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Assessment of the risk to Norwegian biodiversity from private import and keeping of Northern Cardinal

Lawrence Kirkendall, Anders Bryn, Daniel Flø, Martin Malmstrøm, Gaute Velle, Paul R. Berg, Sonya R. Geange, Kjetil Hindar, Kyrre Kausrud, Brett K. Sandercock, Eva Thorstad and Anders Nielsen

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

Abstract: VKM has evaluated the risk to biodiversity from allowing private import and keeping of the Northern Cardinal as a caged bird in Norway, for birds acquired through the bird trade. VKM has reviewed the invasion ecology of non-native birds in general and of the Northern Cardinal specifically. The assessment includes evaluation of various mechanisms that invasive birds generally have a negative impact through, and includes competition, hybridization, spread of pathogens and interactions with other alien species in Norway. VKM has also evaluated two different scenarios establishment and how climate change can influence both the negative impact and the likelihood of establishment. Overall, VKM finds that there is low risk in regards negative effects on biodiversity in Norway in regard to import and keeping of the Northern Cardinal.

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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 three VKM members and two VKM staff. Two referees commented on and reviewed the draft opinion. The Committee, by the Panel on Biodiversity, 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/or the VKM Panel on Biodiversity.

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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

Background for the assignment

The striking shape and colour of the Northern Cardinal (*Cardinalis cardinalis*) as well as its cheerful song—sung by both males and females—have long made it a coveted caged bird. The songbird is currently widely bred and traded in Europe. The Norwegian Environment Agency has asked VKM to evaluate the risks to biodiversity associated with importing and keeping caged Northern Cardinals in Norway, both under current environmental conditions and under a changing climate.

Taxonomy, biology and invasion history of the Northern Cardinal

The Northern Cardinal is one of three species in its genus. It ranges from south-eastern Canada to southern Mexico, Belize, and northern Guatemala. The Northern Cardinal is a resident, non-migratory species where it occurs. The Northern Cardinal is subdivided into 19 subspecies, but recent DNA-based analyses show that these sort into four distinct, geographically separated mainland clades and two clades each restricted to a small island. The large distribution of the main clade (eastern North America down into coastal Mexico) means that the species can thrive in a wide range of climatic conditions, including conditions quite similar to those found in coastal southern Norway. We discuss the significance of the northwards and westwards range expansion of Northern Cardinal that has taken place since the mid-1800s, which is likely due to changes in forests and other landscapes, climate change, and augmentation of winter food by bird feeders.

Throughout its range, the Northern Cardinal uses similar habitat: areas with shrubs, bushes and trees. Dense vegetation with short woody plants seems to be especially important for nesting. Cardinals are frequent in fragmented landscapes including suburbs and come to feeders throughout most of the year. Cardinals are common birds in favourable habitats, and it is estimated that the species numbers roughly 100 million birds.

The Northern Cardinal is omnivorous and adaptable. The thick conical bill indicates that they are primarily seed eaters and frequently visit bird feeders, but they also consume a wide range of fruits, buds, flowers and foliage. When breeding and raising offspring, the birds prioritize insects and other invertebrates. Depending on local climate, cardinals may raise up to four broods a year.

Like other songbirds, cardinals can be infected and spread a wide variety of diseases. A number of pathogenic organisms and parasites that cardinals could potentially vector are presented in the report. We also list and discuss briefly predators known to kill Northern Cardinals where the species is native.

Despite a number of sightings of cardinals in Europe (including a few in Norway and Sweden), there is no indication of any established populations in Europe. Escaped birds in most other countries have not led to establishment of permanent populations. Naturalized populations of Northern Cardinals are only found in Hawaii (all main

islands), Bermuda, and southern California and Arizona. In Hawaii, the Northern Cardinal plays a role as reservoir for avian malaria as an invasive pathogen. No reports of detrimental ecological effects associated with the naturalized populations are reported elsewhere.

Methods for the risk assessment

VKM established a small working group with expertise in invasive ecology, climate modelling, avian diseases, and risk analysis. The group combed the scientific literature and relevant websites for information on the causes and consequences of avian invasions and on the ecology and behaviour of the Northern Cardinal. We modelled areas of current or future climatic suitability using the several millions of data points available in GBIF (Global Biodiversity Information Facility) and eBird for observations of the Northern Cardinal. To do this, we used Maxent to model potential species distributions. Using recent reviews of invasive birds and the EICAT (Environmental Impact Classification for Alien Taxa) system developed by the IUCN, we identified a list of key mechanisms ("hazards") through which the species could affect biodiversity in Norway should it be established in Norwegian nature, and characterized the risk related to each of these. We also conducted a semi-quantitative risk assessment for the species using the Norwegian Biodiversity Information Centre risk assessment scheme.

Are there areas of Norway that are suitable for the Northern Cardinal?

Under the current climate regime, much of the coastal region of eastern, southern and central Norway provides habitat with suitable temperature and humidity regimes. The suitable areas include some red-listed nature types in Norway. Under a projected future climate regime, the potential distribution is predicted to increase northward along the coast, further inland, and towards higher elevation.

Potential pathways, establishment, spread

The only likely pathways for cardinals to enter Norwegian nature are escapes of privately owned caged birds in Norway and dispersal of escaped individuals from northern Europe. The likelihood of any impact on biodiversity would depend primarily on there being enough individuals in a suitable habitat at the same time to establish a viable population. However, we assess the likelihood of entry as "Very unlikely", and the likelihood of establishment also as "Very unlikely". However, should a viable population become established, we believe that further spread within Norway would be "Likely".

Hazards: how likely, how impactful, and overall risks

We used the IUCN guidelines for Environmental Impact Classification for Alien Taxa (EICAT) to assess the potential impacts of Northern Cardinals on native biodiversity in Norway. We conclude in this report that there are four EICAT mechanisms that could produce negative impacts of cardinals on native biodiversity: competition for food, territories, and nest sites; hybridization with other species; disease transmission to native birds; and indirect effects of Northern Cardinals due to interactions with other species, such as spreading seeds of non-native plants.

- We conclude that competition for food, particularly at bird feeders during winter be "Likely", but competition for nest sites and territories "Unlikely". We assess the likelihood of potential magnitude of the effects of competitive interactions for food, territory, and nesting sites as "Minor". The overall risk, then, is judged to be "Low".
- Interspecific hybridization in nature is possible with only one bird species in Norway, the common chaffinch (Norw. *bokfink*), and we assess the likelihood of this to be "Very unlikely". We assess the magnitude of that impact, should hybridization occur, to be "Minimal". The overall risk, then, is judged to be "Low".
- The likelihood of transmission of diseases in nature from Northern Cardinal to native birds we assess as "Very likely", if they are established in Norway. We assess the potential magnitude of the impact, caused by transmission of diseases, to be "Minor" but emphasize that it is with low confidence due to many unknown factors. The overall risk, then, is judged to be "Moderate" for this mechanism of impact.
- With respect to indirect effects, there is a possibility that establishment of large populations of cardinals could disperse non-native plants. We assess the potential magnitude of this impact to be "Minor", although "Likely" given that the Northern Cardinal establishes in Norway. The overall risk, then, is judged to be "Low".

Effects of climate change

Using the predicted effects of a high-end climate change scenario (RCP8.5 based on SSP5), we found that environmental conditions (e.g., winter warming) would be favourable for the Northern Cardinal in Norway. Suitable areas for viable populations would extend further north and further inland, and conditions would be improved along the coasts. The modelling suggests there would be higher winter survival and hence larger populations, producing a more rapid expansion of the species' range. In addition, the predicted climate change would improve conditions for the bird throughout Europe, which could increase the chances of an influx of birds from outside Norway.

Risk reducing measures

We propose risk reducing measures specifically for diseases and more generally to reduce the likelihood of escapes. We recommend measures, such as including maintaining proper hygiene with caged birds and at bird feeders, quarantine and health checks for imported birds, and information campaigns regarding importing alien birds.

Uncertainties and data gaps

We discuss in some detail uncertainties associated with the types of modelling methods used. There is some uncertainty as to the genetic diversity and origins of the breeding

stock currently in central Europe. We lack information on diseases that might be present in either wild or captive Northern Cardinals.

KEY WORDS. Invasion ecology, risk assessment, competition, hybridization, pathogens, Northern Cardinal, non-native birds, caged birds, bird trade, Norway

Sammendrag på norsk

Bakgrunn for vurderingen

Rødkardinal (*Cardinalis cardinalis)* har, på bakgrunn av sin slående farge og kroppsform, samt lystige sang – synges av både hanner og hunner – lenge vært en populær burfugl. Arten blir hyppig oppdrettet i Europa. Miljødirektoratet ha bedt VKM om å vurdere risiko knyttet til eventuelle negative følger for biologisk mangfold ved import og privat hold av arten i Norge, både under dagens klima og i et endret klima.

Taksonomi, biologi og invasjonshistorie av rødkardinalen

Rødkardinal er en av tre arter i sin slekt. Utbredelsen strekker seg fra sørøst i Canada til sør i Mexico, Belize og nord i Guatemala. Arten er ikke en trekkfugl og lever i samme område hele året. Arten er delt inn i 19 underarter. Nyere DNA-undersøkelser viser at disse utgjør seks distinkte, geografisk separerte grupper. Fire av gruppene finnes på fastlandet og to kun på mindre øyer. Utbredelsen av den største gruppen (fra østre Nord-Amerika ned til kysten av Mexico) tilsier at arten, og denne gruppen spesielt, kan trives i et bredt spekter av klimatiske forhold, inkludert forholdene vi har langs kysten av Sør-Norge. VKM diskuterer relevansen av den nordlige og østlige ekspansjonen som arten har hatt i Nord- og Mellom-Amerika siden midten av 1800-tallet, som antagelig har skjedd som en følge av endringer i skog og landskap, varmere klima, samt tilgang på mat fra mennesker gjennom vinteren.

Rødkardinal benytter samme type habitat, preget av mye busker og trær, i hele utbredelsesområdet. Tett vegetasjon ser ut til å være spesielt viktig for vellykket hekking. Arten trives også godt i fragmenterte områder, der tett vegetasjon brytes opp av små åpne områder og spredt bebyggelse. Arten er også vanlig på fuglebrett gjennom hele året. Rødkardinal er svært vanlig i de habitatene den trives i og det antas å være over 100 millioner individer totalt i utbredelsesområdet. Rødkardinal er altetende og tilpasningsdyktig. Det tykke, koniske, nebbet indikerer at arten primært spiser frø, men den livnærer seg også hyppig av frukt, blomster, skudd og blader. I hekkesesongen, og når ungene skal fores opp, prioriterer den insekter og andre invertebrater som føde. Avhengig av det lokale klimaet kan arten få opptil fire kull i året.

Som andre sangfugler kan rødkardinal bli infisert med, og spre, et bredt utvalg av sykdommer og parasitter. I rapporten gjennomgås en rekke ulike virus, bakterier og parasitter som arten kan fungere som bærer av. Rapporten tar også for seg artens predatorer i sitt naturlige habitat.

Til tross for at individer av arten er blitt observert en rekke ganger i Europa (inklusive et par ganger i Norge og Sverige) er det ingen tegn til at den har klart å etablere seg i Europa. Fugler som har rømt fra privat hold har svært sjelden ført til etableringer av permanente ville populasjoner. Slike populasjoner har kun oppstått på Hawaii og Bermuda, samt i de amerikanske statene California og Arizona. På Hawaii fungerer arten som et reservoar for malaria. Ut over dette er det ikke rapportert om noen negative effekter på miljøet i de områdene arten har spredt seg til.

Metoder

VKM etablerte en mindre arbeidsgruppe med ekspertise innen invaderende arter, økologi, klimamodellering, fuglesykdommer og risikovurdering. Gruppen har gjennomgått den vitenskapelige litteraturen og relevante nettsider etter informasjon om mulige negative effekter av arten, i lys av dens økologi og adferd.

VKM har modellert hvilke områder i Norge som vil kunne være klimatisk egnet for arten, både nå og i år 2100, basert på flere millioner datapunkter fra databaser (GBIF og eBird) som registrerer observasjoner av arten og klimatiske faktorer i hvert enkelt område. Maxent ble brukt til denne modelleringen.

På hvilken måte arten skulle kunne ha en negativ påvirkning ble vurdert gjennom å se på nyere litteratur om invasive fugler generelt, kombinert med et system for påvirkningsfaktorer (EICAT) utviklet av verdens naturvernunion (IUCN). VKM vurderte at fire av påvirkningsfaktorene kunne anses som relevante, og gjennomførte en risikovurdering knyttet til hver av disse. Arten ble i tillegg vurdert separat i Artsdatabankens system for risikovurdering av fremmede arter (FAB).

Finnes det egnet habitat for rødkardinalen i Norge?

Med dagens klima vil store deler av kystområdene i Øst-, og Sør-Norge, opp mot/til Trondheim, kunne anses som klimatisk egnet habitat for rødkardinal, primært med bakgrunn i temperatur og nedbørsmengder. Områdene omfatter enkelte rødlistede naturtyper, som diskuteres i rapporten. Legges realistiske klimaforandringer til grunn vil større områder kunne egne seg for arten. Det er da snakk om lenger nord langs kysten, lenger inn fra kysten samt lengere opp i høyden.

Mulige etableringsveier

Rødkardinal kan kun spres til norsk natur gjennom enten å rømme fra privat hold eller forflytte seg fra populasjoner i Europa dersom slike blir etablert. Til tross for at det er kjent at arten rømmer fra privat hold anses dette som såpass sjelden at det klassifiseres som «svært usannsynlig». Sannsynligheten for at det vil samles tilstrekkelig antall individer, på samme sted og til samme tid, til å kunne etablere en populasjon i Norge anses av VKM også som svært lite sannsynlig. Dette gjelder for begge spredningsveiene. Skulle imidlertid arten etablere seg her anses videre spredning som sannsynlig.

Risiko knyttet til arten

Basert på risikovurderingen av de fire mulige påvirkningsfaktorene (EICAT-kategoriene) som ble ansett som relevante for arten i Norge konkluderer VKM med at:

- Konkurranse med norske arter om mat, spesielt på fuglebrett og lignende om vinteren, er «sannsynlig», mens konkurranse om reirplasser og territorier er «usannsynlig». Effekten av konkurranse, uansett form, vurderes til å være «liten» og risikoen knyttet til konkurranse er derfor å anse som «lav».
- Hybridisering er kun teoretisk mulig med én art i Norge (bokfink), og dette vurderes som «svært usannsynlig». Skulle hybridisering likevel inntreffe anses effekten av dette på det biologiske mangfoldet som «minimal». Risikoen knyttet til hybridisering er derfor vurdert til «lav»
- Overføring av sykdommer fra rødkardinal til hjemmehørende fugler anses som «svært sannsynlig». Imidlertid er det stor usikkerhet knyttet til hvilke sykdommer som eventuelt finnes blandt individene som holdes privat i Europa (og som anses som eneste kilde for import). Den potensielle effekten av slik spredning anses som derfor som «liten». I sum konkluderer VKM med at risikoen knyttet til spredning av smittsomme sykdommer er «moderat», men i nedre del av skalaen.
- Interaksjoner med andre fremmede arter i Norge, da spesielt fremmede frøplanter, er «sannsynlig». De negative effektene av slike interaksjoner (spredning av frø) vurderes imidlertid til å være «liten». VKM konkluderer derfor med at risikoen knyttet til at rødkardinal vil ha negativ påvirkning på biodiversiteten gjennom denne mekanismen er «lav».

Effekter av klimaforandringer

VKM har benyttet klimascenarioet som ligger i den øvre enden av skalaen (RCP8.5 basert på SSP5) i sine vurderinger. Basert på disse er det klart at endringer i klimaet, som varmere vintre, vil være fordelaktig for rødkardinalens muligheter til å trives i Norge. Dette innebærer at større områder vil være tilgjengelig for etablering og spredning og at økt vinteroverlevelse vil kunne føre til større populasjoner og høyere spredningshastighet. I tillegg vil et endret klima medføre større sjanser for etablering i Europa, med påfølgende muligheter for naturlig spredning av arten til Norge.

Risikoreduserende tiltak

I rapporten diskuteres ulike risikoreduserende tiltak. Disse går på å forhindre rømming generelt, samt spesielt på å redusere risikoen knyttet til spredning av sykdomsfremkallende organismer. Tiltakene omfatter generell hygiene, karantene og helseundersøkelser av importerte individer i tillegg til informasjon til relevante miljøer.

Usikkerhet og datamangler

VKM påpeker at all modellering medfører usikkerhet, og denne diskuteres i rapporten. VKM peker også på at det er usikkerhet knyttet til den genetiske bakgrunnen til dyrene som oppdrettes og holdes privat i Europa. Det er også manglende data på hvilke sykdommer som finnes i disse populasjonene, etter mange generasjoner i privat hold.

Background to the terms of reference as provided by the Norwegian Environment Agency

The Northern cardinal (*Cardinalis cardinalis*) is a North American passerine with a natural distribution from Central America in the South to Hudson Bay in Canada in the North.

The species is kept as a caged bird and according to the Global Biodiversity Information Facility (GBIF), has been found in several places in Central Europe. The Norwegian Environment Agency receives applications for importation of the species for private keeping. The Agency considers keeping birds in outdoor cages/aviaries as release in accordance with the regulation on alien organisms. It is also a known fact that birds kept in indoor cages escape on a regular basis.

The report would form the basis for a decision as to whether the importation of the species for private hobby keeping should be permitted.

Terms of reference as provided by the Norwegian Environment Agency

The Norwegian Environment Agency asks VKM to assess:

1. The risk to biological diversity associated with importation and keeping of Northern Cardinal (*Cardinalis cardinalis*).

2. Possible scenarios for distribution in Norway as a result of dispersal from Central Europe or from private keeping in Norway.

3. Effects of a changing climate on the assessments described in points 1 and 2.

1 Introduction

1.1 Invasive birds

Birds are prized by humans around the world, whether for aesthetic or practical purposes, and there is a long history of caging, training, and domesticating birds. For centuries, birds have been widely transported; as a result of deliberate releases or escapes, over 200 species of birds are now naturalized world-wide (Lever 2005, cited in Martin-Albarracin 2015). In Europe, there are 26 well-established alien bird species with breeding populations persisting for more than 25 years and over 100 additional alien species now in Europe which could become long-term non-native residents in the future (Kumschick and Nentwig 2010). Humans have moved birds between regions for hundreds if not thousands of years, whether for direct use (eggs or hunting) or for the pleasure of having certain species in homes or in the local avifauna (Dyer et al. 2017). Using the database for Global Avian Invasions (GAVIA, Dyer et al. 2017), Codesido and Drozd (2021) identified two main peaks for bird introductions around the world: in the decades leading up to the turn of the 20th century, deliberate transportation and release of alien species by acclimatization societies or other groups for hunting or aesthetics; in the 1990s, nearly exclusively from accidental escapes or deliberate releases of caged birds.

An introduced or alien bird is a species that has viable populations outside its native range and was brought to the new area deliberately or accidentally by human activity (Brochier et al. 2010). Invasive introduced species are non-native species that have demonstrable negative environmental or socioeconomic impact (Brochier et al. 2010, Nentwig et al. 2018). Naturalised non-native birds—introduced species that establish free-living populations in nature—can have major ecological and socioeconomic impacts. Species causing major impacts are relatively rare; species have major impacts where they are non-native include feral Rock Pigeons (*Columba livia*), Common Starlings (*Sturnus vulgaris*), and House Sparrows (*Passer domesticus*). Consequently, there is now considerable literature on the subject of invasive birds.

Kumschick and Nentwig (2010) developed a descriptive scoring system for evaluating and comparing the impacts of alien bird species in Europe, based on a similar scheme that Nentwig et al. (2009) had developed for alien mammals. This system was modified slightly and expanded by Blackburn et al. (2014) to be applicable to all invasive alien species. Impacts in this system are categorised as being either environmental or economic. Environmental impacts can be via competition, predation, hybridization with native species, the transmission of diseases, herbivory (including frugivory), and other impacts on ecosystem functions. Economic impacts can be on crop production, livestock, forestry, human health, infrastructure, and human social life such as impacts on recreational areas from bird droppings or noise disturbance.

1.1.1 Characteristics of invasive birds

Kumschick et al. (2013) and Evans et al. (2014) used the scoring system of Kumschick and Nentwig (2010) and literature reviews to test for life history traits that might be consistently correlated with the impacts of alien birds in Europe and Australia. Given that the economic losses due to invasive alien birds are estimated to be in the billions of US dollars (Pimentel 2002) and given the known environmental and social impacts they can have (see sections 1.1.2 and 1.1.3), it would be desirable to be able to predict the impacts of non-native species while their populations are still small and control is still possible (Kumschick and Richardson 2013, Evans et al. 2014). If applied early, effective management strategies could prevent an invasive species from reaching its maximum impact (Kumshick et al. 2016).

Building on the generic scoring system of Nentwig et al. (2009), Kumschick and Nentwig (2010) combined scores for levels of environmental and economic impact (each divided into six subcategories) with sizes of current distributions to estimate the potential impact of 26 alien birds in Europe. These 26 were species not native to anywhere in Europe that have now self-sustaining populations in Europe, and which had been present for at least 25 years at the time of the study (i.e., since 1984). Anatidae (ducks, geese swans) and Psittacidae (parrots, parakeets, and relatives) were the families with species having the greatest impact on biodiversity. Generally, the highest environmental and economic impacts were associated with species having large body mass, wide habitat breadth, and extensive geographic range.

The only life-history trait that was consistently correlated with impact in both Europe and Australia was habitat generalism: the number of broad habitat types that a species could occupy (Evans et al. 2014). Habitat generalists are species which can use a wide variety of resources for nesting or feeding and are more likely to succeed at colonizing new regions and to have negative impacts once established. Evans et al. (2014) emphasized that population size might correlate with impact. Thus, small-bodied passerines that attain high population densities, such as the Common Starling (*Sturnus vulgaris*), Red-whiskered Bulbul (*Pycnonotus jocosus*), and Common Myna (*Acridotheres tristis*), have especially severe economic impacts in Australia.

The above studies on life history traits of invasive birds were followed by an exhaustive global analysis of published research on the impacts of non-native birds on native ecosystems. Building on the work of Shirley and Kark (2009), Martin-Albarracin et al. (2015) conducted an extensive literature search of cases worldwide, that resulted in a dataset of 39 naturalized species from 18 families for which they could find sufficient data for their analyses. This study used the system of Kumschick and Nentwig (ibid.) to score the impacts of species on native ecosystems. The authors added an environmental impact category to the original six criteria of Kumschick and Nentwig: interaction with other non-native species, such as non-native birds spreading seeds of non-native plants (Woo 2008, LaRosa et al. 1985). The study found that hybridization and disease transmission were the most important impacts, affecting both populations and communities of native birds. They also identified structural and chemical ecosystem-level impacts: seed dispersal by alien birds can, for example, alter ecosystem structure; invasive waterfowl can have chemical impacts on water quality such as eutrophication.

