Figure 14. As an example of the dynamical nature of model predictions, this is the predicted average occurrence (PN, or proportion of habitat patches with an of >2 birds over a 10-year period, like in the previous figures) on a duck species in the absence of hunting when adult annual survival (S1) varies from 0.05 to 0.95 and the number of breeding sites (K) summed over all of 100 available habitat patches vary from 1000 to 8000 potential nesting sites. A species with poor survival and rare habitat will occur in few patches (and naturally have a low population,), whereas the opposite becomes true as habitat availability and survival increases. All other parameters are constant at:

S0	a0	R0	Etemp	Espat	m0	b0
0.2	0.4	9	1.25	1.5	0.75	2

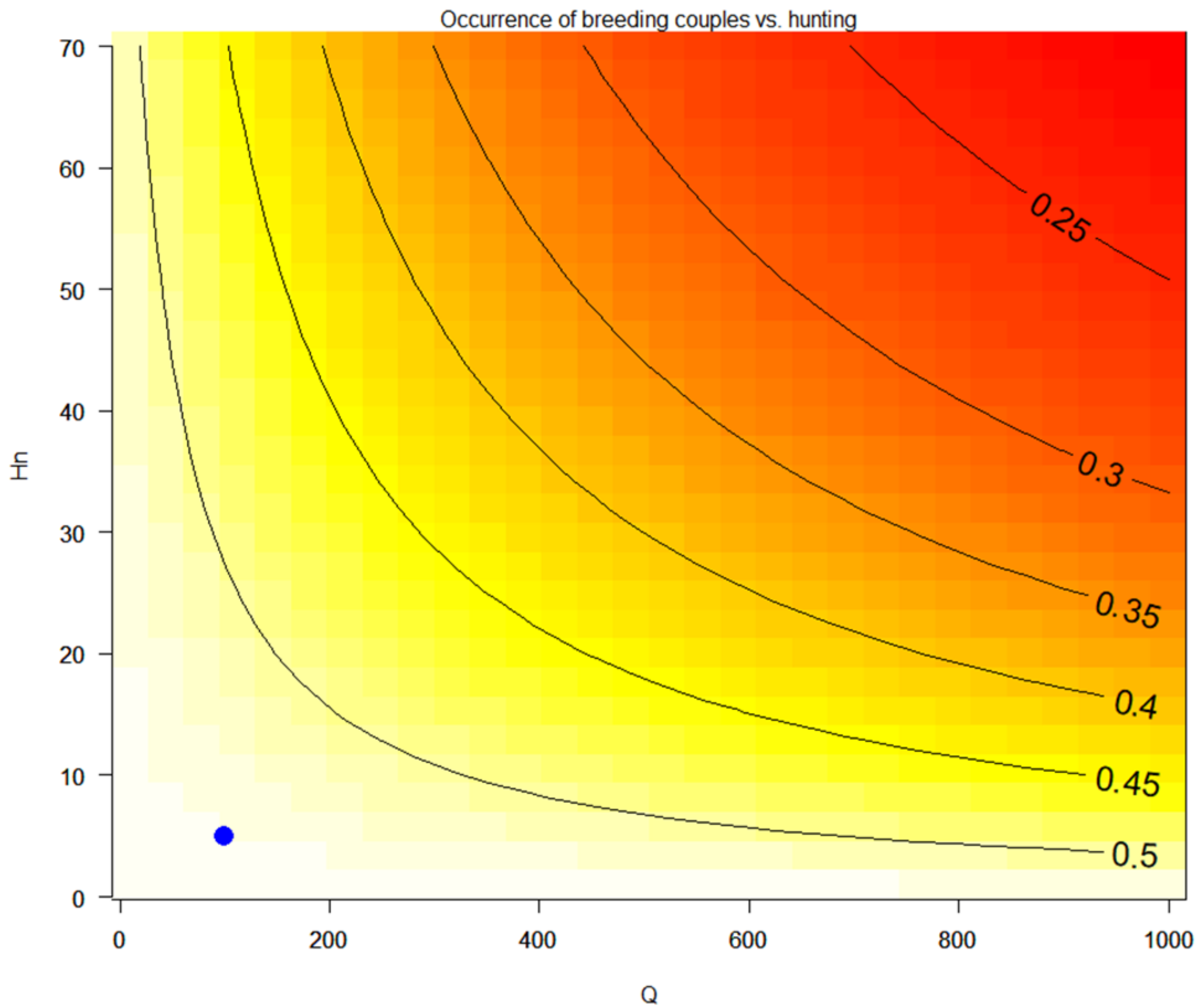

Figure 15. Taking hunting into account and choosing a set of parameters that would give a duck species common enough to be present in on average 50% of its potential habitat patches (see Figure 13), we can assess the expected effects of spring hunting pressure. Here we see that the effect of hunting quota Q depends heavily on how many of the habitat patches are affected, i.e., hunted in (Hn). Here we have 100 habitat patches so Hn can be read as indicating %.