1.1.2 Known ecological impacts

The potential ecological and socioeconomic impacts of non-native birds were summarized in the central papers described above (Kumschick and Nentwig 2010, Evans et al. 2014, Martin-Albarracin 2015). In these two subsections, we present examples of known impacts that might be relevant concerning potential introduction of a passerine like the Northern Cardinal, impacts that are ecological or socioeconomic in character.

1.1.2.1 Competition

Non-native birds can outcompete native birds for key resources, like nesting sites and food. Competition is one of the key factors that drive population declines and changes in bird communities (Martin-Albarracin 2015, Colléony and Shwartz 2020).

Native species are most vulnerable when they are physically smaller and have similar habitat requirements as the invasive alien species (Evans et al. 2021). Island populations are particularly vulnerable. The Japanese White-eye (or Warbling White-eye: *Zosterops japonicus*) was introduced to Hawaii in 1929 to control insects, and by the 1970s was the most common bird in the state (Freed and Cann 2014). On the island of Hawaii, white-eyes compete for food (insects, nectar, and fruit) with all of the eight native passerine species, and both the population size of Hawaii Akepa (*Loxops coccineus*) and Hawaii Creeper (*Oreomystis mana*) have declined dramatically by major increases in the population of the Japanese White-eye (Freed and Cann 2009, 2014, Rozek et al. 2017). The competition for food has led to population declines in the native species as a result of stunted growth, altered sex ratios, and changes in foraging behavior. In this nature reserve, in the period of the study, avian malaria played little or no role.

1.1.2.2 Hybridization

Hybridization is widespread in birds, and it is well documented because hybrid birds have always fascinated both professional scientists and amateur collectors or bird watchers (Mayr 1942). Hybridization is one of the threats posed by introduced birds that has the most impact on native species (Baker et al. 2014, Martin-Albarracin et al. 2015). The impacts of matings with alien species include introducing new genetic material into the gene pool of a native species and reducing the reproductive rate of a native species via “wasted” mating efforts. Matings with alien species can also introduce unfamiliar parasites or diseases to indigenous bird populations.

In an overview of bird hybridization, Grant and Grant (1992) showed that approximately 10% of species are known to have produced hybrids. Propensity for hybridization varies among different Orders of birds but is more common among waterfowl, cranes and hummingbirds. As of its last update in 2017, the Serge Dumont Bird Hybrid Database (http://www.bird-hybrids.com) contains nearly 9000 instances of interspecific or intraspecific hybridization (the latter being between subspecies) taken from 5622 references that document bird hybrids. Though many instances in that database are of hybrids in captivity, many are presumed to have occurred in nature; for example, Cockrum (1952) presented a checklist of bird hybrids for North America that only included cases in which hybrids had presumably resulted from crosses between wild birds, and Grant and Grant (1992) similarly excluded crosses that occurred in cages or laboratory studies. In most cases, successful hybridization results from the mating of closely related species, but in rare cases, it can occur among species in different genera. Thus, while most Mallard hybrids are with species in the same genus (*Anas*), hybrids with the Red-crested Pochard (*Netta rufina*) are relatively common in Central Europe (Randler 2008), and hybridization with Mallards seriously threatens New Zealand's Grey Duck (*Anas superciosa*, Rhymer et al. 1994) and the American Black Duck (*Anas rubripes*, Mank et al. 2004). Hybridization with the invasive alien Ruddy Duck (*Oxyura jamaicensis*) is one of the main threats to the globally endangered Old World White-headed Duck (*Oxyura leucocephala*, Brochier et al. 2010). Baker et al. (2014) emphasizes, though, that such extreme impacts of introduced on native birds are rare.

1.1.2.3 Disease transmission

Disease transmission is the second-highest scoring category among the threats analysed by Martin-Albarracin et al. (2015). Examples they highlight include Japanese White-eye and the Red-billed Leiothrix (*Leiothrix lutea*), each a reservoir for avian malaria; and the Common Pheasant, which shares a nematode parasite with the wild Grey Partridge (*Perdix perdix*) in the United Kingdom. The shared parasite may be one factor responsible for the recent decline of the partridge (Thomkins et al. 2000). Defecation by Canada Geese can increase the concentration of fecal bacteria in water bodies, and might transmit salmonella to cattle (Borchier et al. 2010).

1.1.2.4 Interaction with other non-native species

Interaction with other non-native species was added by Martin-Albarracin et al. (2015) to the six categories originally established by Kumschick and Nentwig (2010). In the analysis by Martin-Albarracin et al. (2015), this was one of the three most highly ranked impacts of alien invasive bird species, along with hybridization and disease transmission. This category was for birds that feed on seeds or fruits of alien plants and thus increase the impacts of the plant invasion. The best studied examples seem to be those from Hawaii, where various invasive birds have been shown to increase the dispersal of such invasive plants as firetree (*Myrica fava*) (LaRosa et al. 1985), Bermuda cedar (*Juniperus bermudiana*) (Woo 2008), and tree poppy (*Bocconia frutescens*) and common lantana (*Lantana camara*) (Chimera and Drake 2010).

1.1.2.5 Effects on ecosystem services

Effects on ecosystem services by alien invasive bird species include damage to water bodies due to pollution or eutrophication; damage to vegetation that leads to erosion of lake or stream banks; compaction of soil through trampling; and impacts on successional processes (Kumschick and Nentwig 2010: Appendix). The environmental impacts can produce changes in vegetational succession or in aquatic species composition, strong declines in population sizes of plant species or aquatic species, loss of habitat characteristics, and damage to sites of conservation importance. Overabundant Canada Geese provide a prime example of such impacts, as their activities can significantly change grassland and wetland habitats (Brochier et al. 2010).

1.1.3 Known economic effects

Invasive bird species can lead to economic losses in such sectors as crop production, livestock farming, and forestry. Economic impacts are greatest in species that are abundant and can form large flocks locally. The most important economic impacts from alien birds are from damage to grains and to vegetable and fruit crops (Shirley and Kark 2009, White et al. 2019). The alien invasive species showing the greatest economic impact were the Canada Goose, two parakeets, the Sacred Ibis and the Ruddy Duck. On the other hand, Kumschick and Nentwig (2010) did not find any economic impact of passerine birds in Europe.

Invasive birds can also damage human infrastructure and negatively impact human health (by spreading diseases) and reduce people's enjoyment of their surroundings from noises they make (such as parakeet calls) or from accumulations of droppings. Damage to human infrastructure can arise where birds nest or defecate, and includes damage to fences, power transformers for electricity, or buildings (burrowing or nesting damage), as well impacts through pollution and accumulation of droppings, and even damage to flood defense systems, and includes impacts from collisions with planes (Shirley and Kark 2009, Kumschick and Nentwig 2010).

1.1.4 Establishment of invasive birds – success and failure

The success rate for the establishment of alien organisms in general is low. A common rule of thumb—the tens rule—is that only 10% of introductions of non-native species succeed, and only 10% of those cause significant ecological or economic problems (Williamson 1996). Birds are no exception to this pattern (Dyer et al. 2017). To establish and spread, the founder population of newly arrived non-native birds must overcome a set of ecological, environmental and stochastic barriers to become established (Lockwood 2017). They must find areas that provide suitable habitat for nesting and have large enough quantities of appropriate food. They must be able to deal with competitors for nest sites and food, and with local parasites and diseases. At high latitudes, winter survival can limit population growth for non-migratory birds, as they must be able to obtain enough energy daily to survive cold winter nights (Newton 1969, Root 1988a, b) and to survive extreme winter events of cold and snow (Newton 2007). A founding population must tolerate inbreeding and is vulnerable to large fluctuations in mortality as long as the population remains small (Lande 1988, Drake and Lodge 2006, Billing et al. 2012). Population level inbreeding can affect a wide variety of traits related to reproduction and survival in birds, particularly under stressful conditions (Keller and Waller 2002).

It is difficult to derive firm conclusions about the factors determining success of bird introductions from publications on alien birds. Most introductions fail, whether they are from escapes or deliberate introductions (Dyer et al. 2017). In the case of the Canada

Goose in Norway, repeated introductions of hundreds of birds were needed before the species gained a foothold in the country (Jansson et al. 2008, Ielmini and Pullajah 2021). At the other extreme, one of several introduced populations in Chile started with an escape from a ranch of only a dozen California Quail (*Callipepla californica*) in 1864 (Jaksic 1998), and a release of only ten pairs of this species in 1943 led to the establishment of viable populations in Argentina (Codesido and Drozd 2021). Also, small numbers of escaped pet birds have led to the establishment of breeding populations in many countries; examples include escapes of Common Starlings and Crested Mynas (which are also a species of starling, *Acridotheres cristatellus*) in and around Buenos Aires in Argentina (Codesido and Drozd 2021). Generally, though, escapes rarely lead to successful establishment, and establishing permanent populations of species that are deliberately released usually requires repeated efforts. The establishment of Common Starlings and House Sparrows in North America, two species now ubiquitous, apparently required numerous and widespread deliberate releases, despite the oft-repeated myth that both invasions originated from releases of small numbers of birds in Central Park of New York City obsessed with introducing all the birds mentioned by Shakespeare (Fugate and Miller 2021). Similarly, some 300–500 Northern Cardinals were introduced over several years in the early 20th century to three Hawaiian islands, and the species now is abundant on all the islands (https://birdfact.com/articles/cardinals-in-hawaii). Further, the story of escaped pet birds leading to new invasions needs nuance: there is evidence that successful invasions have arisen from birds that were wild-caught for the pet trade and not captive bred birds that have lost their ability to live in nature (Carrete and Tella 2008).

It is almost never possible to know why a given introduction failed. Statistical analyses of animal or plant introductions present tables and text focussed on trying to understand success, not failure (but see Simberloff and Boeklen 1991, Moulton 1993). Once an incipient invasion has failed (as most do), there are no specimens to analyse and no community to analyse with the failed species present. We can only guess that the non-native species has been outcompeted, the non-native species has succumbed to predation (or overhunting) or to parasites or a disease, or that the local population(s) of the intruding species has met with a random mass mortality event, such as drought, flooding, a hurricane, or a landslide. The physical environment and climate may have been a poor match. It is possible the newly transported individuals could not find mates due to low population numbers or biased sex ratios.

Genetics can also play a key role in establishment failures. Inbreeding depression might have reduced offspring quality and quantity to the point that population growth was negative, when newly established introduced populations fail to survive. When the number of founding individuals is small, the incipient population will start out with a random selection of the genetic variability in the source population. Depending on how small the founding population is and on how long it remains small, the new population will randomly lose further genetic variation due to genetic drift. Lack of genetic variability would hamper the ability of a newly established population to adapt to its new circumstances. Genetic variability will be larger, if the number of founding individuals is larger or if a species colonizes a new region repeatedly; the sum effect of the number of individuals of non-native species that are introduced to an area is referred to as propagule pressure.

Propagule pressure has long been recognized as a factor heavily influencing success and failure (Drake and Lodge 2006, Simberloff 2013, Cassey et al. 2014, Wittmann et al. 2014), but propagule pressure alone cannot explain why some introductions succeed and others fail. As Simberloff (2013) points out, invasion genetics presents a paradox: most invasions began with small numbers of individuals, yet many did not fail due to inbreeding depression or genetic drift.

As is clear from recent global analyses of naturalized alien birds (Uehling et al. 2019), certain taxonomic groups have been much more successful than others. Parrot species are popular in the pet trade and seem to have characteristics that enable them to readily establish permanent populations from occasional escapes and then spread widely. Thus, 56 non-native species of parrots have been reported from the wild in the contiguous USA, 25 of which are known to be breeding (Uehling et al. 2019). Most sightings are of the three most common species, one of which is the Monk Parakeet which is also well established in Europe. Naturalized parrots are now common species in many parts of the USA. Parrots provide an excellent example of species that manage establish and spread despite populations being initiated from small numbers of escaped individuals.

The success or failure of introductions also depends in part on the composition of the community into which the non-native species is introduced (Moulton 1993). Two hypotheses have been put forward to explain successes and failures of 69 non-native birds introduced to the Hawaiian Islands. Moulton and Pimm (1983) and subsequent papers by Moulton and colleagues (reviewed in Moulton 1993) suggested that the composition of current communities of naturalized bird species on the islands results from competition among similar species. Simberloff and Boecklen (1991) argued for a second explanation,that they refered to as "all-or-none": that the success or failure of a given introduction depends on the intrinsic ecological and behavioral characteristics of the species itself and is independent of which other species co-occur. In such a scenario, an invasion would either succeed or fail ("all-or-none") due to the characteristics of the alien species. Moulton (1993) re-analysed the data in Simberloff and Boecklen for passeriform birds (flycatchers and songbirds) and concluded that competition remained the best explanation for the pattern of successes and failures of introductions, while conceding that the "all-or-none" hypothesis could better explain the fates of columbiform birds (doves and pigeons) introduced to islands.

1.1.5 Invasive birds in Norway

Eighteen bird species were evaluated in the most recent list of alien species in Norway, Fremmedartslista 2018[1]. Four of these species are established in Norway, Bar-headed Goose (*Anser indicus*), Snow Goose (*Anser caerulescens*), Canada Goose (*Branta canadensis*), and Ring-necked Pheasant (*Phasianus colchicus*). All but the Canada Goose are considered low risk. The other 14 species are included because it is likely they will become established in the next 50 years (so-called door-knocker species); these are species that are already in Norway but have not spread into nature, are already established in neighboring countries, or are thought to be able to find suitable

[1] https://www.artsdatabanken.no/fremmedartslista2018

habitat in a future Norway and could readily disperse to it. Ten of these 14 species are ducks and geese, some of which already occur locally in ponds or lakes or are kept in captivity but have not become established in the wild. Only one of the species of alien birds was considered to pose a future threat to Norwegian nature; the Egyptian Goose (*Alopochen aegyptiaca,* Norw. *niland*). The Northern Cardinal was not risk assessed in the list of alien species in Norway in 2018. According to the expert group on birds (Stokke and Gershaug 2018): "The species is native to North America and is kept as a caged bird in Europe. In the 1950s, a few pairs were released on a farm in Jeløy near Moss, Østfold. They subsequently nested in bushes and trees near the farm (Bevanger, 2005). As it stands now, it is considered highly unlikely that the species will establish a wild breeding population in Norway. Risk assessment is not conducted" (translated from Norwegian).

The Canada Goose (Norw. *kanadagås*) is considered to have the most damaging impact of any alien bird species in Europe and is the only non-native bird species considered to have a severe impact in Norway (Sandvik et al. 2020). The biology of the Canada Goose and its history in northern Europe is summarized in Jansson et al. (2008) but see also Andersson et al. (1999) in regard to Norway. Introductions were for hunting. The first introductions to Norway apparently failed, but populations of Canada Goose becme well established after introductions of at least 750 birds in the 1960s, 1970s, and 1980s. By the time of the report by Andersson et al. in 1999, the Norwegian population was estimated to be more than 15,000 geese and was increasing all over the country.

The Egyptian Goose was evaluated as having a high potential for harming Norwegian nature, and it is one of four species on the list" Invasive Alien Species of Union concern"[2]. The species can have major ecological effects[3] but does not disperse well. The Egyptian Goose is an African species that has been introduced widely in Europe as an ornamental species in zoos, formal gardens, and urban parks. As of 2014, 12 individuals had been recorded in Norway, thought to originate from naturalized populations in continental Europe (Olsen et al. 2016). The species is large and aggressive, outcompeting native species for food and nesting sites; it is also known to hybridize with other goose and duck species, though this has occurred primarily in captivity. Other threats include overgrazing, eutrophication of ponds and small lakes, and spread of diseases.

1.2 Taxonomy of the *Cardinalis cardinalis*

The Northern Cardinal is one of the birds named by Carl Linnaeus in the 1758 10th edition of *Systema Naturae*. He named the species *Loxia cardinalis,* placing it together with crossbills. The species epithet "*cardinalis*" is thought to refer to the vermilion robes and peaked hats of the Catholic Church officials known as cardinals. Eventually, it was more properly placed with two other species in the genus *Cardinalis* giving rise to its current tautonymous designation *C. cardinalis*. In 1985, the official common name was changed from simply "Cardinal" to "Northern Cardinal", to specify that it is

[2] https://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pdf

[3] https://artsdatabanken.no/Fremmedarter/2018/N/319

the northernmost of the three cardinal species. The other two species in the genera include the Pyrrhuloxia (*C. sinuatus*) of the southern US and northern Mexico and the Vermilion Cardinal (*C. phoeniceus*) of Colombia and Venezuela.

The Northern Cardinal is non-migratory, as shown by banding studies (Laskey 1944, Dow and Scott 1971). The distribution of this species is broad (see 1.3.1), ranging from the boreal forests of southeastern Canada through eastern North America (and parts of the southwest) and down through Mexico to the jungles of northern Guatemala and -Belize.

The International Ornithological Committee's regularly updated list of world birds recognizes 19 subspecies of the Northern Cardinal (Gill et al. 2023), some of which were originally considered distinct enough to be described as separate species (Ridgeway 1885, Ridgeway and Friedmann 1901, Phillips 1997, Halkin et al. 2021). Differences among subspecies are based on differences in characters such as bill size, shape and color; length and stiffness of crest feathers; feather color differences on different parts of the body; relative lengths of wigs, tail, and feet; variation in the face mask; and overall body size differences (e.g. Ridgeway and Friedmann 1901, Parkes 1997, Halkin et al. 2021). Parkes (1997) discussed many of the named subspecies and notes that many of them intergrade with others (see also Halkin and Linville 1999). Most but not all subspecies were described in the 1800s or early 1900s, but a 19th was described as recently as 1997 for a population from a narrow stretch of low scrub on the northern coast of the Yucatan Peninsula in southeast Mexico (Parkes 1997). This subspecies is not recognized as separate from *C. c. yucatanicus* by Halkin et al. 2021. The Parkes subspecies (*C. c. phillipsi*) intergrades with at least one of the other five subspecies on the Yucatan but inhabits a quite different habitat in that most of the Yucatan is tropical rainforest. A clearer picture of infraspecific lineage variation emerges from a recent paper on the phylogeography of the Northern Cardinal (Smith et al. 2011). Using data from mitochondrial DNA sequences, ecological niche models and demographic data, they studied the effects of glaciation on current day patterns of genetic diversity and variation. They identified four continental and two island clades (see section 1.3.1 for further details). The ranges of the four continental clades largely agree with four previous groupings of subspecies based on morphology (Ridgeway and Friedmann 1901, Smith et al. 2011). The *cardinalis* clade, named for the nominate subspecies *C. c. cardinalis,* includes most of the cardinal range, encompassing eastern North America and eastern Mexico down to the Yucatan Peninsula. The other three clades include *igneous* (South-Western USA, Baja California, Sonoran Desert in northwestern Mexico), breeding in xeric shrubland; *coccineus* (Yucatán Peninsula), mainly tropical deciduous forest and rainforest; and *carneus* (a thin strip of coastland of southernmost southwest Mexico), tropical deciduous forest.

The four mainland clades occupy well-delimited biogeographic areas that are well separated by geological and climatic barriers (Smith et al. 2011). The study found that the enormous and climatically varied range of the *cardinalis* clade (3 million km^2) shows little genetic structuring, despite having multiple described subspecies. Ecosystems in the distribution of this clade range from boreal forests to desert to tropical forests.

The Northern Cardinal belongs to the family Cardinalidae (Norw. *kardinaler*). There are no species within Cardinalidae that are native to Europe. The closest relatives of the Northern Cardinal found in Norway are typically from the family Fringillidae (Norw. *finkefamilien*, e.g. *Pyrrhula pyrrhula* Norw. *dompap* and *Chloris chloris* Norw. *grønnfink*), Emberizidae (Norw. *buskspurvfamilien*, e.g. *Emberiza hortulana* Norw. *hortulan* and *E. citronella* Norw. *gulspurv*), and Calcariidae (Norw. *lappspurvfamilien*, e.g. *Calcarius lapponicus* Norw. *lappspurv* and *Plectrophenax nivalis* Norw. *snøspurv*). Species within these families share some similarities in terms of body shape and beak structure.

1.3 Ecology and biology of *Cardinalis cardinalis*

1.3.1 Native range and habitat

The Northern Cardinal (*C. cardinalis*) is a native bird of North and Central America and has a widespread distribution, stretching from Belize and northern Guatemala in the south, all the way to the southern parts of eastern Canada. It so now also established on all of the Hawaiian islands and Bermuda (Figure 1).

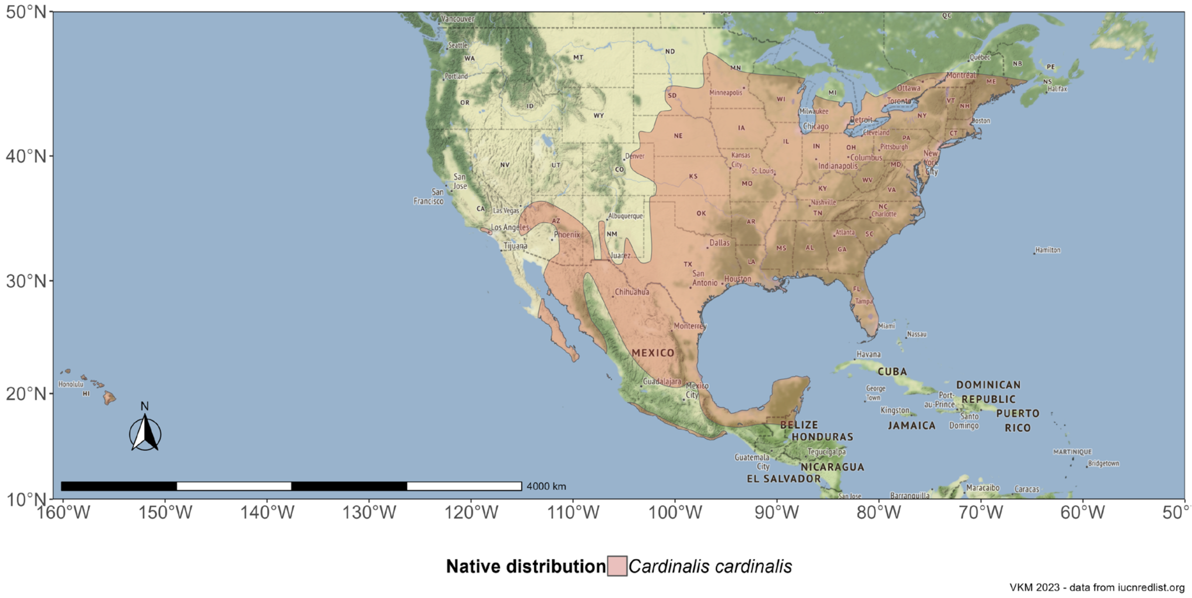

Figure 1: Map illustrating the main distribution of *Cardinalis cardinalis* across North America, based on curated data from Birdlife (2021).

The original native range is unknown but was probably much smaller than today's distribution. According to Halkin et al. (2021), cardinals have expanded northwards, northeastwards, and westwards since at least the mid-1800s. Although less is known of expansion from the southern populations, Ramirez Albores (2010) report at least one case of expansion from coastal regions to interior Mexico.

According to un-curated entries in the Birdlife database the present distribution also includes scattered (and most probably extralimital observations) individuals up to 58° N in High Level, Alberta, Canada) and south-central Canada (Figure 2).

In North America, except for a few scattered observations, the Northern Cardinal is absent from the northwestern regions of US, Alaska, and other parts of western and northern Canada. The relative abundance, based on entries in GBIF and eBird from the US, clearly indicates an eastern to southern range, northwards from the Gulf of Mexico and up to the central midwest. In Mexico, the relative abundance is high around the Gulf of Mexico, on both sides of the Gulf of California and stretching into Arizona. The Northern Cardinal is more or less absent from the central interior of Mexico and avoids high mountain ranges (not registered above 2500 m altitude according to IUCN 2018[4]).

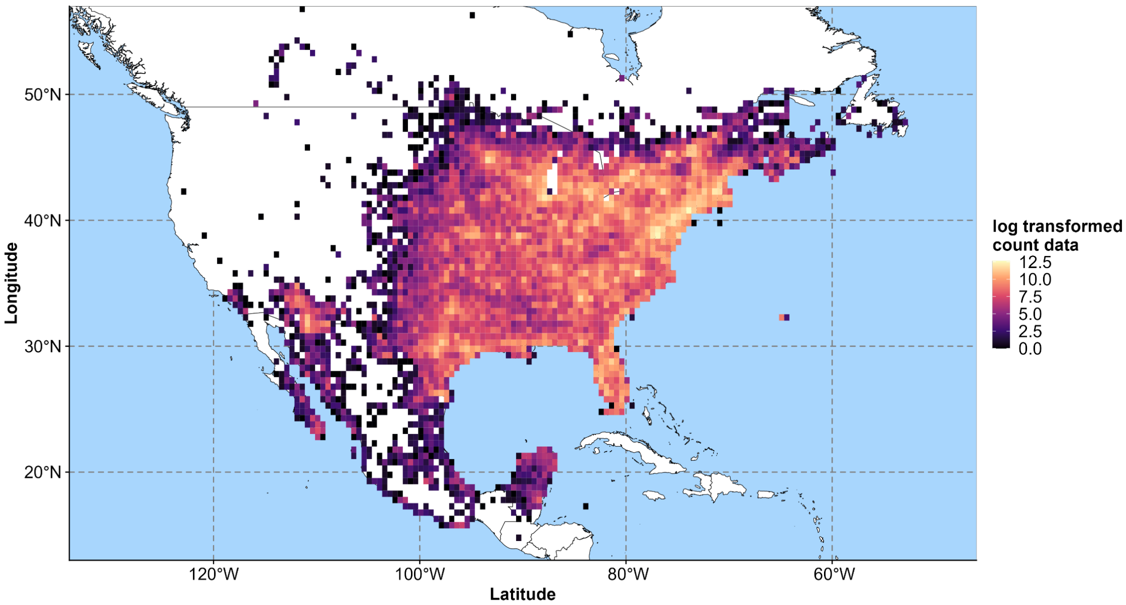

Figure 2: The distribution and density of *C. cardinalis* (including subspecies), based on all coordinates from BirdLife (n = 17,413,800) as of April 2023, illustrating the ongoing northwards expansion. Map shows log-transformed count of coordinates per raster cell.

The Northern Cardinal was introduced and is now naturalized to southern California and Arizona, Bermuda, and all Hawaii's main islands. *C. cardinalis* has also been observed in the wild in The Netherlands and Belgium but there are no indications that it has established free-living populations with no publishes evidence, and few sightings reported in GBIF or relevant national websites. In addition, according to very few entries in GBIF[5], the species has been registered in Spain, Switzerland, Germany, Denmark, Sweden and Norway. These specimens are most likely escapees from captivity and have not been observed to reproduce. Attempts to introduce the Northern Cardinal in Spain (Carette et al. 2008) and Germany (DAISIE 2003) are registered from literature, but we have no indication of naturalization in these countries.

[4] https://www.iucnredlist.org/species/22723819/132024136

[5] https://www.gbif.org/species/2490384

In total, *C. cardinalis* is registered with more than 16,725,000 entries in GBIF (https://www.gbif.org) and above 17,413,800 entries in eBird (most of these are digital replicates). The most frequently registered is the unspecified *C. cardinalis*, which make up more than 99% of all the entries. Nineteen subspecies are registered in GBIF, but Smith & Klicka (2013) combined them into six clades based on multilocus data (see section 1.2). These clades have rather distinct distributions.

The most frequently registered subspecies in GBIF is *C. cardinalis* subsp. *cardinalis* with 4631 entries and a wide distribution. The other subspecies have fewer entries, and more restricted distributions. *C. cardinalis* subsp. *floridanus* is registered with 1111 entries, whereas *C. cardinalis* subsp. *superbus* is registered with 816 entries. *C. cardinalis* subsp. *igneus* has 681 entries, *C. cardinalis* subsp. *magnirotris* has 331 entries, *C. cardinalis* subsp. *yucatanicus* has 211 entries, whereas *C. cardinalis* subsp. *affinis* has 208 entries. *C. cardinalis* subsp. *sinaloensis* has only three registered entries in GBIF, and the subspecies is confined to western Sinaloa region of Mexico.

The broad distribution of the Northern Cardinal (Figure 1) indicates that the species has a rather low specificity in habitat choice. The Northern Cardinal is registered and present in a variety of habitats. According to the IUCN Red List assessment (IUCN 2018), the Northern Cardinalis is a resident in forests, shrublands, and wetlands, as well as in artificial and urban habitats. The common habitat factor seems to be areas with shrubs, bushes, or trees, or with these bush- and tree-layer properties in the proximity (Figure 3).

Figure 3: *Cardinalis cardinalis* male in coniferous forest habitat. Photo: Lightpoet (Mostphotos #17241729)

Common habitats include forest- or marsh-edges, grassland with shrubs, agricultural areas with hedgerows, urban areas with plantings, and forest interior. The Northern Cardinal is also frequent in riparian forests, subtropical mangrove forests, and desert scrubs (Halkin et al. 2021). In wetland ecosystems, the Northern Cardinal uses bogs, swamp, fens, and other peatlands, as well as streams, rivers, and marsh edges (Calmé et al. 2002; IUCN 2018). The Northern Cardinal is common in degraded and successional ecosystems (regrowth), such as logged forest areas, second-growth forests, and successional fields (Dow 1969). All these ecosystems have available shrubs, thickets, or trees in the proximity. The foliage of shrubs, bushes, and trees are used for nesting (protection from predators), and the Northern Cardinal prefers denser vegetation compared to a random background of the same habitat (Leston & Rodewald 2006). The bird is common in fragmented landscapes (Donovan & Flather 2002) and uses a winter habitat that is similar to the summer habitat (Halkin et al. 2021).

The various lineages of the Northern Cardinal, as reported by Smith & Klicka (2013), are likely associated with specific subhabitats found within the general habitats common to the ecoregions within their respective ranges. However, the most relevant lineage for this assessment is the habitat of *C. cardinalis* subspecies *cardinalis*, which is a subspecies that has a wide distribution and a rather low habitat specificity.

1.3.2 Population size and density

Northern Cardinal has increased in numbers and geographic range over the last two centuries, probably due to increases in agricultural and suburban habitats to which the species is well adapted. The association with human habitation goes back at least 1500 years (Smith et al. 2011). In more recent decades, the widespread practice of winter bird feeding in the US and Canada has undoubtedly buffered populations against large losses due to periods of inclement weather. Using data from the North American Breeding Bird Survey[6], the website All About Birds[7] estimates that Northern Cardinal numbers have grown by 0.32% per year since 1966. There are two estimates of total population size of Northern Cardinals. The Animal Diversity Web run by the University of Michigan[8] estimates the number to be 100 million world-wide, while Partners in Flight[9] estimates 120 million. Overall, Northern Cardinals are classified as Least Concern in the IUCN Red List since their numbers seem to be either stable or increasing globally. Local densities vary greatly, depending on the amount and quality of suitable habitat for summer breeding and for fall to spring feeding and sheltering. Using four years of breeding bird census data for eastern North America taken from Audubon Field Notes (what later became the American Birds publication), Woolfenden and Rohwer (1969) calculated that the average survey density was 67 pairs per km^2, ranging from seven pairs to 220 pairs per km^2. For their own research data from suburban Florida sites, the densities ranged from 20 per km^2 to 72per km^2, and they attributed the variation to densities of low trees and shrubs suitable for nesting.

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[6] https://www.mbr-pwrc.usgs.gov

[7] https://www.allaboutbirds.org/guide/Northern_Cardinal/lifehistory#conservation

[8] https://animaldiversity.org/accounts/Cardinalis_cardinalis/

[9] https://pif.birdconservancy.org/ACAD/Database.aspx

1.3.3 Climate tolerance

The specific climate tolerance of the Northern Cardinal, with respect to several different climate variables and interactions, is not very well known or documented. However, they tend to cope well during winter and survive cold winter conditions in the northern part of their native range in southern Ontario and Québec (Figure 4). Since the Northern Cardinal is not a migratory bird species, it is from the distribution of well established, reproducing and surviving individuals we must seek to understand climatological constrains with respect to the invasive potential within Norway.

The Northern Cardinal can cope with shorter cold events with higher body mass, increased fat score, and increased metabolic ceiling in shorter periods during wintertime. The average wintertime temperature on the other hand, including December, January, and February, could be more important for survival since this is the energetically most expensive period for Northern Cardinalis (Sgueo et al. 2012). The highest frequency of presence of the Northern Cardinal during the coldest quarter (BIO11, Figure 5) however, appears at mean temperatures of around -4° C. The Northern Cardinal can therefore also cope with cold, long-lasting winters.

Figure 4: *Cardinalis cardinalis* in snow. Photo: Patrick Jennings (Colourbox #47921865)

For example, from a population perspective the relative importance of a variety of mortality causes is unknown (Halkin et al. 2021). Likewise, the relative importance of climate for dispersal and successful breeding is not fully understood, since the effects of weather extremes and climate is difficult to separate from contemporary causes influencing the entire life cycle of the species. The only discovered scientific experiment on *C. cardinalis* concerning climate and acclimatization, is the study of Segue et al. (2012).

At high latitudes, a large body of studies points to the importance of winter survival as crucial for non-migratory birds (see e.g., Petit et al. 2016). The winters at high latitudes have lower ambient winter temperatures that are energetically challenging for homoeothermic species in general, particularly for small birds (Williams et al. 2000, Swanson 2021), including the Northern Cardinalis (Sgueo et al. 2012). Winters pose reduced food availability, but also because of physical limitations to access caused by snow or events with ice encapsulation of fruits and seeds and other food items. In addition, short day-length reduces the time for foraging. From an evolutionary perspective, ambient temperature is one of the most influential abiotic factors for thermoregulation and is probably an important driver for a range of morphological, physiological, and behavioral adaptions (Swanson et al. 2014; Zhou et al. 2016). Therefore, based on the distribution of Northern Cardinalis in North America today, compared with Norway, the main efforts in this assessment, have been made to examine the effects of winter climate on the Northern Cardinal.

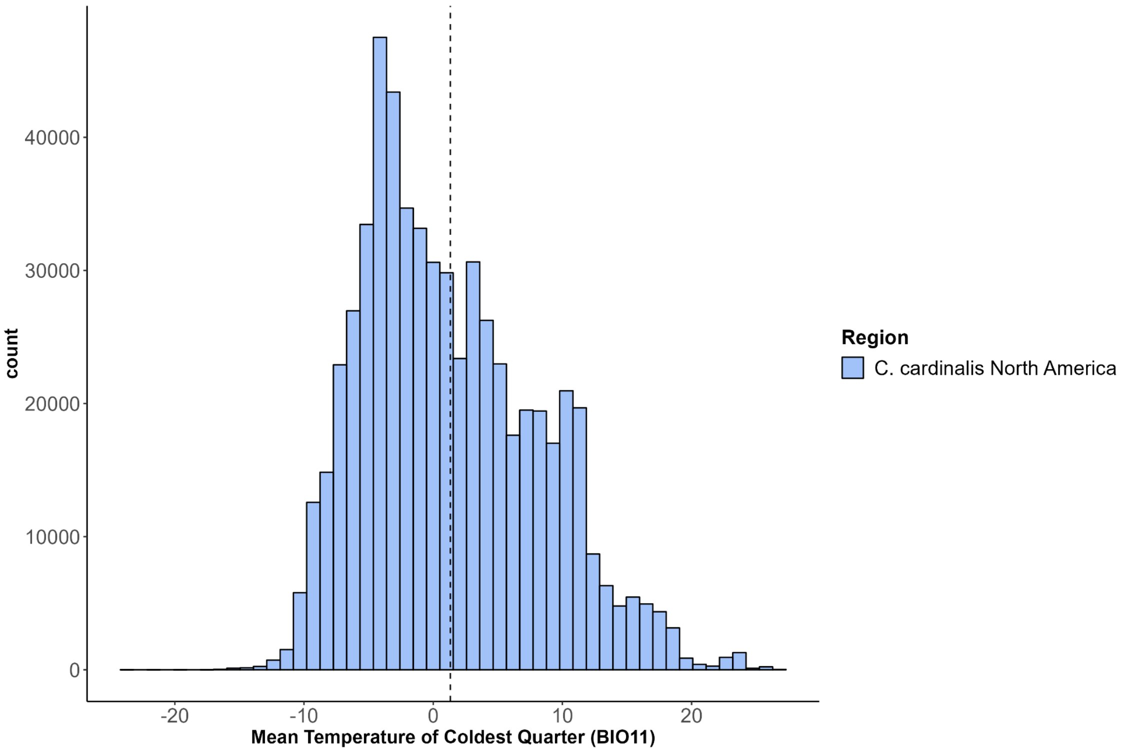

Figure 5: Frequency of presence of the Northern Cardinal along the gradient of mean ambient coldest quarter (BIO11; years 1970-2000) temperatures from WorldClim (Fick and Hijmans, 2017).

As documented by entries in databases (see section 1.3.1), the distribution of the Northern Cardinal goes from subtropical regions north to around 53° N, with some entries even north to 58° N. The temperature niche of C. cardinalis sensu lato should therefore be regarded as very wide. This is evident from the frequency of presence by the Northern Cardinal plotted along the gradient of January minimum ambient temperature (Figure 6). The northern populations experience temperatures down to -25° C during cold events in wintertime. The highest frequency of presence of the

Northern Cardinal, appears at minimum January temperatures of around -10° C. Shorter cold spells or low temperature extremes are therefore not challenging within the present distribution.

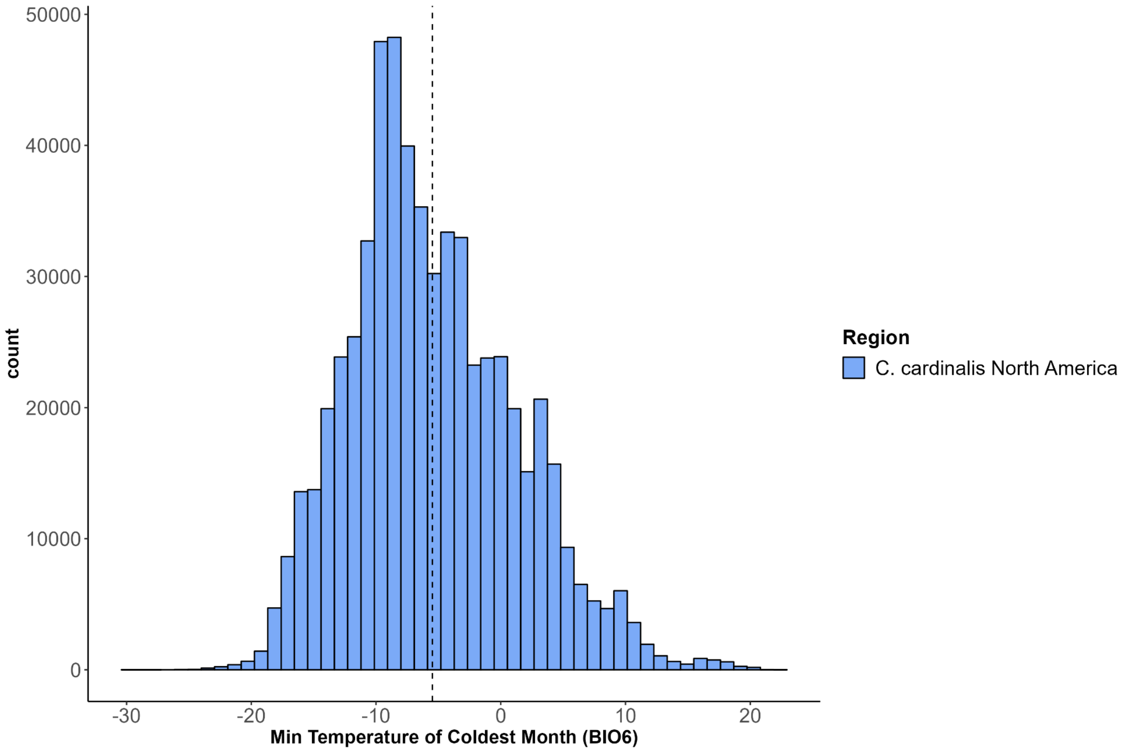

Figure 6: Frequency of presence of the Northern Cardinal along the gradient of the minimum ambient temperature during the coldest month (BIO06; years 1970-2000). Temperatures from from WorldClim (Fick and Hijmans, 2017).

According to our analyses with the Maxnet model and Jackknife cross-validation (see sections 2.2.4 and 2.2.5), based on CHELSA data (Karger et al. 2017; 2018; 30 min resolution), net primary productivity (NPP) and precipitation during the driest month (BIO14), are the two most important variables explaining the distribution, without interaction. In addition, the mean daily air temperature of the warmest quarter and the area of cultivated and managed vegetation are important. The importance of these four variables points to the need for sufficient food, shelter, and breeding spots within a bush- and tree layer (edge habitats in rural areas and trees in urban areas), for the Northern Cardinalis to survive and reproduce. None of these environmental restrictions is relevant for Norway, which is in an oceanic climate region, influenced by frequent and moist low-pressure weather systems along the North Atlantic Ocean. Agriculture is widespread in Norway on the 3.5% of land that is arable[10], but regrowth and successional forest are common (Bryn et al. 2018). On the other hand, the winter temperatures are likely contributing strongly to regulating the northwards distribution of *C. cardinalis*. From studies of Northern Cardinal in Ohio, with a humid continental climate not unlike the climate of southeastern Norway, winter abundance is best explained by the minimum January temperatures (Leston & Rodewald 2006). *Cardinalis cardinalis* living at the northern edge of their range are likely close to the limit of their physiological ability to maintain homeostasis (Root 1991). Root (1994) describes the

[10] https://www.ssb.no/en/natur-og-miljo/areal/statistikk/arealbruk-og-arealressurser

importance of climate and vegetation features for their northern range and predicts a potential northwards range shift with a warmer climate.

1.3.4 Spread and pathways

The Northern Cardinal has been introduced and naturalized in several US regions and islands (section 1.3.1). However, the occurrence and spread of a bird species into a new and previously un-inhabited areas can also result from colonization (Brochier et al. 2010). Colonization is the ecological process in which a species naturally spreads into new areas, for example because of climate change or other environmental changes. The term range expansion is often considered synonymous to colonization, but it can be difficult to separate the effects of introduction and colonization in regions close to the native range. In addition, local migration, in search for available space, resources, partners for reproduction, or new habitats, is a common feature of all existing species colonizing new ranges. The Northern Cardinal has expanded westwards and northwards since the mid-1800s (Halkin et al. 2021). In the context of this risk assessment, the northward expansion is most relevant. According to Halkin et al. (2021), the northward breeding range expansion the last 100 years, is likely related to three causes:

- Climate change; especially warmer winters resulting in lesser snow depth and greater winter foraging opportunities.

- Human land use and disturbance; especially related to forest areas, where human encroachment is increasing the area of suitable edge habitats and secondary successional forests with shrubs and thickets.

- Assistance from humans; especially establishment of winter-feeding stations which is increasing food availability at times when body fat for winter metabolism and survival is crucial (Robb et al. 2008, Sgueo et al. 2012).

There is limited knowledge about the specific pathways of the northward expansion. The expansion to South Dakota could be a result of an increase in riparian woody habitat (Ducey 1988), whereas the Midwest expansion could be influenced by the increase of urban parks and residential land (Robbins & Easterla 1992). Anyway, the pathways of the Northern Cardinal are most likely facilitated by forest encroachment and regrowth (secondary forest succession), as well as residential land and extensive land use resulting in more edge habitats and shrubby vegetation.

1.3.5 Feeding biology

The Northern Cardinal has an omnivorous diet that is highly adaptable (Halkin et al. 2021, Long 2020). They are primarily seedeaters since they have a strong conical bill that allows them to crack open seeds and remove shells from a variety of sources (Halkin et al. 2021). Northern Cardinals are primarily ground feeders but are also adept at feeding while perching on branches. The birds consume seeds from plants, such as bristle grass, dove weed, grasses, knotweed, panic grass, sedges, and smartweed

(Long 2020). They can also eat plant buds, flowers, and foliage. They are a common garden bird that uses birdfeeders in their native habitat (Figure 7).

Figure 7: *Cardinalis cardinalis* male on birdfeeder. Photo: Miromiro (Mostphotos #60663263)

Northern Cardinals are also known to eat berries and fruits, including blackberry, grape, hackberry, and mulberry (Long 2020). During the spring and summer, cardinals may feed on arthropods, such as ants, beetles, caterpillars, moths, centipedes, dragonflies, flies, grasshoppers, mayflies, and spiders, and they can also eat slugs and snails (Long 2020). Invertebrates provide them with the protein and nutrients they need to breed and raise their young.