S0	S1	a0	K0	R0	Etemp	Espat	m0	b0
0.2	0.7	0.4	5000	9	1.25	1.5	0.75	2

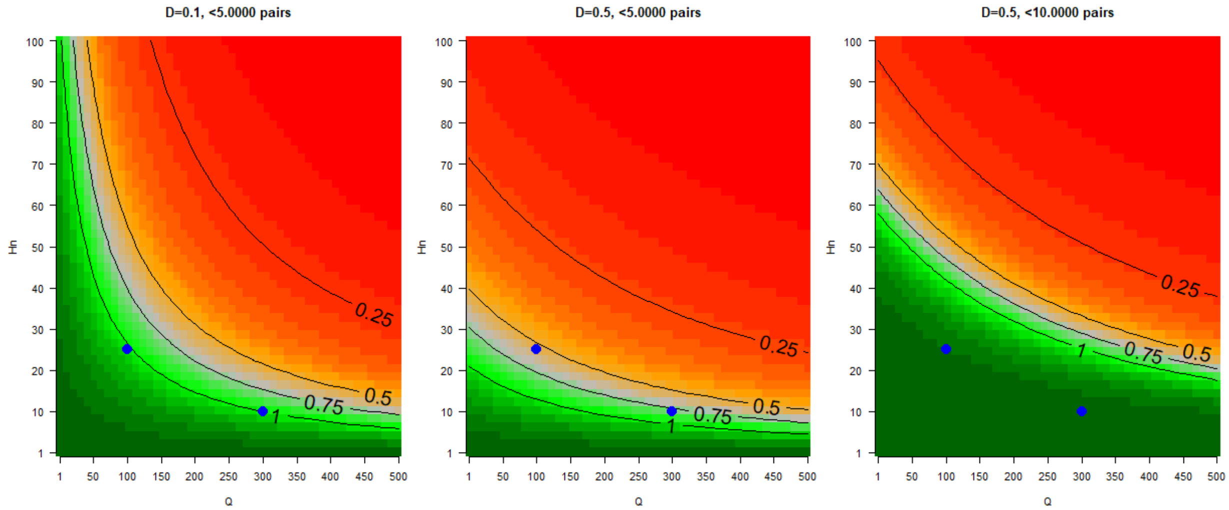

Figure 16. From Figures 12, 13, 14 and 15 we see that we may infer stability, i.e., for which combinations of factors otherwise equal to Fig 14 and 15 predicted occurrence does not decrease from one year to another. Here we see stability plots for the occurrence of breeding couples as a function of the range of hunting quotas (1-500 males) and affected habitat patches (1-100 out of 100). The blue dots indicate quotas of 100 and 300 ducks respectively, with the hunt taking place in 25% and 10% of that species' habitat patches. In the leftmost panel, disturbance is low (D=0.1), and both scenarios are sustainable (stable). However, with increasing disturbance per hunter (say, from increased use of motorized vehicles, dogs and so on) to D=0.5, none of the strategies are sustainable, as both leave fewer habitat patches with ducks in them next year. However, if the duck habitat patches contain twice as many viable breeding sites (K=10 000 as opposed to 5 000) both strategies would be safely sustainable. This underlines the crucial importance of population surveillance over time to assess sustainability of hunting strategies.

In summary, the simulation results suggest that a wide range of spring hunting efforts can be either sustained indefinitely or contribute to local extinction, or at least the hunted population becoming a demographic sink for the larger metapopulation or species as a whole. Of course, a larger population can sustain a larger number of harvested males than a small one. But the proportion of males that can be safely harvested in a spring hunt also depends strongly on three factors:

(a) how large a proportion of the population is effectively being hunted on (here measured as the number of habitat patches being available for hunting, but the population congregating in a few ice-free huntable habitats in spring could have much the same effect as having many habitats open for hunting).

(b) average annual survival of yearlings and adults, but also the variance in annual survival (environmental stochasticity): even with a mean contribution of zero – meaning good and bad years even out in the long run – simply increasing the variability between years makes a species more vulnerable.

(c) the strength of the disturbance response, i.e., the impact the presence of hunters and their associated gear and activities have on bird fecundity and survival beyond the actual harvest, and the ability of the birds to re-distribute between habitat patches after hunting before breeding.