1.3.6 Breeding biology

Northern Cardinals reach sexual maturity when they are around one year old and typically start to breed the spring after hatching (Halkin and Linville 1999). The breeding season of the Northern Cardinal varies depending on their geographical location. Breeding can begin as early as February in the southern part of their range, and in May or June in the northern part of their range (Oberholder 1974). The species is a territorial songbird and males establish a territory and sing to attract females. The purpose of the song is also to defend the territory and he will chase off other males entering his territory. Once a female is selected, the pair will engage in courtship behavior. Northern Cardinals are serially monogamous, though polygyny occasionally occurs (Breitwisch et al. 1999).

The only apparent nest requisite are adequate amounts of woody cover and sufficient song posts (Dow 1970). Northern Cardinals typically build their nests in shrubs, vines, or small trees, usually 1-3 meters off the ground (Ehrhart and Conner 1986). The nest is constructed by the female, who uses twigs, leaves, and grasses, and lines the nest with soft materials, such as feathers, animal hair, or grass (Halkin and Linville 1999). The nest building process can take up to two weeks. Once the nest is built, the female lays eggs (Figure 8). A typical clutch size is two to four eggs, which are incubated by the female for about 11 to 13 days before they hatch (Laskey 1944).

Figure 8: Female *Cardinalis cardinalis* incubating. Photo: David Wood (Mostphotos #22035257)

Once the eggs hatch, both parents care for the chicks. The chicks are born altricial, meaning they are blind, mostly naked, and completely dependent on their parents for food. The developing young are fed a diet of insects and seeds. The chicks remain in the nest for about 9 to 11 days before they fledge (Halkin and Linville 2020). Once they fledge, the parents continue to feed and care for them for several weeks until they become independent (Halkin and Linville 1999). Pairs usually raise two broods a year but may raise as many as four broods during good years (Laskey 1944).

1.3.7 Diseases/pathogens and parasites

We use the term "disease" to encompass illnesses caused by pathogens or parasites. Common diseases in domesticated birds include bacterial, viral, and fungal infections, as well as parasitic infestations, such as mites, lice, and ticks. Animals in captivity may also spread inherited disorders or diseases to the wild cardinal population, especially in cases of heavy inbreeding. We will not consider inherited diseases and disorders here since wild populations of Northern Cardinals do not occur in Norway.

Introduced birds could transmit diseases to the native bird population, and especially on remote islands (Ishtiaq et al. 2006, Deem et al. 2008), including introduced strains of diseases (Farmer et al. 2005, Soos et al. 2009). Birds have great mobility, which can allow them to spread diseases across large geographic areas (Reed et al. 2003). The spread of diseases in birds also depends on the specific disease and its transmission mechanisms. Some diseases, such as avian influenza, can be highly contagious and can quickly spread through populations of birds (Gaidet et al. 2012). Other diseases, such as some haemosporidian blood parasites, are to a lesser extent dependent on bird mobility for their spread since they also depend on transmission through insect vectors, such as biting midges, mosquitoes or blackflies (Valkiūnas 2004).

Common diseases in wild populations of the Northern Cardinal include West Nile fever, avian pox, avian malaria, mites, lice, eastern equine encephalitis virus, and ticks (Adams et al. 2006, Amin et al. 2014, CABI 2019, Dybey 2002, Heller et al. 2016, Kounek et al. 2011, Nardoni et al. 2019, Pistone et al. 2021, Stelzer et al. 2019, Walstrom and Outlaw 2017). We lack information on the prevalence of these diseases in the domesticated population of Northern Cardinals. However domesticated birds can act as vectors or reservoirs for a range of diseases (Ritchie et al. 2013). Birds in captivity can disseminate diseases into a wild avian population if they escape from their cage. Birds can transmit or be infected by diseases to- or from wild birds through direct contact, indirect contact, or via vectors. Some avian diseases are zoonotic and can be transmitted to humans. Examples of zoonotic diseases include chlamydiosis, salmonellosis, avian influenza, eastern equine encephalitis, avian tuberculosis, Lyme disease, and West Nile virus (Boseret et al. 2013). Predators, like domestic cats, can also be infected. Thus, birds in captivity potentially can spread diseases that they could have contracted in their original breeding facility or from humans (Vanrompay et al. 2007, Boseret et al. 2013).

1.3.7.1 Haemosporidian blood parasites

Northern Cardinals in the wild are often parasitized by intra-cellular haemosporidian blood parasites, also known as avian malaria parasites. Haemosporidia is a diverse group of blood parasites that can infect a wide range of bird species worldwide. Haemosporidian blood parasites have been found in considerable prevalence from several species of passerines on mainland Norway (Eide et al. 1969). The parasites include a wide diversity of *Plasmodium* and *Parahaemoproteus* species in the Northern Cardinal (Walstrom and Outlaw 2017). The prevalence of infected birds can reach 67% of the population (Walstrom and Outlaw 2017), which is a higher prevalence than other North America bird species (Kimura et al. 2006, Durrant et al., 2008, Pagenkopp et al 2008). Haemosporidian parasites are transmitted by biting midges (Valkiūnas 2004). The Northern Cardinal tends to live near water and nest in riparian corridors not far from the ground. The density of blood sucking parasites is also high in these habitats, which may explain the high avian haemosporidian prevalence (LaPointe et al. 2012). Cardinals are resistant carriers of malaria. Birds in Scandinavia become infected with the disease during their wintering sites in Africa, and the initial infections they contract are likely to have more severe effects compared to the chronic phase of the infection during the summer Bensch et al. 2007. The Northern Cardinal is a reservoir for avian malaria as an invasive pathogen in Hawaii (Van Riper et al. 1986).

1.3.7.2 Avian trichomoniasis

Avian trichomoniasis is a parasitic disease caused by the protozoan parasite *Trichomonas gallinae* or *T. gallinarum*. The disease primarily affects birds, including various wild bird species, like the Northern Cardinal, and domesticated birds (CABI 2019, Amin et al. 2014). It is commonly transmitted through the ingestion of food or water contaminated with the parasite or by direct contact with infected birds.

Avian trichomoniasis can have significant impacts on wild bird populations, particularly in cases where the disease is highly prevalent or affects vulnerable species (Andersen et al. 2009). Avian trichomoniasis can sometimes be transmitted to raptors through the consumption of infected birds (Rogers et al. 2014). The pathogen has been reported in finches from Norway (Neimanis et al. 2010). Avian trichomoniasis can be treated by the administration of antiprotozoal medications. Proper hygiene practices, such as cleaning and disinfecting bird feeders and water sources, can help reduce the transmission of the parasite.

1.3.7.3 Avipox

Avian pox caused by the avian poxvirus is one of the most noticeable, and therefore commonly reported, viral diseases of birds, like in the Northern Cardinal (Adams et al. 2006). Infections can manifest in different forms, including cutaneous (skin), diphtheritic (mucous membranes), and systemic (internal organs).

Avipox virus is highly contagious and can spread among birds through direct contact, aerosols, or exposure to contaminated surfaces (Weli and Tryland 2011). Mosquitoes and other biting insects can also act as mechanical vectors, transmitting the virus between birds (Weli and Tryland 2011). Avipox can have significant impacts on individual birds and populations. It is present in wild birds in Norway (Weli et al. 2004).

1.3.7.4 Toxoplasmosis

Toxoplasmosis is a parasitic disease caused by the protozoan *Toxoplasma gondii*. The parasite has a global distribution, including Norway (Kapperrud 1978). While it primarily affects mammals, including humans and livestock, toxoplasmosis can also impact birds and the Northern Cardinal (Dybey 2002, Stelzer et al. 2019, Nardoni et al. 2019). Birds can become infected with *T. gondii* through ingestion of contaminated food or water, ingestion of infected prey, or exposure to contaminated environments. Birds are intermediate hosts for *T. gondii*, while cats are the definitive host. Infected birds shed oocysts in their feces. The oocysts are resilient and can survive for extended periods in soil, water, or other substrates, making them a potential source of infection for other animals (Nardoni et al. 2019).

Toxoplasmosis can lead to a range of symptoms in birds depending on the species and severity of the infection. Northern Cardinals can for example develop pneumonia when they are infected (Baker er al. 1990, Speer et al. 1997). Toxoplasmosis can have significant negative impacts on populations of passerine birds and other birds (Dybey 2002). Birds also can act as a reservoir for *T. gondii*, potentially transmitting the infection to other animals. Prevention and control measures for toxoplasmosis in birds involve minimizing exposure to contaminated environments and providing proper hygiene practices in captive bird facilities and food, and proper handling and disposal of cat feces.

1.3.7.5 Eastern equine encephalitis (EEE)

Northern cardinal can be wild host of EEE (CABI 2019), which is caused by the Eastern equine encephalitis virus. The virus is spread by a mosquito vector and can infect a wide range of animals, including mammals, birds, reptiles, and amphibians. EEE is present in North-, Central-, and South America, and the Caribbean (Cabi 2019). It has not been found in Europe.

1.3.7.6 West Nile virus (WNV)

WNV is a mosquito-borne disease that causes morbidity and mortality in infected birds, and can also infect mammals, domestic livestock and humans (CDC 2010). A large part of the Northern Cardinal population (36% in female cardinals and 21% in male cardinals) have WNV antibodies (Marshall 2006), suggesting a high infection rate. WNV has worldwide distribution that primarily occurs in urban and agricultural environments (Kilpatrick 2011, Ruiz et al. 2007, Gómez et al. 2008). Here, the abundance of mosquito hosts is often high (Bowden et al. 2011]. It is interesting to note that stress hormones can affect the host responses to this zoonotic pathogen. Half of WNV-infected wild Northern Cardinals with high levels of corticosterone in an experiment died, whereas one of nine birds with normal levels of corticosterone died (Owen 2012). The results suggest that populations of Northern Cardinals may be disproportionately at risk of mortality from WNV in stressful environments, such as long-term inclement weather, food shortage and anthropogenic pollution. The finding also suggest that pet birds can be particularly vulnerable to diseases if they are not properly cared for. Factors, such as poor nutrition, crowded living conditions, and inadequate hygiene that induces stress can increase the risk of disease transmission.

1.3.7.7 Gastrointestinal worms and other internal worms

Passerines can harbor several species of gastrointestinal worms, including roundworms (Ascaridae), tapeworms (Cestodes), and threadworms (Strongyles). Parasitic worms reside in the intestinal tract and can cause digestive disturbances, nutrient depletion, and overall health issues. Examples of internal parasites in wild populations of Northern Cardinals from Texas include helminth eyeworms (*Oxyspirura petrowi*) and ascaridian tetrameriasis (*Tetrameres* sp.), with 43% and 14 % infection rates, respectively (Herzog et al. 2021).

1.3.7.8 External parasites

Birds, like the Northern Cardinal, can have many species of external parasites, like mites, lice, and ticks. Ectoparasites can infest the feathers and body surface of birds to feed on blood and skin and can cause irritation and feather damage. Infected birds may show signs of excessive grooming behaviour, such as feather plucking and preening. These behaviours can lead to feather loss, which can affect the bird's ability to regulate its body temperature. Infestations can be particularly harmful to Northern Cardinal nestlings. Heavy loads of external parasites on nestlings can cause anemia, weakening the birds and potentially leading to mortality. The blood loss from feeding ticks can be significant, particularly in young and vulnerable individuals. Tick bites can create open wounds or introduce pathogens into the bird's bloodstream. Examples of external parasites of Northern Cardinals include chewing lice (*Myrdidae* sp. and *Menacanthus* sp.) (Kounek et al. 2011, Pistone et al. 2021) and ticks (*Ixodes* sp.) (Heller et al. 2016).

1.3.8 Predation on Northern Cardinals

Predation is often a main cause of nest failure for passerines (Newton 1998, Thompson 2007). Predators of the Northern Cardinal include species of hawks, owls, snakes, raccoons, and other middle-sized carnivores. In addition, domestic cats can depredate nests in suburban and rural habitats. Because of predation, the daily survival rate of nests of the Northern Cardinal is about 0.91 (Weatherhead et al. 2010), implying a nest success rate of 9.5% (based on an average 3 days for egg-laying, 12 days for incubation, and brood-rearing of 10 days).

While specific dietary habits can vary among different raptor species, many raptors are known to be opportunistic and generalist feeders that feed upon songbirds. Several species of raptors may eat Northern Cardinals. Two of the bird predators include the Cooper's Hawk (*Accipiter cooperii*) and Sharp-shinned Hawk (*A. striatus*). These raptors are adept at hunting other birds in mid-flight, including Northern Cardinals, and are also known to depredate bird young at nests.

Snakes are also known to prey on Northern Cardinals (Sperry et al. 2012). These reptiles climb trees to reach the bird's nest. Rat snakes (*Elaphe* spp.) are a common predator of the Northern Cardinal (Weatherhead et al. 2010, Sperry et al. 2012). These snakes are capable climbers and can easily access nests located in trees or shrubs and swallow the eggs or young birds whole.

Domestic cats (*Felis catus*) are a significant predator of the Northern Cardinal (Crane 2001). Cats are natural hunters and often stalk and kill birds, including Northern Cardinals, even when the housecats are well-fed and cared for (Loss et al. 2013). Other mammalian predators of the Northern Cardinal include northern raccoons (*Procyon lotor*) and squirrels (*Sciurus* spp.), and these species often raid bird nests in search of food.

Crane (2001) lists some known American predators of Northern Cardinal:

- domestic cats (*Felis catus*)
- domestic dogs (*Canis lupus familiaris*)
- Cooper's hawks (*Accipiter cooperii*)
- loggerhead shrikes (*Lanius ludovicianus*)
- northern shrikes (*Lanius excubitor*)
- eastern gray squirrels (*Sciurus carolinensis*)
- long-eared owls (*Asio otus*)
- Eastern screech owls (*Otus asio*)
- milk snakes (*Lampropeltis triangulum elapsoides*)
- black racers (*Coluber constrictor*)
- pilot black snakes (*Pantherophis obsoletus*)
- blue jays (*Cyanocitta cristata*)
- eastern fox squirrels (*Sciurus niger*)
- North American red squirrels (*Tamiasciurus hudsonicus*)
- eastern chipmunks (*Tamias striatus*)
- brown-headed cowbirds (*Molothrus ater*)

In addition to predation, brood parasitism from brown-headed cowbirds (*Molothrus ater*) is common and can be in the range from 29 to 44% of broods (Robinson and Robinson 2001).

The Northern Cardinal has developed several anti-predation adaptations, but do not aggressively mob predators (Halkin and Linville 1999). For example, it nests in dense foliage, making it difficult for predators to locate and access their nests. Also, Northern Cardinals are alert and vocal birds, often sounding alarm calls when predators are nearby, and sing from less exposed perches when near nests of hawks (Duncan and Bednekoff 2006). They also adjust foraging to prevailing perceptions of risk (Stanback and Powell 2010).

1.3.9 Known ecological effects

The Northern Cardinal is a reservoir for avian malaria as an invasive pathogen in Hawaii (Van Riper et al. 1986). The native species of Hawaiian honeycreepers are highly susceptible to introduced diseases (avian malaria and poxvirus) which are transmitted by introduced insects (mosquitos). Surveys of wild birds show that infection rates with Plasmodium relictum are much higher among native birds (2.1-29.2%) than introduced birds (0-11.6%), including Northern Cardinals (2.2%, Table 2 of Van Riper et al. 1986, Fig. S6 of Rozek et al. 2017). Experimental infections demonstrate that the novel pathogens cause high mortality rates among native Hawaiian birds but introduced birds can survive the infections (Fig. 6 of van Riper et al. 1986). The highest rates of malarial infections of birds are found in mid-elevation habitats (1000-1500 m) that are suitable for the parasite and the vector (Fig. 4 of van Riper et al. 1986). As a consequence, most native species of Hawaiian birds have relictual distributions where they are confined to high elevation sites (>1500 m) above the current distribution of mosquitoes (Fig. 1 of Atkinson and Lapointe 2009). The extant range of the native birds is highly fragmented and restricted to patches of high elevation forests, including Hakalau Forest NWR (Figs. 1-2 of Rozek et al. 2017). Among the introduced species of birds, Japanese White-eyes are the dominant species (29-53% of all birds at 8 study sites) and Northern Cardinals are less common (5-17%, see Fig. 1 of McClure et al. 2020). Freed and Cann (2014) suggested that interspecific competition with Japanese White-eyes after 2000 caused additional population declines among native bird species at Hakalau Forest during a 20-year period (1987-2007). In contrast, more recent analyses of survey data from the same site did not find evidence that increases in numbers of white-eyes caused population declines and instead numbers of two native species appeared to be stable over a 25-year period (1987-2012, Rozek et al. 2017). Thus, the negative impacts of Northern Cardinals and other introduced species of birds on the native honeycreepers of Hawaii are likely through their epidemiological role as a reservoir for introduced diseases, but also as a possible ecological competitor for food resources.

1.3.10 Private keeping

In its native range in the United States and Canada, private keeping of native songbirds is prohibited by law under the Migratory Bird Treaty Act [11]. The prohibition includes capturing or killing and is punishable by strict fines and imprisonment. However, in Europe Northern Cardinals are a popular bird for private keepers. Buying and selling cardinals is legal in Europe as long as the birds were raised in captivity.

1.3.10.1 In Europe

In Europe, and especially in the Benelux area, *C. cardinalis* is common in private collections, and often kept in larger aviaries outside. According to the Dutch industry organization for pet-trade, Dibevo[12] (pers. comm. Svein Fosså, Norwegian pet-trade industry organization, NZB) there are about 5,000 private persons that have registered that they have bred *C. cardinalis* in the Netherlands. The same source estimates that each of these breeders keep a minimum of four individuals. The Northern Cardinal is also readily available for sale on the private market (*e.g.* marktplaats.nl and vogelmarkt.nl) for around €150–€200 per specimen.

According to the largest platform of nature observations in the Netherlands, (Waarneming.nl), there has been 31 sightings of *C. cardinalis* in the wild since year 2000[13]. The majority of these are confirmed to be ring-marked and appear to be of a few escaped individuals (pers. com. Melissa Rowe, Department of Animal Ecology, Netherlands Institute of Ecology). Although individuals have been documented to escape, the number of birds per year is likely low.

1.3.10.2 In Norway

According to the Norwegian Environmental Agency, there has been at least one import of *C. cardinalis* to Norway in the last 20 years for private keeping. As these birds appear to thrive and breed easily in captivity, it is likely that there are still descendants

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[11] https://www.fws.gov/law/migratory-bird-treaty-act-1918

[12] https://dibevo.nl/

[13] https://waarneming.nl/species/19284/maps/?start_date=2000-02-24&interval=2592000&end_date=2023-03-26&map_type=grid10k

of this early import living in Norway today. There are also two observations of this species from Stryn municipality in Vestland, (very likely the same individual) from May 2020 in the register of the Norwegian Biodiversity Information Centre, which strengthen the notion that these are currently kept in Norway.

2 Methodology and Data

2.1 Methods

2.1.1 Risk assessment

The International Union for Conservation of Nature (IUCN) has recently developed general guidelines for classification of the impact of alien species on the environment. The system - 'Environmental Impact Classification for Alien Taxa' (EICAT) - is not a method for risk assessments *per se*, but rather a method for classifying alien taxa into impact categories according to the magnitude of the detrimental impacts to the environment. The system is similar to the IUCN system for red listing of threatened species and habitats and is mainly established for informing scientists, environmental managers and relevant stakeholders of the impacts of alien taxa and provide a basis for the evaluation of management policies and actions. Alien species are classified into five categories from negligible impacts (Minimal Concern) to small effects (Minimal) and further to Moderate, Major, and Massive impacts. Impacts that fall within the categories Moderate, Major, or Massive are termed 'harmful' (IUCN 2020).

To describe how an organism poses a threat to biodiversity (and aquaculture), VKM utilises the EICAT system to describe the key mechanisms that determine how alien invasive species affect biodiversity in Norway. The twelve potential mechanisms identified by IUCN include:

1) Competition
2) Predation
3) Hybridization
4) Transmission of disease to native species
5) Parasitism
6) Poisoning / toxicity
7) Biofouling or other direct physical disturbance
8) Grazing / herbivory / browsing
9) Chemical impact on ecosystems
10) Physical impact on ecosystems
11) Structural impact on ecosystems
12) Indirect impact through interactions with other species

Of these mechanisms, the project group identifies factors which are relevant for each organism and assesses the risk the alien invasive species pose through each of them for the specific hazards, following the steps outlined below.

2.1.2 Assessment of specific hazards

For the questions outlined in the Terms of Reference (ToR), hazards were identified and assessed independently. VKM assesses each potential hazard in four standardized steps: hazard identification, hazard characterization, likelihood, and risk characterization. These steps are judged by the project group experts. Table 2.1.2-1 describes the ratings for the level of confidence the project group has given the assessments.

Table 2.1.2-1: Ratings used for describing the level of confidence.

Rating	Descriptors
Low	There is limited information on the specific subject, in particular from comparable environmental settings. Subjective expert judgements may be introduced without supporting evidence. Little peer reviewed literature available and there are limited empirical and quantitative data to support the assessment.
Medium	Relevant information on the specific subject is available, but only limited information from comparable environmental settings. Some subjective expert judgements are introduced. Both grey literature and peer reviewed literature are used and there are some empirical and quantitative data to support the assessment.
High	There is extensive information on the specific subject, also from comparable environmental settings. Little or no subjective expert judgements is introduced. Primarily peer reviewed literature is used and there are empirical and quantitative data to support the assessment.

Under "**Hazard identification**" we describe the specific hazard and why this hazard is considered in the current assessment. Examples include specific species relevant for import, predation on or competition with native species, and a hitchhiking disease-causing organism. The known effects of the hazard are presented and referenced with examples of the known impacts from other countries.

Under "**Hazard characterization**" the specific potential effects of the hazard in question are described under Norwegian conditions. Examples include which areas or habitats that a species can thrive in, which species the invading species would compete with or prey upon, and which species can be infected by pathogens from the hitchhiking organism. The potential magnitude of the specific hazard is then characterized from "Minimal" to "Massive" as described in Table 2.1.2-2.

Table 2.1.2-2: Ratings for the magnitude of impact on biodiversity in Norway.

Rating	Descriptors
Minimal	Potential impact is limited to occasional deaths of individuals. No expected effects on the local-, regional-, or national population size.

Minor	Potential impact includes limited reductions in local abundance of one or a few species and these effects are temporary and spatially limited. No expected effects on the regional-, or national population size.
Moderate	Potential impact can result in moderately reduced abundance of one or more species, with potential implications on population viability on a regional level.
Major	Impacts may cause severe reductions in the abundance of one or more species, including potential extinction of local and regional populations. Consequences may also affect ecosystem functions and services. The consequences are regarded to be reversible should the alien species be eradicated.
Massive	Impacts may cause detrimental reductions in the abundance of more than one species, including the extinction of local populations, and potentially threaten the extinction of the national population. Consequences are likely to affect ecosystem functions and services and are regarded to likely be irreversible.

Under "**Likelihood**" we assess how likely it is that the characterized hazard occurs. Likelihood intervals range from "Very unlikely" to "Very likely", as described in Table 2.1.2-3.

Table 2.1.2-3: Ratings for the likelihood of the specific impacts in the assessment.

Rating	Descriptors
Very unlikely	Negative consequences would be expected to occur with a likelihood of 0–5%
Unlikely	Negative consequences would be expected to occur with a likelihood of 5–10%
Moderately likely	Negative consequences would be expected to occur with a likelihood of 10–50%
Likely	Negative consequences would be expected to occur with a likelihood of 50–75%
Very likely	Negative consequences would be expected to occur with a likelihood of 75–100%

Finally, under "**Risk characterization**", the risk to biodiversity in Norway, posed by the specific hazard, is characterized as either "Low", "Medium" or "High", based on the magnitude of the potential impact of that hazard and the overall likelihood of this occurring. This characterization follows the matrix presented in Figure 9.

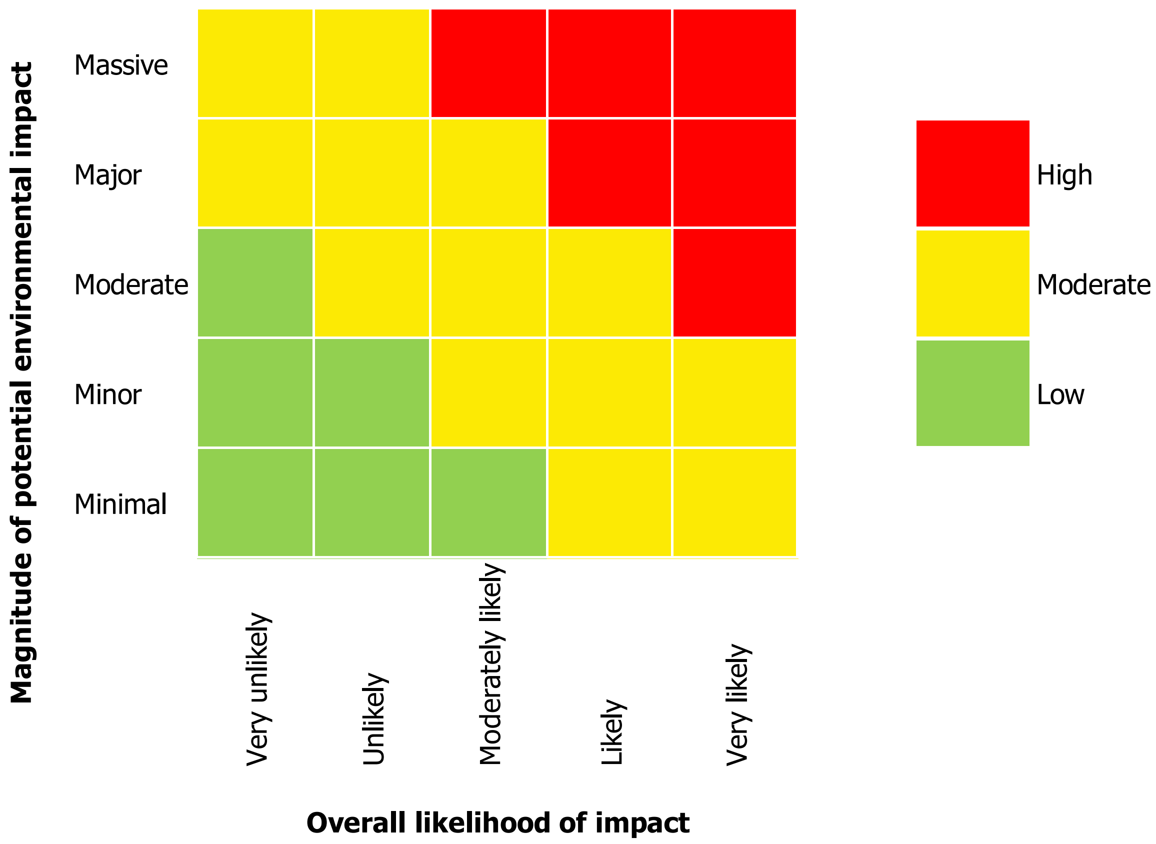


Figure 9: The conclusion of the risk assessments (Low, Moderate, or High) is based on the overall likelihood of the impact and the magnitude of the potential consequences of that impact on Norwegian biodiversity.

2.1.3 NBIC assessment scheme

The Norwegian Biodiversity Information Centre (NBIC) performs assessments of the ecological impact of alien species in Norway. The last assessment, the Alien Species List, was released in June 2018, and a new assessment will be published in 2023. The Northern Cardinal was screened, but not fully assessed in 2018. We performed the risk assessment scheme, as developed by NBIC. The assessment scheme follows the GEIAA protocol (Generic Ecological Impact Assessment of Alien Species; Sandvik et al. 2019) that involves three criteria for invasion potential (median population lifetime, expansion speed and colonization of ecosystems) and six categories of effect (effects on threatened or keystone species, effects on other Red-List assessed species, effects on threatened or rare ecosystems, effects on other ecosystems, transfer of genetic material and transmission of parasites or pathogens). The risk assessment involves an impact matrix, which considers both the potential for invasion and effect scored from 1 to 4 (Figure 10). The conclusion of the risk assessment includes the categories: No known impact (NK), Low impact (LO), Potential high impact (PH), High impact (HI), and Severe impact (SE). NBIC (2022) provides a detailed description of the methods used for assigning these impact categories.

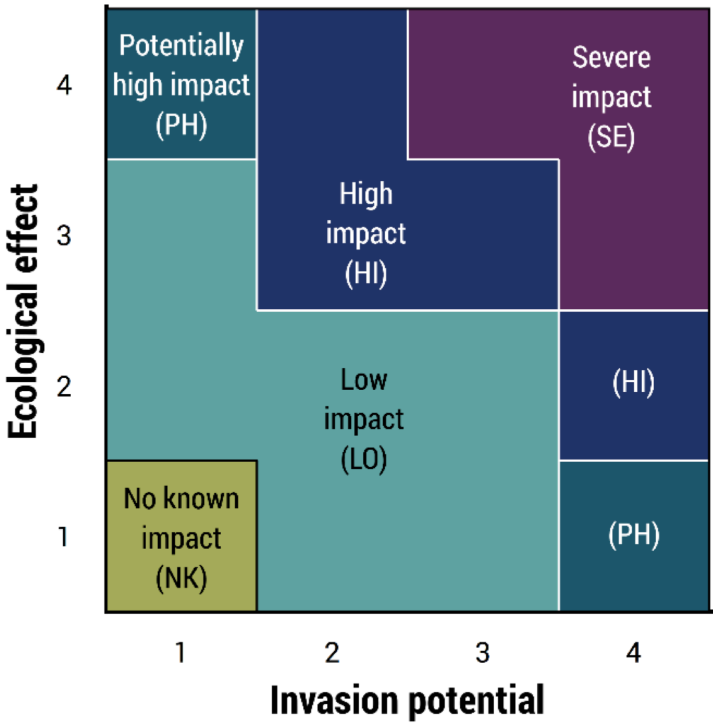


Figure 10: The impact matrix summarizes the risk assessment for a species based on scores on invasion potential (Table 7) and ecological effect. Image source: NBIC (2022).

2.2 Literature search and selection

Key sources of scientific literature have been ISI Web of Science, PubMed and Google Scholar. Thorough searches in these databases, primarily by use of Northern Cardinal or *Cardinalis cardinalis* and relevant key words to identify relevant literature. In some instances, additional literature has been found by searching in the reference list of relevant published articles. Relevant search terms for diseases included "disease", "parasite", "pathogen", "virus" and "bacteria". Search terms to identify Northern Cardinals as alien species included search terms, such as "non-native", "alien", "introduced", "risk assessment", "environmental impact" and "invasive". Searches to identify ecological interactions included terms, such as "predation", "competition", "feeding", "breeding", "clutch".

We also conducted a general Google search, using the species names or English common names. These searches sometimes revealed webpages with relevant information. Some webpages were linked to databases maintained by experts or governmental organizations, such as the CABI Digital Library, Global Invasive Species Database (IUCN), Birds of the World by Cornell Lab of Ornithology and Serge Dumont Bird Hybrid Database. These databases were useful as they sometimes provide a summary of ecology and diseases and give references to relevant scientific literature.

2.3 Data and Modeling

2.3.1 Data collection and preparation

Polygons depicting the distribution of *C. cardinalis* were obtained from BirdLife (2021), while most of the *C. cardinalis* occurrence data (19,208,080) were sourced from Birdlife (2022). Additionally, we consulted other databases such as GBIF (The Global Biodiversity Information Facility), BISON (Biodiversity Information Serving Our Nation), iDigBio (Integrated Digitized Biocollections), inat (iNaturalist), and ecoengine (Berkeley Ecoinformatics Engine) to gather additional occurrence records (83,794). After pooling all the occurrence data points (19,291,874), we cleaned them using the R library CoordinateCleaner (Zizka et. al. 2019). This includes removing records with duplicate coordinates, with identical latitude and longitude, as well as records found in country capitals. We also deleted records in the vicinity of biodiversity institutions, non-terrestrial coordinates, invalid latitude and longitude coordinates, zero-zero coordinates, country centroids, and country capitals, and coordinates assigned to the GBIF Headquarters. Finally, we thinned the occurrence data to one point per raster cell at a resolution of 30 arc sec, which is approximately 1km. We accepted a total of 601,404 unique occurrence points for modelling, but as a precautionary measure to avoid computational overload, we randomly selected a subset of 150,000 occurrence points for the final maxent model. We also used Setseed to ensure reproducibility.The data used were prepared and processed using R software, R Core Team (2023).

Instead of randomly sampling background points (environment samples) across the landscape, background points were sampled from 200 km polygons around each presence point to get more restricted and representative environmental samples (Phillips 2008). A total of 40,000 samples were drawn, but only 20,887 unique points were used due to duplicated background points, points outside the the study area, or points in the ocean.

A total of 50 environmental raster layers (Karger et al. 2018) were obtained from the CHELSA (Karger et al. 2021) database at ~1km spatial resolution for current climate (1981-2010), and future climate (2071-2100 Max Planck Institute Earth System Model mpi-esm1-2-hr scenario ssp585[14]). In addition, 12 land-cover layers from EarthEnv (Tuammu and Jetz 2014) were added. All environmental data layers were cropped, masked, and resampled to the study area covering North America and Europe.

2.3.2 Maxent species distribution modeling

A Maxent species distribution model was deployed to determine the potential distribution of *C. cardinalis* across geographic space based on the chosen environmental and land use variables. Maxent was run using the library SDMtune (Vignali et al. 2022), over "maxnet", which fits Maxent models using the glmnet package for regularized generalized linear models (Phillips et al. 2017). Also, it reduces

[14] GMD - Max Planck Institute Earth System Model (MPI-ESM1.2) for the High-Resolution Model Intercomparison Project (HighResMIP) (copernicus.org)

computational time and avoids the standard Java implementation. The SDMtune functions for data-driven variable selection and hyperparameter tuning were used to optimize the models.

The first step involved running a standard Maxent model that used all variables (all 50 raster layers described above), a regularization multiplier of 1, and the feature class combinations linear, quadratic, threshold, and hinge (see Halvorsen et al. 2015 for a more comprehensive description of MaxEnt). Then, we dropped environmental variables that contributed less than two percent to training the initial model. Data-driven variable selection was then performed on the remaining environmental variables. Afterwards, a grid search was conducted over a selection of hyperparameter values. The final optimized Maxent model was then executed with a regularization multiplier of 1 (the regularization multiplier was relaxed from the selected hyperparameter value of 0.5 to reduce model complexity and increase generalization), and only linear and quadratic relationships were used for the explanatory variables. To evaluate model performance, we conducted five replicate runs using a cross-validation approach.

2.3.3 Model evaluation

The performance of the model was evaluated through the area under the receiver operating characteristic curve (AUC). AUC values range from 0 to 1, with values above 0.5 indicating performance better than random. An AUC value of 0.9 can be considered very good, which means the classifier can accurately distinguish between classes. Our model's average AUC value from five replicate runs was 0.9 - indicating outstanding discriminatory ability (Araujo et al. 2005; Hosmer et al. 2013).

2.3.4 Variable importance analysis

Variable importance was assessed using the percent contribution and permutation importance metrics provided by SDMtune. Percent contribution represents the relative contribution of each environmental variable to the model, while jackknife permutation importance represents the reduction in model performance when each variable is separately removed from the set of variables.

The five most important variables for predicting the distribution of the *C. cardinalis* were net primary productivity (NPP, 54%), the mean temperature of the warmest quarter of the year (Bio 10, 16%), temperature seasonality (Bio 4, 10%), and the potential evapotranspiration penman range variable (PET Penman Range, 9%), and cultivated and managed vegetation (3%). These five variables were consistently ranked high across all runs.

2.3.5 Model Interpretation and validation

The final maxent model was used to produce all maps of the potential distribution of *C. cardinalis* across the study area. These maps are compared to known range maps under the current climate regime (Figures 11, 12 and 13), and under future climate regime (Figures 14, 15 and 16). Expert opinions and ecological species knowledge were used to assess model validity and predictions.

Net Primary Productivity (NEP) is the difference between the amount of carbon plants fix through photosynthesis, and the amount of carbon plants release through respiration. This variable may be important because it provides information about the energy available to support herbivores, such as *C. cardinalis,* in the ecosystem. Especially in dry regions and windy regions at high latitudes along the coast, higher NEP is probably an important indicator of available habitat provided by a vital shrub- and tree-layer.

The mean temperature of the warmest quarter of the year represents the mean temperatures during the warmest three months of the year (see 2.3.1 for description of the data source). Warm temperatures may affect *C. cardinalis* summer distribution. The temperature seasonality variable affects species adapted to stable temperature regimes and may have a limited distribution in areas with high-temperature variability. The "PET Penman Range" variable is calculated as the difference between each year's maximum and minimum potential evapotranspiration (PET) values. Potential evapotranspiration range can strongly influence water availability and plant growth, such that areas with high PET values and low precipitation may be prone to drought and have limited plant growth. In contrast, areas with low PET values and high precipitation may have excess water and support more diverse communities. Cultivated and managed vegetation provides more open habitats and is consistent with the habitat preferences of *C. cardinalis,* dense shrubby areas such as forest edges, overgrown fields, hedgerows, backyards, marshy thickets, regrowing forest, and ornamental landscapes (Dow 1969a, Dow 1969b, Emlen 1972a).

3 Assessment

3.1 Suitable habitats in Norway today

Using Maxent species distribution modeling, we created potential distribution maps for the Northern Cardinal in Norway. The maps show the predicted habitats suitable for the Northern Cardinal based on the selected environmental variables and occurrence data from the native range of the species in North America (section 2.3), based on current climate (Figure 11, 12 and 13), and future climate conditions (Figure 14, 15, and 16).

The colour gradient employed in the maps portrays the potential distribution, with darker blue indicating lower habitat suitability (zero) and lighter yellow shades denoting higher suitability (one). Our model output displays the extent of novel suitable habitats across Europe under the current climate regime (Figure 11), and future climate regime (Figure 15), and together they provide valuable insights into the potential distribution patterns of the species.

The Maxent model predicts suitable habitats for the greater parts of Europe under the current climate regime (Figure 11), only a few areas, e.g. Spain (dry and warm, low NEP) and the Alps (high altitude, low temperature), show a low probability of suitability (Figure 12). In Figure 13, we show the areas in Norway where Northern Cardinal has a higher probability of becoming established if introduced.

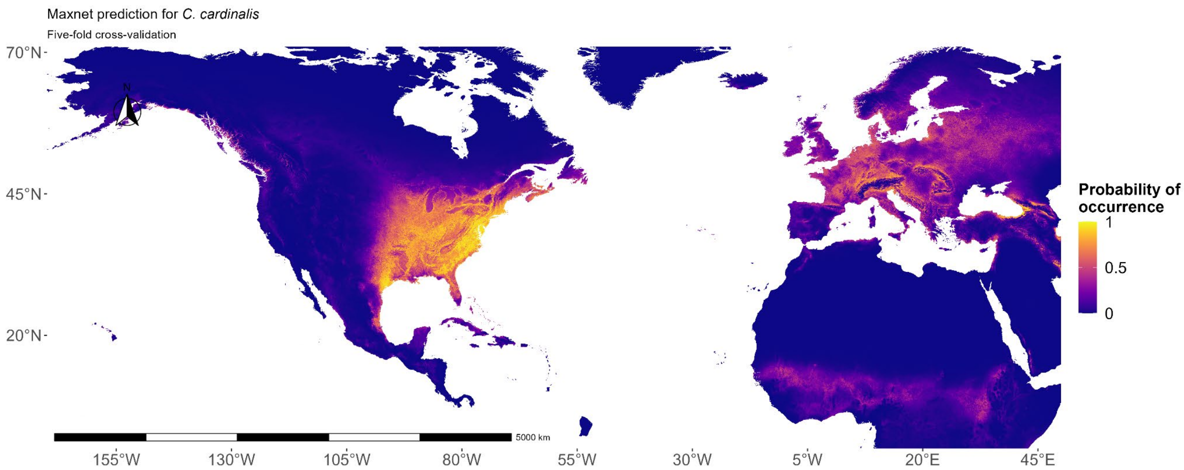


Figure 11: Map of *C. cardinalis* predicted probability of occurrence inferred by Maxent under current climate regime in North America and Europe. Color gradient represents the probability of presence for the *C. cardinalis* from blue (zero probability) to yellow (one equals high probability). Because of the small grid-cell size, some regions with geographically scattered presences of C. cardinalis will be difficult to observe within the map (cartographic effect).

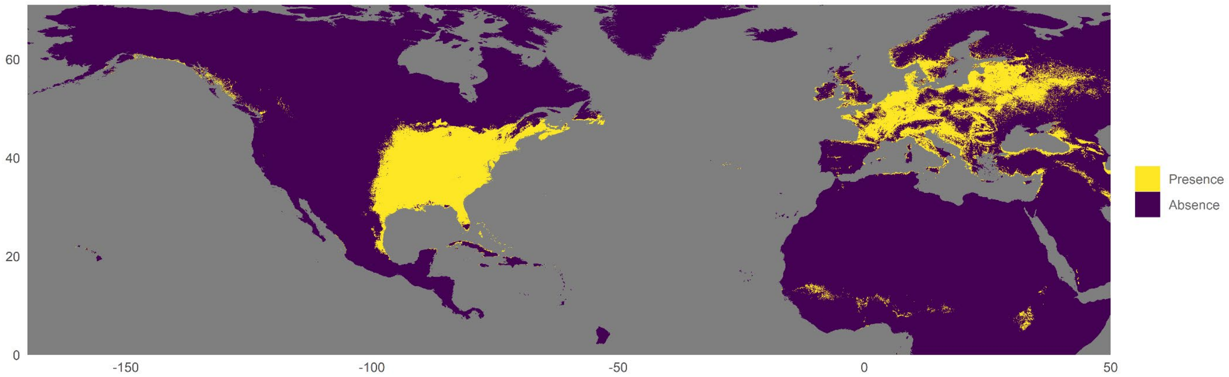


Figure 12: Presence/absence map where threshold values for present climate regime has been reclassified into presence (yellow suitable habitat) or absence (purple unsuitable habitat) for the *C. cardinalis*. Because of the small grid-cell size, some regions with geographically scattered presences of C. cardinalis will be difficult to observe within the map (cartographic effect).

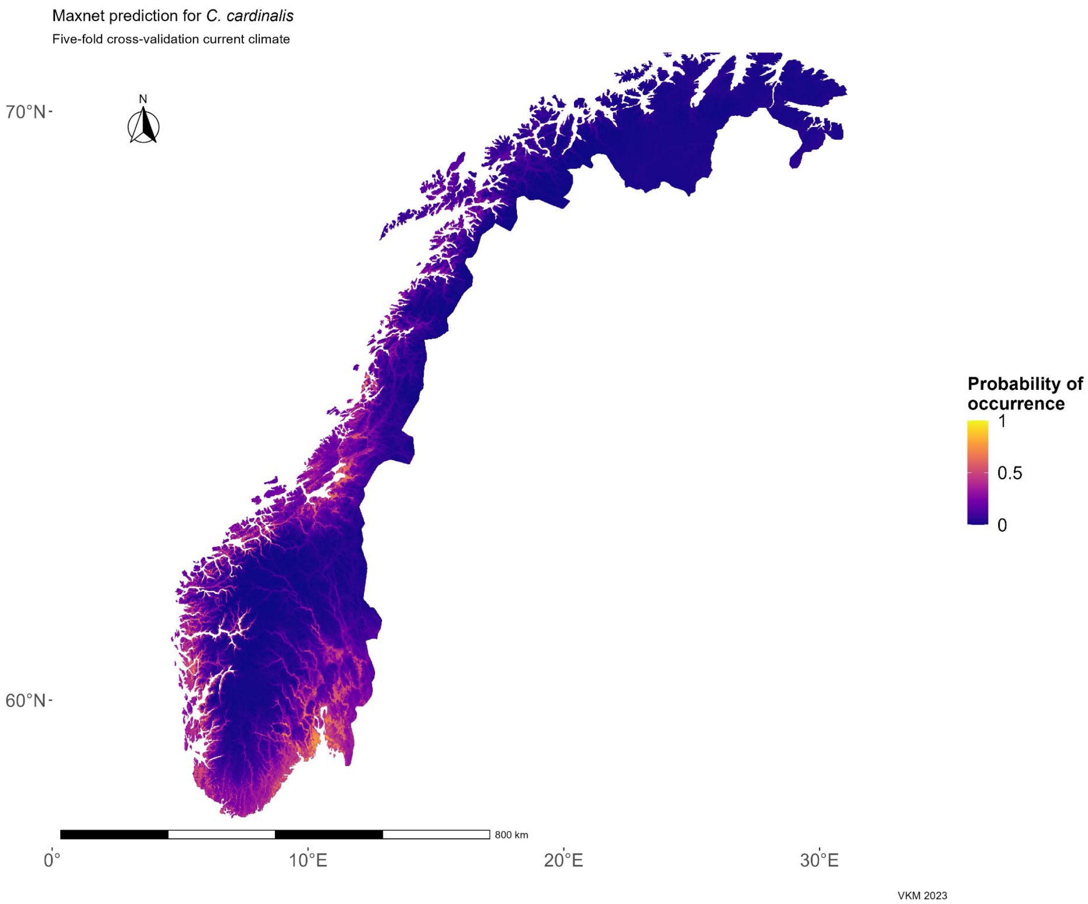


Figure 13: Map of *C. cardinalis* predicted probability of occurrence inferred by Maxent under current climate regime in Norway. Color gradient represents the probability of presence for the *C. cardinalis* from blue (zero probability) to yellow (one equals high probability).

3.2 Suitable habitats in Norway in 2100

Maps in Figures 14, 15 and 16 highlight the spatial extent of suitable habitats for *Cardinalis cardinalis* in the study area during the 2071-2100 period, based on the projected climate conditions provided by the MPI-ESM1-2-HR model under the SSP5-8.5 scenario. Under future climate regimes the suitable habitats for *C. cardinalis* are expected to increase in most of the modeled area. In Norway, the potential distribution increases northward along the coast and towards higher altitudes (Figures 15 and 16).

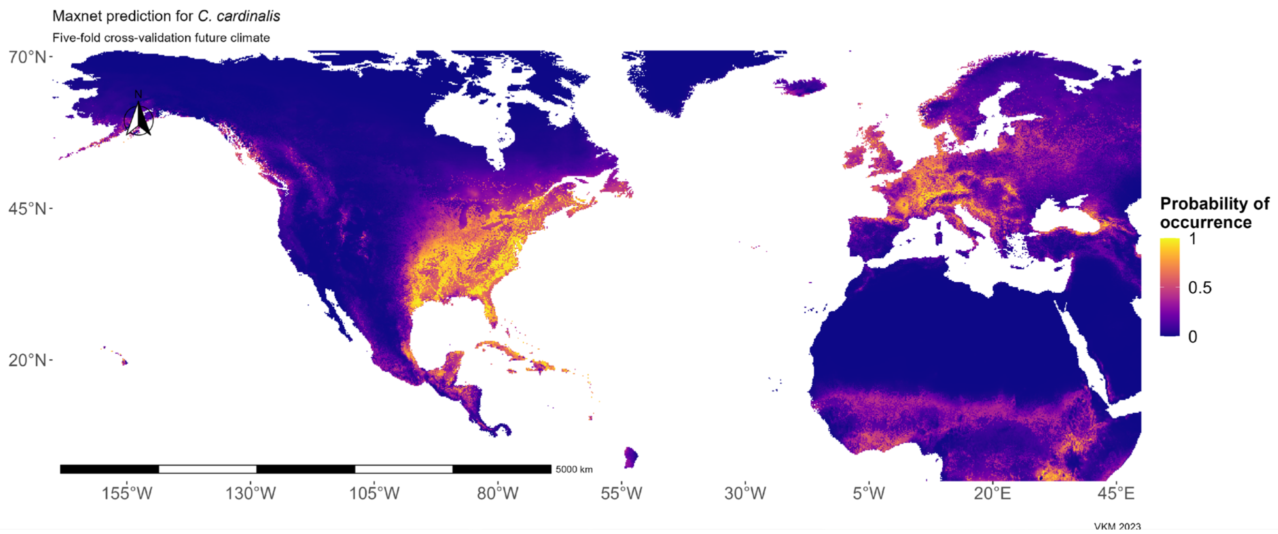


Figure 14: Map of *C. cardinalis* predicted probability of occurrence inferred by Maxent under future climate regimes (SSP5-8.5) in North America and Europe. Color gradient represents the probability of presence for the *C. cardinalis* from blue (zero probability) to yellow (one equals high probability). Because of the small grid-cell size, some regions with geographically scattered presences of *C. cardinalis* will be difficult to observe within the map (cartographic effect).

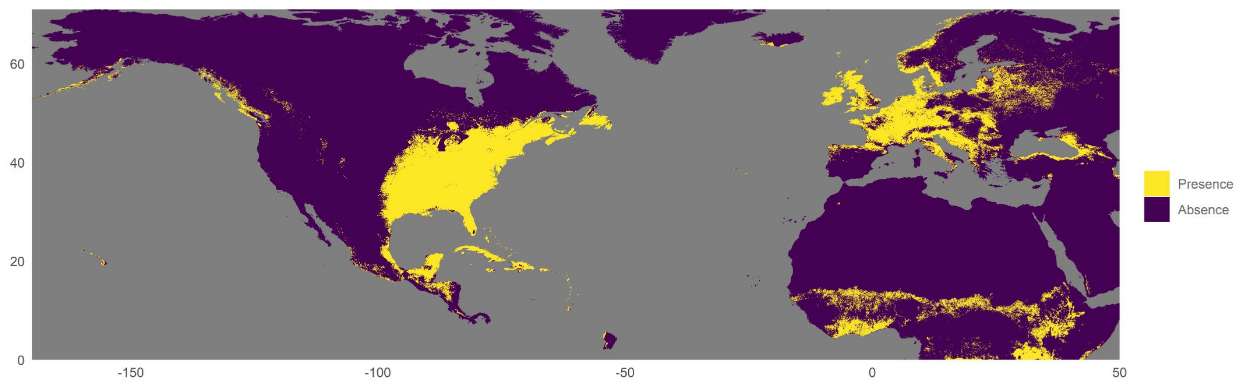


Figure 15: Presence/absence map where threshold values for future climate regime (SSP5-8.5) have been reclassified into presence (yellow suitable habitat) or absence (purple unsuitable habitat) for *C. cardinalis*

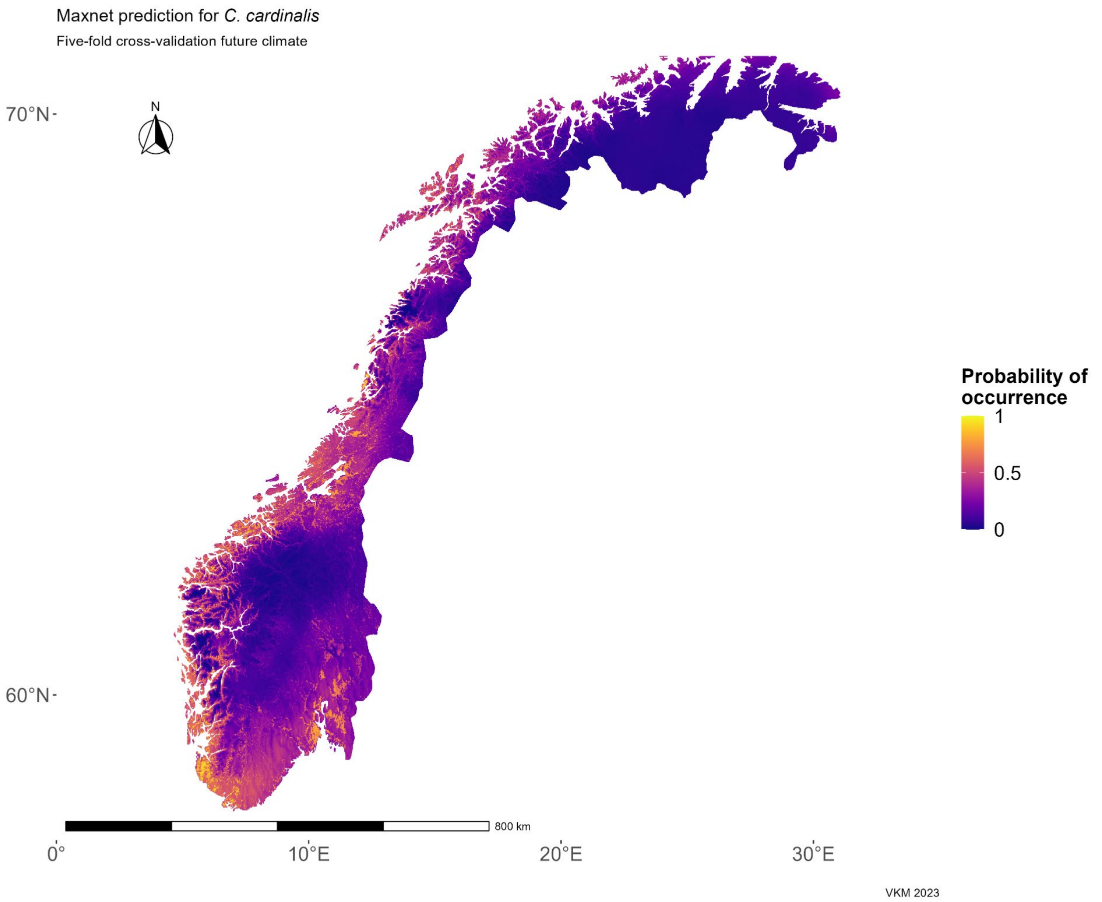


Figure 16: Map of *C. cardinalis* predicted probability of occurrence inferred by Maxent under future climate regime (SSP5-8.5) in Norway. Colour gradient represents the probability of presence for the *C. cardinalis* from blue (zero probability) to yellow (one equals high probability). Because of the small grid-cell size, some regions with geographically scattered presences of C. cardinalis will be difficult to observe within the map (cartographic effect).

The future climate projections introduce additional uncertainties to the model predictions. The SSP5-8.5 scenario represents a high-emission pathway, implying a future with increased greenhouse gas emissions. Consequently, the distribution map provides insights into potential changes in the species' range under greenhouse gas emissions and associated climate changes. However, the maps have a high degree of uncertainty, which includes the inaccuracy of the climate model projections and the underlying maxent assumption of species-environment relationships. Also, influence by other variables such as predation, competition and food availability also affect the potential distrubution and add uncertainty.

3.3 Endangered areas in Norway

An "endangered area" is an ecosystem in Norway where presence of an alien species could result in unacceptable detrimental effects should it be introduced. The present habitat use of the Northern Cardinal in North America indicates it could possibly establish populations in some red-listed nature types in Norway, particularly if the species could manage to establish and expand in warmer regions along the coasts of Norway (Figure 13 and 16). However, establishment of cardinals seems unlikely to lead to major habitat loss or conversion to other types of land cover. Red-listed nature types in Norway that are likely candidates as habitat for Northern Cardinal include:

Strandeng (Tidal meadow)
Semi-naturlig eng (Semi-natural meadow)
Slåttemark (Scythe meadow)
Semi-naturlig strandeng (Semi-natural tidal meadow)
Flomskogsmark (Alluvial forest)
*Høgstaude edelløvskog (*Tall herb nemoral deciduous forest)
Lågurtedellauvskog (Low herb nemoral deciduous forest)
Kalkedellauvskog (Lime-rich nemoral deciduous forest)
Rik vierstrandskog (Productive tidal forest dominated by *Salix* species)
Semi-naturlig myr (Semi-natural fen)
Sørlig slåttemyr (Southern scythe fen)
Rik svartorsumpskog (Productive forest dominated by *Alnus glutinosa*)

3.4 Potential pathways for introduction

The project group assesses that the potential pathways of entry of *C. cardinalis* to Norway are limited to import for private keeping and natural dispersal of escaped individuals from northern Europe. The specific pathways after import are unknown since they potentially can be released from any points in space where they have been imported to. The most likely pathway of escaped individuals from Sweden or Denmark would be northwards along the coast, where the climate for Northern Cardinal is best (high winter temperatures and warm summers).

3.5 Potential mechanisms for impact

VKM assesses that *C. cardinalis* could potentially have a negative impact on biodiversity in Norway through the following mechanisms, as described by IUCN Environmental Impact Classification for Alien Taxa (EICAT) (Hawkins et al., 2015; Nentwig et al. 2010; Kumschick et al. 2012 and Blackburn et al. 2014): Competition, hybridization, transmission of disease and indirect effects through interactions with other species.

3.6 Potential impacts on biodiversity in Norway – Hazard identification

The project group has assessed what species or ecosystems that might be affected in Norway through each of the four potential EICAT mechanisms that *C. cardinalis* can negatively influence biodiversity in Norway through. These are described in more detail below.

3.6.1 Competition

Competition is a well-known biotic interaction that influences populations and distributions of species with overlapping fundamental niches (Armstrong & McGehee 1980). For Northern Cardinals, competition for food, territory and nesting sites would probably be most important for other small bird species. Competition for food would be determined by the dietary overlap with other bird species, whereas competition for territory and nesting sites will be influenced by the specific habitat choices of the species involved.

From the US, the Northern Cardinal is known to compete with Gray Catbird (*Dumetella carolinensis*) and American Robin (*Turdus migratorius*) for nest sites and feeding grounds, but the Northern Cardinal is subordinate to robins in competition for nesting locations (Winter 1981). Cardinals are open-cup nesters that build new nests each year and suitable nest sites are unlikely to be a limiting resource for shrub-nesting birds (Halkin et al. 2021). The Northern Cardinal is also known to exclude House Sparrows (*Passer domesticus*), Field Sparrow (*Spizella pusilla*), and Harris's Sparrows (*Zonotrichia querula*) from feeding stations (Nice 1927). Outside those reported above, interspecific competition for nesting sites with other birds is limited in the US, and Govoni et al. (2009) even reported nest sharing between a female Northern Cardinal and a female American Robin. There are some debate whether the Northern Cardinal caused population declines of two native bird species in Hawaii (see section 1.3.9).

3.6.2 Hybridization

Hybridization is common in birds (Grant and Grant 1992) and is the most important threat that introduced birds pose to the native avifauna (Baker et al. 2014). Hybridization is less common in songbirds, though, than in other groups of birds (Grant and Grant 1992). The Pyrrhuloxia or Desert Cardinal (*Cardinalis sinuatus*) is a congeneric species that occurs in much of the southern part of the range of the Northern Cardinal. Where the two species overlap, they show no interspecific territoriality, and territories of the two species were found to overlap considerably in southeastern Arizona and southeastern Texas (Gould 1961, Halkin et al. 2021). There are more than 100 recorded occurrences of interspecific hybrids between *C. cardinalis* and *C. sinuatus* [15]. There are single records of hybridization between captive Northern Cardinals and the common chaffinch (*Fringilla coelebs*, Norw. *bokfink*); the Northern Cardinal hybridizing with the South American species red-breasted cardinal (*Paroaria coronata*); and the Northern Cardinal hybridizing with another South American species, the Yellow Cardinal (*Gubernatrix cristata*)[16]. It must be emphasized that the latter three cases are single records and took place in captivity. The Red-breasted Cardinal and the Yellow Cardinal are in different families despite both being named "cardinal"

[15] https://ebird.org/species/x00774

[16] http://www.bird-hybrids.com/engine.php?search=cardinalis&searchby=nomenclature&nomenclature=ALL&family=ALL

due to a similarity in body shape with the Northern Cardinal. The Common Chaffinch is also in a separate and unrelated family. The crosses with these three species occurred in captivity (unrelated birds kept together in cages or outdoor enclosures) and successful crosses have rarely been reported. The Northern Cardinal's family Cardinalidae is part of a New World radiation of bird families and is thus quite unrelated to songbird families in Norway (Oliveros et al. 2019), further diminishing the chances for successful hybridization between escaped Northern Cardinals and native birds in Norway.

3.6.3 Transmission of disease

Northern Cardinals in the wild can be host to a range of diseases, like haemosporidian blood parasites, avian trichomoniasis, avipox, toxoplasmosis, eastern equine encephalitis, west Nile virus, gastrointestinal worms and other internal worms, and external parasites. These pathogens and parasites affect health status, reproduction, and mortality of infected birds. Domesticated birds can act as vectors or reservoirs for a range of diseases (Ritchie et al. 2013), however, we lack information on the prevalence of disease in domesticated populations of Northern Cardinals. Many of the diseases in Northern Cardinals can infect other bird species, and especially passerines (Herzog et al. 2021). Birds can transmit or be infected by diseases to- or from wild birds through direct contact, indirect contact, or vectors.

3.6.4 Indirect effects through interactions with other species

Indirect effects through interaction with other species may take many forms and pathways, for example dispersal of non-native plants on the Northern Cardinal's diet. The highly adaptable and omnivore diet of the Northern Cardinal makes it challenging to predict the effect that the bird might have on dispersal of non-native plants in Norway. However, from the US, the diet indicates that the Northern Cardinal could take a role as dispersal vector for introduced fruit-producing trees and shrubs. This should be true especially for plants that are edge species, which is one of the main habitats of the Northern Cardinal. An example is the red elderberry (*Sambucus racemosa* subspecies *racemosa*), introduced to Norway from Eurasia, is closely related and similar to the red elderberry (*Sambucus racemose* subsp. *pubens*) in the US, which is in the Northern Cardinal's diet (Stutchbury et al., 2005).

3.7 Potential magnitude of impacts on biodiversity in Norway – Hazard characterization

The potential magnitude of the different potential impacts has been made under the assumptions that:

1) The species is established in Norway and occupy at least 50% of the assessed suitable habitat under current climate conditions (see section 3.1).

2) That the density of individuals is the same as in their native habitat, which are quite low in the northern parts of USA and eastern parts of Canada (see Figure 2 and section 1.3.2). The impact will necessarily be density dependent.

3.7.1 Competition

The Northern Cardinals are resident birds which do not migrate or perform large vagrant flights, though a few birds may move large distances (Laskey 1944, Dow and Scott 1971). Adults establish a territory and breed, and then the new generation of young birds move out of that territory and establish new territories. Therefore, the Northern Cardinal moves by slowly expanding their range over time. Between the years 1980 and 2005, Zuckerberg et al. (2009) calculated that the latitudinal centroid of the breeding distribution in New York moved about 8 km northwards. When the Northern Cardinal reached Ontario in North America, the north-western spread had taken decades and many generations of birds (Peck and James 1987, Dow 1994). Lately, however, the Northern Cardinal has expanded faster northwards (Halkin et al. 2021) and is presently found north to 58° N in Canada (see section 1.3.3). There is debate whether the Cardinal causes direct ecological effects on native birds from competition on Hawaii, or whether negative effects on native birds are caused by avian malaria spread by cardinals (see section 1.3.9).

Competition for food would be determined by the dietary overlap with native birds in Norway. The Northern Cardinal, however, has an omnivore diet which is highly adaptable. They are primarily ground feeders, in search for seeds, but they are also frugivores. In spring and summer, during the brooding time, the Northern Cardinalis feed on a variety of invertebrates. During wintertime, they are frequently reported from feeding stations in rural and urban areas. The Northern Cardinal, being an omnivore, would therefore probably be able to adapt to the local food resources and compete with other passerine birds such as sparrows (family *Passeridae*) and finches (family *Fringillidae*) native to Norway. The Northern Cardinal may also compete with other ground feeders, such as the common blackbird (*Turdus merula,* Norw. *svarttrost*), with insectivore species such as the common starling (*Sturnus vulgaris,* Norw. *stær*), or with frugivore passerine species such as Bohemian waxwing (*Bombycilla garrulus,* Norw. *sidensvans*). The ecological effect of competition for food with native bird species is therefore probably relevant, but not possible to quantify. It may turn out to have different effects in different regions of Norway, and the competition would probably be skewed towards sparrows and finches. The competition would probably be most relevant during spring, when they would compete for insects, or during wintertime, when food resources are limited and vital for day-to-day survival. During winter, the dietary overlap with other passerine birds would be constrained to fewer sites (e.g., feeding stations) and fewer resource types (e.g., fruits of rowan during periods with snow on the ground). VKM assesses that the potential magnitude of competitive interactions is **Minor** with low confidence.

Similarly, the competition for territory and nesting sites would probably be skewed towards sparrows and finches but would also include the European Robin (*Erithacus rubecula*, Norw. *rødstrupe*). The Northern Cardinal is found in areas with shrubs, small trees, including forest edges and interior, shrubby areas in logged and second-growth forests, marsh edges, grasslands with shrubs, successional fields, hedgerows in agricultural fields, and plantings around buildings (Dow 1969a, b, Emlen 1972a). In those habitats, the Northern Cardinal is territorial. Males establish a territory and sing to attract females. The purpose of the song is also to defend the territory and he would chase off other males entering his territory. The females also defend the territory from other cardinals, and from intraspecific brood parasites (Jawor et al. 2004, DeVries et al. 2015, Winters & Jawor 2017). To what extent the Northern Cardinal would defend its territory against males from other passerine bird species has not been studied, but they do not react aggressively to males of the closely related Desert Cardinal (*Cardinalis sinuatus*) and hence territories of the two species can overlap considerably (Halkin et al. 2021). VKM assesses that the potential magnitude of these interactions is **Minor** with low confidence.

3.7.2 Hybridization

In Norway, hybridization is assessed to be a potential risk only regarding the common chaffinch (*Fringilla coelebs*, Norw. *bokfink*). The potential magnitude is assessed to be **Minimal** with high confidence.

3.7.3 Transmission of disease

Many bird diseases have a wide geographic distribution, thanks to the great mobility of birds (Reed et al. 2003). An unknown part of the diseases that are present in wild populations of the Northern Cardinal are therefore already present in wild population of birds in Norway, and especially in passerines. Evidence from other species of birds on islands still suggests that introduced birds on islands can transmit new diseases to the native bird population (Ishtiaq et al. 2006, Deem et al. 2008), including introduced strains of diseases (Farmer et al. 2005, Soos et al. 2009). However, we lack knowledge on the prevalence of most diseases in wild populations of Northern Cardinal, in domesticated populations of Northern Cardinal, and in the wild populations of birds in Norway. Avian malaria stands as a notable exception to the limited understanding (section 1.3.7).

The time required for Northern Cardinal to become naturalized in northern Europe would also expose them repeatedly to avian pathogens already present. If cardinals spread to Norway from a naturalized population in northern Europe, the pathogens they would most likely carry would be mostly or entirely those already present in other bird species in northern Europe. Cardinals that have been kept in captivity for many years are likely to carry diseases transmitted while in captivity and not novel variants or forms from the Americas, which might further reduce the risk of novel pathogen spread by cardinals as the vector.

The potential magnitude of risk caused by the transmission of diseases to Norway is assessed to be **Minor** with low confidence.

3.7.4 Indirect effects through interactions with other species

It is unknown, but possible that the Northern Cardinal could contribute to somewhat increased dispersal of non-native plants in Norway, through seed dispersal of plants with fruits or seeds which are in their diet. trees and shrub that retain fruit in winter, for example species from the genera *Sorbus* (Norw. *rogn*), *Cotoneaster* (Norw. *mispel*) or *Rosa* (Norw. *rose*) which have many introduced species in Norway (Artsdatabanken 2018[17]), would probably be favoured by the Northern Cardinal. Such species can potentially be more actively dispersed if the Northern Cardinal is introduced to Norway. The effect of such dispersal on the ecosystems is hard to quantify but assessed to be **Minor** with low confidence.

3.8 Likelihood of impacts on biodiversity in Norway

The likelihood of impact on biodiversity in Norway is determined by both the individual likelihood related to each of the specific impacts, but most prominently by the overall likelihood that enough individuals enter a suitable habitat and manage to establish and eventually spread in Norway. Also, the two possible pathways of entry, as assessed above, have different likelihoods regarding resulting in entry to a suitable habitat and subsequent establishment:

The likelihood of entry to a suitable habitat through the pathway "Import for private keeping" again depends on several factors, like how many birds are kept at each location, and the rate at which birds escape to natural areas. We can assume that the species would be kept in similar quantities as in the Netherlands (see section 1.3.10.1), which is in groups of at least four, but probably not more than ten. To assess the likelihood of any given individual should escape from private keeping we can use data on ownership available from The Netherlands (section 1.3.10.1). As there has been on average 1-2 registered observations of escaped individuals each year, for the last 20 years, in this country (which accounts to 0.1%, based on the estimated number of at least 20,000 individuals kept), VKM assess that escaping is **Very unlikely** with high confidence.

Further, for an alien species to have an impact, it needs to establish a viable population. Establishment requires that sufficient individuals are released in the same area at about the same time and in a suitable habitat (see section 1.1.4 for further information regarding restrictions to establishment of non-native birds). Given the unlikely event of any individual escaping, and the fact that only the coastal areas of Norway are assessed to function as a suitable habitat, VKM assess that establishment of the Northern Cardinal in Norway, from escaped individuals kept in private homes, is **Very unlikely** with medium confidence.

Likelihood of entry to a suitable habitat through the pathway "natural dispersal from Europe" also rests on some of the same assumptions as above. However, for sufficient individuals to disperse from countries in Europe where this species is currently kept,

[17] https://artsdatabanken.no/fremmedartslista2018

the species first need to establish wild populations in this area. We know that the Northern Cardinals can inhabit a wide variety of habitats and spread easily within America (see section 1.3.1). However, as there is no wild population established in the Netherlands, despite birds have been kept in high numbers in captivity for at least 20 years. Also, there have previously been deliberate releases of larger numbers of the Northern Cardinal in Germany and Spain (see section 1.3.1) without resulting in establishment. We therefore assess the probability of establishment (in Central Europe) as **Unlikely** in the next 50 years. Our evaluation is assessed with medium confidence. Entry and establishment in Norway, following this unlikely event is thus assessed as **Very unlikely**, following the same arguments as for establishment through escaped individuals imported to Norway.

However, based on the species history of spreading in suitable habitats (see section 1.3.1), VKM assess that if the species manages to establish a viable population anywhere in the assessed suitable habitat in Norway (see such. 3.1), further spread within Norway is **Likely**. Our assessment is made with high confidence.

3.8.1 Competition

Competition for food, in nature and on winter feed-stations, between escaped Northern Cardinals and sparrows, finches, and other native birds in Norway is **Likely**. Our assessment is made with high confidence.

Competition for nest sites and territories with native Norwegian bird species is **Unlikely**, given the low degree of competition reported from the US. Our assessment is made with medium confidence.

3.8.2 Hybridization

Hybridization in nature between escaped Northern Cardinals and Norwegian bird species is **Very unlikely** given the differences in song and plumage between Northern Cardinals and native species. In addition, cardinals and their relatives are not closely related to any taxa in Norway, and hybridization rates for songbirds generally are low in nature. Our assessment is made with high confidence.

3.8.3 Transmission of disease

Birds can transmit or be infected by diseases to or from wild birds through direct contact, indirect contact, or vectors. Some diseases of birds can be highly contagious (Ishtiaq et al. 2006, Deem et al. 2008, Gaidet et al 2012), both because birds are highly mobile and because birds are social animals. Other diseases are less contagious since they depend on transmission through vectors, such as biting midges, that may or may not be present in the habitat (Valkiūnas 2004). Bird feeders are now adding to the risk of spread of diseases (Lawson et al. 2018). Supplying extra food for wild birds at garden feeding stations is a widespread and ongoing practice. Although this practice can benefit wildlife, there is an increased risk for disease transmission due to repeated gatherings of birds in high densities and interactions between species that typically do not associate closely (Lawson et al. 2018).

Transmission of diseases in nature between escaped Northern Cardinals and Norwegian bird species is **Very likely**. Our assessment is made with with high confidence.

3.8.4 Indirect effects through interactions with other species

If the Northern Cardinal establishes viable populations in Norway, increased dispersal of some invasive plant species introduced to Norway, is **Likely**. This is assessed with high confidence, based on the diet of Northern Cardinals in northern USA.

3.9 Characterization of risks associated with *C. cardinalis* in Norway

3.9.1 Competition

The impact of competition for food is assessed to be Minor, but Likely to happen under the given assumptions. However, as entry and establishment are assessed to be Very unlikely, the risk associated with competition for food, in nature and on winter feed-stations, between escaped Northern Cardinals and Norwegian native bird species (e.g. passerines and finches) is assessed as **Low** (bordering to moderate). This is assessed with low to medium confidence since the impact from competition for food is density dependent. If the Northern Cardinal, after escapes, in some favorable sites can establish large populations, the risk of negative impact would be greater. The low densities reported from northern locations in Canada and USA, however, indicate that this is very unlikely to happen.

The risk associated with competition for nest sites and territories with native Norwegian bird species is assessed to be **Low**, given the low degree of competition reported from USA. This is assessed with medium confidence.

3.9.2 Hybridization

Hybridization between Northern cardinal and other species of passerines does occur in nature and in captivity. However, this is not frequent, nor shown to cause any notable impact on biodiversity in its native range. In Norway, hybridization is assessed to have Minimal impact on biodiversity, and this impact is assessed as Very unlikely. VKM therefore concludes that there is a **Low** risk associated with hybridization, should Northern cardinal establish in Norway. This is assessed with high confidence.

3.9.3 Transmission of disease

Several diseases could be transmitted to native birds that have not been exposed to these diseases, from Northern Cardinal, should it be established in Norway. The impact of such spread is assessed to be Minor, but Very likely to occur. However, the likelihood of entry into a suitable habitat, and subsequent establishment in Norway (through any of the evaluated pathways), is Very unlikely. Thus, VKM concludes that the overall risk associated with this mechanism is **Moderate** (bordering to Low), with medium confidence.

3.9.4 Indirect effects through interactions with other species

The only indirect effect VKM could identify is the potential increased dispersal of invasive plant species. This mechanism is assessed to have Minor impact on biodiversity, but Likely to occur. However, as the entry and establishment of Northern Cardinal is Very unlikely, the risk associated with increased spread of invasive plant seeds is **Low** (bordering to Moderate). This is assessed with medium confidence.

3.10 Scenarios for spread in Norway

3.10.1 From natural dispersal from Benelux or Denmark

Natural dispersal from Benelux countries, Denmark, or Sweden, is very unlikely, in the next 50 years, given the present situation. Escaped Northern Cardinals in Europe have so far not established reproducing populations. But if they manage to naturalize in other European countries, the most likely route of expansion towards Norway would be along the coast of Sweden, where the climate conditions are most favourable for Northern Cardinals (see figure 12 and 15). Alternatively, individuals may cross Skagerak directly from Denmark. However, it is less likely that scattered appearance of individuals of Northern Cardinal from Denmark would be able to naturalize into stable populations in Norway.

3.10.2 From imported birds

Individuals of Northern Cardinals can, in theory, escape from captivity anywhere in Norway with settlements. The probability of survival and further dispersal, however, would depend on the time of year and region. If cardinals escape during wintertime in continental parts of Norway, with low ambient winter temperatures, they would most likely not survive. On the other hand, if they escape during summertime along the warmer coastal region, the probability of survival and establishment, and subsequently further dispersal, is much more likely.

The expected scenario for dispersal after escapes in Norway, is therefore along the coast, mainly in south Norway. Based on the slow but increasing northward expansion of the species reported from USA and Canada, a potential spread along the coastal regions in Norway would take many decades. Establishment in rural and urban areas, however, with higher access to winter feeding stations, is expected to go faster.

3.11 Effect of climate change

According to results of our the Maxent models, tested with a high-end climate change scenario (RCP8.5 based on SSP5), the predicted climate changes would improve the conditions for Northern Cardinals in Norway (see fig 16 and 17). Specifically, the species would experience improved climate conditions further north and in more continental regions, but the conditions would also improve along the coast with higher probabilities of habitat suitability? in southwestern Norway. The most important variable would be increased winter temperatures leading to higher winter survival and subsequently larger populations and a faster expansion northward. Based on the reported expansion of Northern Cardinals in USA and Canada the last century (Halkin et al. 2021), partly explained by winter warming (see chapter 1.3.4), it is likely that winter warming would have similar effects for potential expansion in Norway.

However, the predicted climate change is also likely to improve the conditions for Northern Cardinals elsewhere in Europe. Since birds already have escaped from captivity, but so far not been naturalized in the Benelux region, the probability of survival and dispersal in these regions would increase. This could lead to a future higher influx of escaped birds from the region of Benelux, Germany, Sweden and Denmark. The likelihood of such influx would increase with the tested climate change scenario, also because the migration pathways to Norway from these locations, would have improved climate conditions. In summary, the tested climate change scenario would lead to higher reproduction and survival, larger populations and faster expansion northward.

3.12 NBIC risk assessment scheme

According to the NBIC risk assessment scheme, Northern Cardinal would have an overall "**Low impact (LO)**" on the native biota in Norway. This conclusion was reached based on an invasion potential of 2 (with uncertainties towards 1 and 3) and an ecological effect of 2 (Figure 17). The decisive criteria for the conclusion included the median population lifetime (criterion 2A) along the invasion axis and effects on threatened or rare ecosystems (criterion 2f) along the effects axis.

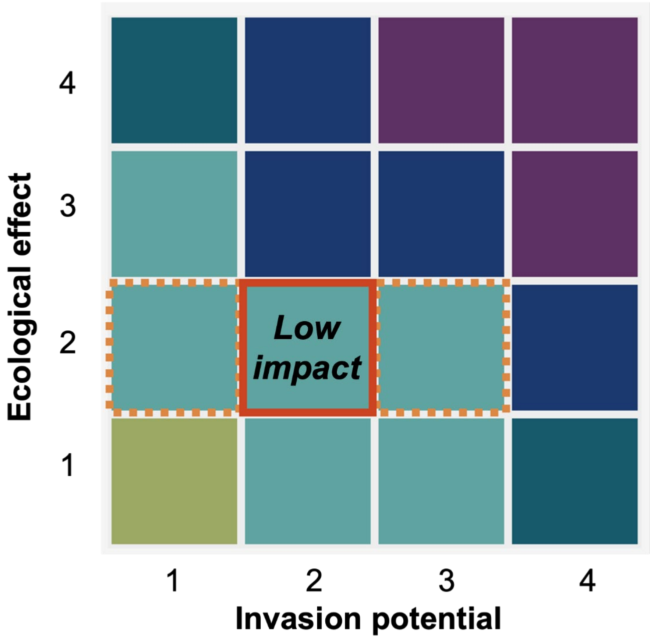


Figure 17: The impact matrix on ecosystems in Norway caused by the Northern Cardinal, as assessed by the generic ecological impact assessment of alien species (NBIC 2022). The conclusion is Low impact (LO).

4 Risk reducing measures

4.1 Diseases

Birds have the potential to act as vectors or reservoirs for a range of diseases, including parasites. Pet birds can be vulnerable to infectious diseases if they are not properly cared for. Factors, such as poor nutrition, crowded living conditions, and inadequate hygiene can increase the risk of disease outbreak and transmission. To prevent the spread of disease in pet birds, it is important to practice good hygiene, provide proper nutrition and living conditions, and take birds to a veterinarian regularly for checkups and vaccinations. It is also important to prevent direct and indirect contact between captive birds and wild populations of birds, mammals, and other pet animals, especially cats.

Bodies, eggs, feather, or bird feces from domesticated birds must not be disposed of in nature. The same applies for material that have been in contact with the birds, such as food, water, gravel, or ornamental plants. Material and equipment that have been in contact with captive birds should be sterilized. Decontamination should be conducted with disinfectants such as Virkon S, chlorine, ethanol, complete desiccation, boiling or burning. Some pathogens would not be eliminated by ultraviolet sterilizers, and some pathogens may survive contact with saltwater or freezing.

4.2 Quarantine and health certificates

To ensure the prevention of contagious diseases and illegal trade, the Norwegian Food Safety Authority (Mattilsynet) has enforced strict rules for the import of animals into Norway. However, there are slightly simpler conditions for traveling with pets, known as non-commercial movement. The rules state that an identification document issued by an authorized veterinarian in the country of dispatch is required for non-commercial movement of five or fewer birds, rabbits, or rodents. The document should include a health certificate confirming that the animals underwent a disease-free health examination. It must also be accompanied by a declaration from the owner or authorized person stating the non-commercial nature of the movement. For non-commercial movement of more than five birds, rabbits, or rodents, the animals must meet the conditions for commercial import.

Even for newly imported birds with a health certificate, we suggest quarantine and conduct thorough screenings for all likely diseases. The recommended approach involves employing molecular tests, specifically qPCR, for detecting these diseases. Even known pathogens that have minor impacts in their area of origin can cause significant harm when introduced into new habitats with naïve hosts. However, it is important to note that such screening can only identify birds with known diseases. Molecular metagenomic analyses of exotic birds may potentially discover unknown diseases. This approach is expensive, and the consequences of encountering unknown microorganisms, including their potential harm or benign nature, are difficult to predict.

During the quarantine period, the specimens should be placed in a separate cage and carefully observed for signs of illness. Knowledge of disease symptoms and familiarity with the normal appearance and behavior of the birds are valuable in recognizing potential diseases. Regular observation, particularly for abnormal signs or unusual behavior, is essential.

4.3 Information campaigns

Information campaigns are important risk-reducing measures, both regarding the importance of preventing birds in captivity to escape and to prevent direct and indirect contact between captive birds and wild populations of birds and mammals, domesticated cats, and rodents. This is especially important to prevent unintended introduction of pathogens.

There is much information available regarding criteria and responsibilities in the legal framework of importing alien species (c.f. the regulation regarding alien species) that must be followed. The legal framework is complex when the risk of importing pathogens is also considered. A leaflet or guide with information to help both professional and hobby bird keepers is needed that should cover regulations, requirements, consequences of (illegal) release, and provide to reduce the risk of pathogen-import and dissemination to natural habitats. Also, many people feed birds. Supplementary feeding of birds can induce ecological changes in avian populations (Robb et al., 2008), emphasizing the need for information campaigns that promote the importance of refraining from feeding invasive bird species.

4.4 Import birds from captivity

There is a higher likelihood of successful invasions from wild-caught birds for the pet trade than for captive bred birds that may have less ability to live in nature (Carrete and Tella 2008). Hence, it is likely a lower likelihood of successful invasions to nature if imported birds have been in captivity over some generations.

5 Uncertainties and data gaps

5.1 Uncertainties

Distribution modelling methods, which is used to assess the potential for the Northern Cardinal to survive and establish in Norway if released here or immigrate from northern Europe, have some well-known uncertainties (Beale and Lennon 2012; Bryn et al. 2021). The main uncertainty related to the models presented in this assessment, is the challenges with spatial transferability of models (Yates et al. 2018). We only have two observations of free-living Northern Cardinals from Norway, so the model is in principle built on training data from another continent (and a few entries from Benelux). Several biotic and abiotic factors differ between the two continents (North America versus Europe), and only a handful of mainly climatic variables are tested in the models (see chapter 2.2). On another continent, new competitors, other predators, different flora for feeding and hiding, and so forth, are therefore not accounted for in the models.

In addition, most of the explanatory variables used in the distribution models are models themselves, with inherited uncertainty (Peters et al. 2009). The present-day climate variables are interpolated as wall-to-wall models from a limited number of weather stations (Fick and Hijmans 2017), whereas the predicted future climate variables are generated with global scale climate models using different greenhouse gas concentration trajectories, and then downscaled (e.g., Fyfe et al. 2021). The total uncertainty within the presented distributions models is therefore not neglectable (see Bryn et al. 2021), but such models are presently among the best scientific tools we have for predicting the potential present and future distribution of Northern Cardinals in Norway.

VKM assess that the individuals, were they to be imported to Norway, would originate from central European countries, like The Netherlands, where these are commonly kept and bred. Therefore, there is uncertainty regarding the genetic origin of these individuals, and what subspecies they belong to.

5.2 Data gaps

We lack information on the occurrence of diseases in wild and domesticated populations of Northern Cardinal. We also lack information of the effects of diseases in Northern Cardinal and potential for spread to other species of birds or mammals. This data gap resulted in a generic risk assessment of diseases, where all diseases were assessed together and with no separation among areas of origin of source population.

6 Conclusions (with answers to the terms of reference)

6.1 The risk to biodiversity in Norway associated with importation and keeping of Northern Cardinal (*Cardinalis cardinalis*).

With regard to potential risks to biodiversity, VKM found that there was reason to assess four different mechanisms through which the Northern Cardinal could have negative impacts. The mechanisms include competition for food resources and for territory/nesting sites, hybridization, transmission of disease and indirect interactions through other species. In terms of magnitude, VKM concludes that none of these mechanisms can be assessed to represent more than Minor negative impact. In terms of likelihood, VKM concludes that it is Very unlikely that *C. cardinalis* would succeed in establishing a sustainable population in Norway, as establishment requires a larger number of individuals to enter a suitable habitat at the right time together.

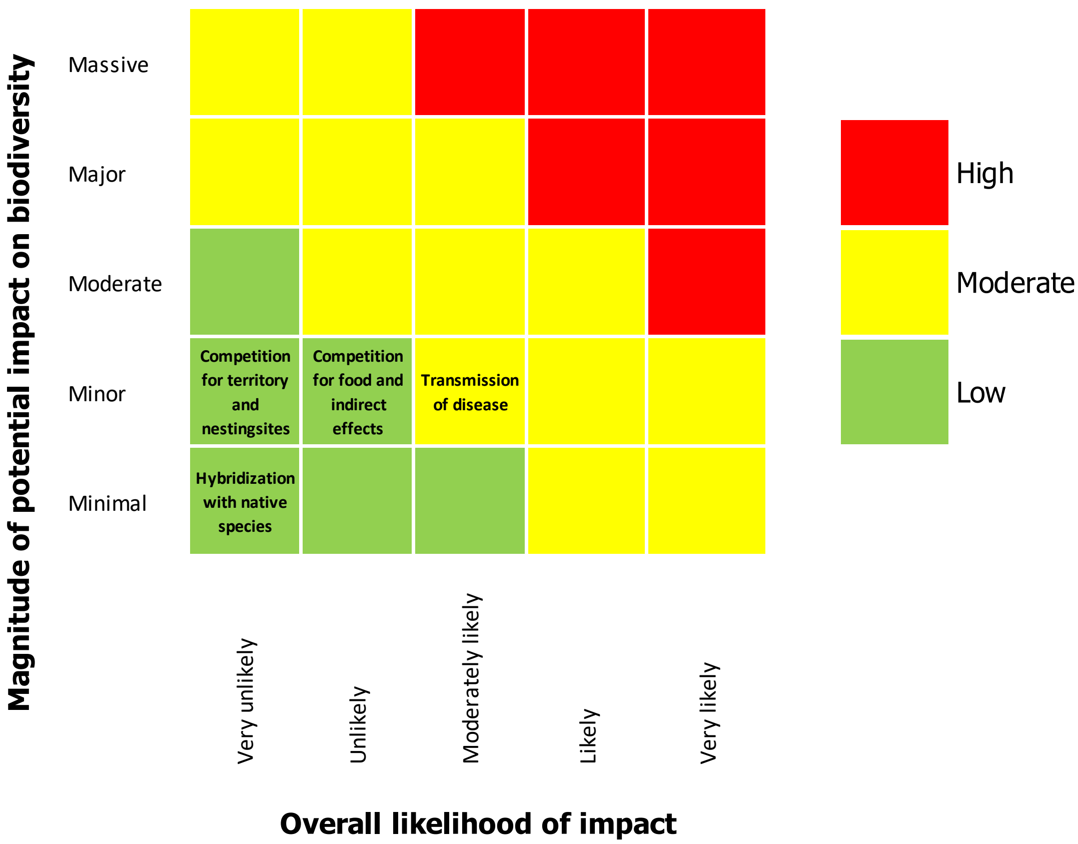


Figure 18: Summary of risks associated with *Cardinalis cardinalis* in Norway.

However, should *C. cardinalis* establish viable populations and spread in Norway, VKM further conclude that some competition with native birds for food is Likely to occur, while it is Unlikely that there would be competition for territories or nesting sites. As there are no close relatives to the Northern cardinal in Norway, VKM finds that negative effects due to hybridization would be Very unlikely even if the species should establish in Norway. Transmission of diseases from *C. cardinalis* to native bird species would however be Very likely if they establish. Similarly, would negative effects though interactions with other species such as spread of seeds from alien plants, be Likely.

Due to the fact that establishment is Very unlikely, the overall likelihood of negative impacts ranges from Very unlikely to Moderately likely, and consequently the risk is assessed to be **Low** for all assessed mechanisms, exempt transmission of disease, which is assessed to pose a **Moderate** risk (Figure 18).

6.2 Possible scenarios for distribution in Norway as a result of dispersal from Central Europe or from private keeping in Norway

The notable difference between the two possible pathways of entry is that entry through dispersal from Central Europe would require establishment of viable populations there first, and that dispersal would lead to entry in southern Norway (if dispersed directly from Denmark) or southeastern Norway should they spread along the Swedish coast first.

6.3 Effects of a changing climate on the assessments described in points 6.1 and 6.2

VKM concludes that climatic changes, as predicted by the SSP5-8.5 scenario, would result in more suitable habitats for *C. cardinalis* both along the Norwegian coast, and more importantly, also in central Europe where many more birds are kept (and could then possibly escape and establish). This would, in principle, result in a higher likelihood for future establishment in Norway through dispersal.

In terms of climatic effects on the impact of *C. cardinalis* in Norway, the assessments made in this report are made under the assumption that the species would already be established, and there are no climatic restrictions in relation to the assessed mechanisms themselves. Therefore, the potential magnitude of impact is not expected to be affected by changing climate and would remain as in Figure 18.

7 References

Adams, C., Feldman, S., and Sleeman, J. (2006) Phylogenetic analysis of avian Poxviruses among free-ranging birds of virginia. *Avian diseases*. 49. 601-5. 10.1637/7369-041805R.1.

Amin, A., Bilic, I., Liebhart, D., and Hess, M. (2014) Trichomonads in birds - a review. *Parasitology*. 141. 1-15. 10.1017/S0031182013002096

Anderson, N. L., Grahn, R. A., Van Hoosear, K., and BonDurant, R. H. (2009) Studies of trichomonad protozoa in free ranging songbirds: prevalence of *Trichomonas gallinae* in house finches (*Carpodacus mexicanus*) and corvids and a novel trichomonad in mockingbirds (Mimus polyglottos). *Veterinary Parasitology*, 161(3-4), 178-186.

Araujo, M.B., Pearson, R.G., Thuiller, W. and Erhard, M. (2005) Validation of species–climate impact models under climate change. *Global Change Biology* 11: 1504–1513.

Armstrong, R. A., & McGehee, R. (1980) Competitive exclusion. *The American Naturalist*, 115(2), 151-170.

Atkinson, C. T., and LaPointe, D. A. (2009) Introduced avian diseases, climate change, and the future of Hawaiian honeycreepers. *Journal of Avian Medicine and Surgery* 23:53-63.

Baker, D. G., Speer, C. A., Yamaguchi, A., Griffey, S. M., and Dubey, J. P. (1996) An unusual coccidian parasite causing pneumonia in a northern cardinal (*Cardinalis cardinalis*). *Journal of wildlife diseases*, 32(1), 130-132.

Beale, C. M., and Lennon, J. J. (2012) Incorporating uncertainty in predictive species distribution modelling. *Philos. Trans. R. Soc. B* 367, 247–258. doi: 10.1098/rstb.2011.0178

Bensch, S., Waldenström, J., Jonzán, N., Westerdahl, H., Hansson, B., Sejberg, D. and Hasselquist, D. (2007) Temporal dynamics and diversity of avian malaria parasites in a single host species. *Journal of Animal Ecology*, 76:112-122.

Bevanger, K. (2005) Nye dyrearter i norsk natur. *Landbruksforlaget*, Oslo

Billing, A. M., Lee, A. M., Skjelseth, S., Borg, Å. A., Hale, M. C., Slate, J. O. N., and Jensen, H. (2012) Evidence of inbreeding depression but not inbreeding avoidance in a natural house sparrow population. *Molecular Ecology*, 21(6), 1487-1499

BirdLife International and Handbook of the Birds of the World (2021). Bird species distribution maps of the world. Version 2021.1. Available at: http://datazone.birdlife.org/species/requestdis.

Blackburn, T.M., Essl, F., Evans, T., Hulme, P.E., Jeschke, J.M., Kuh,n I., Kumschick, S., Markova, Z., Mrugala A., Nentwig W., Pergl J., Pysek P., Rabitsch W., Ricciardi A., Richardson D.M., Sendek, A., Vila, M., Wilson, J.R., Winter, M., Genovesi, P. and, Bacher, S. (2014) A unified classification of alien species based on the magnitude of their environmental impacts. *PLoS Biol* 12:e1001850. DOI: 10.1371/journal.pbio.1001850.

Bochkov, A. V., Oconnor, B. M., Klompen H. (2015) A review of the mite subfamily Harpirhynchinae (Acariformes: Harpirhynchidae)--parasites of New World birds (Aves: Neognathae). *Zootaxa* 4023:1-130. DOI: 10.11646/zootaxa.4023.1.1.

Boseret, G., Losson, B., Mainil, J.G. et al. (2013) Zoonoses in pet birds: review and perspectives. *Veterinary Research* 44, 36. https://doi.org/10.1186/1297-9716-44-36

Bowden, S. E., Magori, K. and Drake, J. M. (2011) Regional differences in the association between land cover and West Nile virus disease incidence in humans in the United States. *Am J Trop Med Hyg*. 84:234–238. doi: 10.4269/ajtmh.2011.10-0134.

Breitwisch, R., Schilling, A. J. and Banks, J. B. (1999) Parental Behavior of a bigamous male Northern Cardinal. *Wilson Bull*., 11 (2), 1999, pp. 283-286.

Brochier B., Vangeluwe D., and van den Berg T. (2010) Alien invasive birds. *Revue Scientifique Et Technique-Office International Des Epizooties* 29:217–226.

Bryn, A., Strand, G-H., Angeloff, M. and Rekdal, Y. (2018) Land cover in Norway based on an area frame survey of vegetation types. *Norwegian Journal of Geography* 72(3): 131-145.

Bryn, A., Bekkby, T., Rinde, E., Gundersen, H. and Halvorsen, R. (2021) Reliability in distribution modeling - A synthesis and step-by-step guidelines for improved practice. *Front. Ecol. Evol*. 9: 658713. doi: 10.3389/fevo.2021.658713

CABI (2019) Digital Library. Eastern equine encephalitis virus. Available at: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.84274

Calmé, S., Desrochers, A. and Savard J. L. (2002) Regional significance of peatlands for avifaunal diversity in southern Quebec. *Biological Conservation* 107:273–281

Carrete M. and Tella J. (2008) Wild-bird trade and exotic invasions: a new link of conservation concern? *Frontiers in Ecology and the Environment* 6:207-211. DOI: 10.1890/070075.

Cassey P., Prowse T.A.A. and Blackburn T.M. (2014) A population model for predicting the successful establishment of introduced bird species. *Oecologia* 175:417-428. DOI: 10.1007/s00442-014-2902-1.

CDC (2010) West Nile Virus: Statistics, Surveillance, and Control. Book West Nile Virus: Statistics, Surveillance, and Control. http://www.cdc.gov/ncidod/dvbid/westnile/

Chimera C.G., Drake D.R. (2010) Patterns of seed dispersal and dispersal failure in a Hawaiian dry forest having only introduced birds. *Biotropica* 42:493-502. DOI: 10.1111/j.1744-7429.2009.00610.x

Cockrum E.L. (1952) A check-list and bibliography of hybrid birds in North America north of Mexico. *The Wilson Journal of Ornithology* 64: 140–159.

Codesido M., Drozd A. (2021) Alien birds in Argentina: pathways, characteristics and ecological roles. *Biological Invasions* 23:1329-1338. DOI: 10.1007/s10530-020-02444-w.

Crane, J. (2001) "Cardinalis cardinalis" (On-line), Animal Diversity Web. April 17, 2023 at: http://animaldiversity.ummz.umich.edu/site/accounts/information/Cardinalis_cardinalis.html

Crowell K.L. and Rothstein S.I. (2008) Clutch Sizes and Breeding Strategies among Bermudan and North American Passerines. *Ibis* 123:42-50. DOI: 10.1111/j.1474-919X.1981.tb00171.x.

DAISIE (2003) European Invasive Alien Species Gateway Retrieved 15.04.11, from http://www.europe-aliens.org

Deem, S. L., Cruz, M., Jimenez-Uzcategui, G., Fessel, B., Miller, R. E., and Parker, P. G. (2008) Pathogens and parasites: an increasing threat to the conservation of Galapagos avifauna. In: GALAPAGOS REPORT 2007–2008. (Galapagos Conservancy: Fairfax, VA.) Available at http://www.galapagos.org/wp-content/uploads/2012/04/biodiv7-pathogens-and-parasites.pdf [Verified 23 October 2013].

Desrochers A., Hannon S.J. and Nordin K.E. (1988) Winter survival and territory acquisition in a northern population of Black-capped Chickadees. *The Auk* 105:727–736.

DeVries, M. S., Winters, C. P. and Jawor J. M. (2015) Testosterone might not be necessary to support female aggression in incubating Northern Cardinals. *Animal Behaviour* 107: 139–146.

Donovan, T. M., and Flather C. H. (2002) Relationships among North American songbird trends, habitat fragmentation, and landscape occupancy. *Ecological Applications* 12(2): 364–374.

Dow, D. D. (1969) Home range and habitat of the Cardinal in peripheral and central populations. *Canadian Journal of Zoology* 47: 103–114.

Dow, D. D. (1970) Distribution and Dispersal of the Cardinal, Richmondena cardinalis, in Relation to Vegetational Cover and River Systems. *The American Midland Naturalist*, 84(1), 198–207. https://doi.org/10.2307/2423736

Dow, D. D. (1994) The Northern Cardinal in southern Ontario. In Ornithology in Ontario., edited by M. K. McNicholl and J. L. Cranmer-Byng, 291-297. Ontario, Canada: Hawk Owl Publ., Whitby.

Dow D.D. and Scott D.M. (1971) Dispersal and range expansion by the cardinal: an analysis of banding records. *Canadian Journal of Zoology* 49:185–198.

Drake J.M. and Lodge D.M. (2006) Allee effects, propagule pressure and the probability of establishment: Risk analysis for biological invasions*. Biological Invasions* 8:365-375. DOI: 10.1007/s10530-004-8122-6.

Ducey, J. E. (1988) Nebraska Birds: Breeding Status and Distribution. Simmons-Boardman Books, Omaha, NE, USA.

Duncan, W.J. and Bednekoff, P.A. (2006) Singing in the shade: song and song posts of Northern Cardinals near nesting Cooper's hawks. *Canadian Journal of Zoology*. 84(6): 916-919. https://doi.org/10.1139/z06-065

Dubey, J. P. (2002) A review of toxoplasmosis in wild birds. *Veterinary parasitology*, 106(2), 121-153.

Durrant, K., Marra, P., Fallon, S., Colbeck, G., Gibbs, H. Hobson, K., Norris, R., Bernik, B., Lloyd, V. and Fleischer, R. (2008) Parasite assemblages distinguish populations of a migratory passerine on its breeding grounds. *Journal of Zoology*. 274. 318-326. 10.1111/j.1469-7998.2007.00387.x.

Dyer E.E., Redding D.W. and Blackburn T.M. (2017) The global avian invasions atlas, a database of alien bird distributions worldwide. *Scientific Data* 4:170041. DOI: 10.1038/sdata.2017.41.

eBird Basic Dataset (2023). Version: EBD_relJan-2023. Cornell Lab of Ornithology, Ithaca, New York.

Ehrhart, R. L. and Conner, R. N. (1986) Habitat Selection by the Northern Cardinal in Three Eastern Texas Forest Stands. *The Southwestern Naturalist*, 31(2), 191–199. https://doi.org/10.2307/3670559

Eide, A .,Fallis, A .M .,Brinkmann, A .,Allen, T. and Eligh, D. (1969) Haematozoa from Norwegian birds.- Acta Univ Berg.,*Ser.Math.Rer.Natur*.6:1-8.

Evans T., Jeschke J.M., Liu C., Redding D.W., Şekercioğlu Ç.H. and Blackburn T.M. (2021) What factors increase the vulnerability of native birds to the impacts of alien birds? *Ecography* 44:727-739. DOI: 10.1111/ecog.05000.

Evans T., Kumschick S., Dyer E. and Blackburn T. (2014) Comparing determinants of alien bird impacts across two continents: implications for risk assessment and management. *Ecol Evol* 4:2957-67. DOI: 10.1002/ece3.1144.

Farmer, K. L., Hill, G. E., and Roberts, S. R. (2005) Susceptibility of wild songbirds to the House Finch strain of Mycoplasma gallisepticum. *Journal of Wildlife Diseases* 41, 317–325.

Fick, S.E. and Hijmans R.J. (2017). WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37 (12): 4302-4315.

Freed L.A. and Cann R.L. (2009) Negative effects of an introduced bird species on growth and survival in a native bird community. *Curr Biol* 19:1736-40. DOI: 10.1016/j.cub.2009.08.044.

Freed L.A. and Cann R.L. (2014) Diffuse competition can be reversed: a case history with birds in Hawaii. *Ecosphere* 5, article 147. DOI: 10.1890/es14-00289.1.

Fugate, L., and Miller, J. M. (2021) Shakespeare's Starlings: Literary History and the Fictions of Invasiveness*. Environmental Humanities*, 13(2), 301-322.

Fyfe, J. C., Kharin, V. V., Santer, B. D., Cole, J. N., and Gillett, N. P. (2021) Significant impact of forcing uncertainty in a large ensemble of climate model simulations. *Proceedings of the National Academy of Sciences*, 118(23), e2016549118.

Gaidet N., Caron A., Cappelle J., Cumming G. S., Balança G., Hammoumi S., Cattoli G., Abolnik C., Servan de Almeida R., Gil P., Fereidouni S. R., Grosbois V., Tran A., Mundava J., Fofana B., Ould El Mamy A. B., Ndlovu M., Mondain-Monval J. Y., Triplet P., Hagemeijer

W., Karesh W. B., Newman S. H. and Dodman T. (2012) Understanding the ecological drivers of avian influenza virus infection in wildfowl: a continental-scale study across Africa. *Proc. R. Soc. B.*2791131–1141

Gómez, A., Kilpatrick, A. M., Kramer, L. D. and Dupuis, A. P. (2008) Land use and West Nile virus seroprevalence in wild mammals. *Emerg Infect Dis*. 14:962. doi: 10.3201/eid1406.070352.

Gould, P.J. (1961) Territorial relationships between cardinals and pyrrhuloxias. *The Condor* 63 (3), 246–256.

Govoni, P. W., Summerville, K. S. and Eaton M. D. (2009) Nest sharing between and American Robin and a Northern Cardinal. *Wilson Journal of Ornithology* 121(2): 424–426.

Halkin, S. L. and Linville, S. U. (1999) Northern Cardinal (*Cardinalis cardinalis*). InThe Birds of North America, No. 440 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA

Halkin, S. L. and Linville S. U. (2020) Northern Cardinal (*Cardinalis cardinalis),* version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. [online] URL: https://doi.org/10.2173/bow.norcar.01

Halkin, S. L., Shustack, D. P., DeVries, M. S., Jawor, J. M. and Linville, S. U. (2021) Northern Cardinal *(Cardinalis cardinalis*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.norcar.02

Halvorsen, R., Mazzoni, S., Bryn, A. and Bakkestuen, V. (2015) Opportunities for improved distribution modelling practice via a strict maximum likelihood interpretation of MaxEnt. *Ecography* 38: 172-183.

Harfoot, M. B., Johnston, A., Balmford, A., Burgess, N. D., Butchart, S. H., Dias, M. P. and Geldmann, J. (2021) Using the IUCN Red List to map threats to terrestrial vertebrates at global scale*. Nature Ecology & Evolution*, 5(11), 1510-1519.

Hawkins, C. L., Bacher, S., Essl, F., Hulme, P. E., Jeschke, J. M., Kühn, I., and Blackburn, T. M. (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions*, 21(11), 1360-1363. https://doi.org/10.1111/ddi.12379

Heller, E. L., Wright, C. L., Nadolny, R. M., Hynes, W. L., Gaff, H. D., and Walters, E. L. (2016) New records of Ixodes affinis (Acari: Ixodidae) parasitizing avian hosts in southeastern Virginia. *Journal of Medical Entomology*, 53(2), 441-445.

Herzog, J. L., Lukashow-Moore, S. P., Brym, M. Z., Kalyanasundaram, A. and Kendall, R. J. (2021) A Helminth Survey of Northern Bobwhite Quail (*Colinus virginianus*) and Passerines in the Rolling Plains Ecoregion of Texas. *The Journal of parasitology*, 107(1), 132-137.

Hilty, J. A., Keeley, A. T., Merenlender, A. M. and Lidicker Jr, W. Z. (2019) Corridor ecology: linking landscapes for biodiversity conservation and climate adaptation. *Island Press*.

Hosmer Jr, D. W., Lemeshow, S. and Sturdivant, R. X. (2013) Applied logistic regression (Vol. 398). John Wiley & Sons.

Ishtiaq, F., Beadell, J. S., Baker, A. J., Rahmani, A. R., Jhala, Y. V., and Fleischer, R. C. (2006) Prevalence and evolutionary relationships of haematozoan parasites in native versus introduced populations of Com- mon Myna Acridotheres tristis. *Proceedings of the Biological Society of London – B. Biological Sciences* 273, 587–594. doi:10.1098/rspb.2005. 3313

Jaksic, F.M. (1998) Vertebrate invaders and their ecological impacts in Chile. *Biodiversity and Conservation* 7:1427–1445.

Jansson K., Josefsson M., Wieidema I. (2008) Invasive Alien Species Fact Sheet—Branta canadensis. Online Database of the North European and Baltic Nework on Invasive Alien Species—NOBANIS.

Jawor, J. M., Gray, N., Beall, S. M. and Breitwisch, R. (2004) Multiple ornaments correlate with aspects of condition and behaviour in female Northern Cardinals, *Cardinalis cardinalis*. *Animal Behaviour* 67(5): 875–882.

Kapperud, G. (1978) Survey for toxoplasmosis in wild and domestic animals from Norway and Sweden. *Journal of Wildlife Disease*; 14: 157–162.

Karger, D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N.E., Linder, P., Kessler, M. (2017) Climatologies at high resolution for the Earth land surface areas. *Scientific Data*. 4 170122. https://doi.org/10.1038/sdata.2017.122

Karger D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N.E,, Linder, H.P., Kessler, M.. (2018) Data from: Climatologies at high resolution for the earth's land surface areas. *Dryad Digital* Repository.http://dx.doi.org/doi:10.5061/dryad.kd1d4

Keller L.F. and Waller D.M. (2002) Inbreeding effects in wild populations*. Trends in Ecology & Evolution* 17:230–241.

Kilpatrick, A. M. (2011). Globalization, land use, and the invasion of West Nile virus. *Science*. 334:323–327. doi: 10.1126/science.1201010.

Kimura, M., Dhondt, A. and Lovette, I. (2006) Phylogeographic structuring of Plasmodium lineages across the North American range of the House Finch (*Carpodacus mexicanus*). *The Journal of parasitology*. 92. 1043-9. 10.1645/GE-639R.1.

Kounek, F., Sychra, O., Capek, M., Lipkova, A. and Literak, I. (2011) Chewing lice of the genus Myrsidea (Phthiraptera: Menoponidae) from the Cardinalidae, Emberizidae, Fringillidae and Thraupidae (Aves: Passeriformes) from Costa Rica, with descriptions of four new species*. Zootaxa*, 3137, 1–16.

Kumschick, S., Bacher, S., Dawson, W., Heikkilä, J., Sendek, A., Pluess T., Robinson T. and Kühn, I. (2012) A conceptual framework for prioritization of invasive alien species for management according to their impact. *NeoBiota*, 15: 69-100. https://doi.org/10.3897/ neobiota.15.3323

Kumschick, S., Blackburn, T.M. and Richardson, D.M. (2016) Managing alien bird species: Time to move beyond "100 of the worst" lists? *Bird Conservation International* 26:154–163. DOI: 10.1017/S0959270915000167.

Kumschick, S. and Nentwig, W. (2010) Some alien birds have as severe an impact as the most effectual alien mammals in Europe*. Biological Conservation* 143:2757–2762. DOI: 10.1016/j.biocon.2010.07.023.

Lande, R. (1988) Genetics and demography in biological conservation. *Science* 241:1455-1460.

Lapointe, D., Atkinson, C. and Samuel, M. (2012) Ecology and conservation biology of avian malaria. *Annals of the New York Academy of Sciences*. 1249. 211-26. 10.1111/j.1749-6632.2011.06431.x.

LaRosa, A.M., Smith C.W. and Gardner D.E. (1985) Role of alien and native birds in the dissemination of firetree (Myrica faya Ait.–Myricaceae) and associated plants in Hawaii*. Pacific Science* 39:372–378.

Laskey, A.R. (1944) A study of the cardinal in Tennessee. *The Wilson Bulletin* 56:27–44.

Lawson, B., Robinson, R. A., Toms, M. P., Risely, K., MacDonald, S. and Cunningham A. A. (2018) Health hazards to wild birds and risk factors associated with anthropogenic food provisioning. *Philos Trans R Soc Lond B Biol Sci*.;373(1745):20170091. doi: 10.1098/rstb.2017.0091. PMID: 29531146; PMCID: PMC5882997.

Lees, A. C., Haskell, L., Allinson, T., Bezeng, S. B., Burfield, I. J., Renjifo, L. M., and Butchart, S. H. (2022) State of the World's Birds. *Annual Review of Environment and Resources*, 47, 231-260.

Leston, L. F. V., and A. D. Rodewald (2006) Are urban forests ecological traps for understory birds? An examination using Northern Cardinals. *Biological Conservation* 131: 566–574.https://doi.org/10.1016/j.biocon.2006.03.003

Lockwood, J.L. (2017) Exotic birds provide unique insight into species invasions. *Proc Natl Acad Sci U S A* 114:9237-9239. DOI: 10.1073/pnas.1712744114.

Lockwood, J.L., Welbourne, D.J., Romagosa, C.M., Cassey, P., Mandrak, N.E., Strecker, A., Leung, B., Stringham, O.C., Udell, B., Episcopio-Sturgeon, D.J., Tlusty, M.F., Sinclair, J., Springborn, M.R., Pienaar, E.F., Rhyne, A.L. and Keller R. (2019) When pets become pests: the role of the exotic pet trade in producing invasive vertebrate animals. *Frontiers in Ecology and the Environment* 17:323-330. DOI: 10.1002/fee.2059.

Long, K. (2020) What Birds Eat: How to Preserve the Natural Diet and Behavior of North American Birds. *Skipstone*, Seattle, 368 pp.

Loss, S., Will, T. amd Marra, P. (2013) The impact of free-ranging domestic cats on wildlife of the United States. *Nat Commun* 4, 1396. https://doi.org/10.1038/ncomms2380.

Mank, J.E., Carlson, J.E. and Brittingham, M.C. (2004) A century of hybridization: decreasing genetic distance between American black ducks and mallards. *Conservation Genetics*, 5, pp.395-403.

Martin-Albarracin, V.L., Amico, G.C., Simberloff, D. and Nunez, M.A. (2015) Impact of non-native birds on native ecosystems: A global analysis. *PLoS One* 10:e0143070. DOI: 10.1371/journal.pone.0143070.

McClure, K. M., Fleischer, R. C., and Kilpatrick A. M. (2020) The role of native and introduced birds in transmission of avian malaria in Hawaii. *Ecology* 101:e03038.

Moulton, M.P. (1993) The all-or-none pattern in introduced hawaiian passeriforms: The role of competition sustained. *American Naturalist* 141:105–119.

Nardoni, S., Rocchigiani, G., Varvaro, I., Altomonte, I., Ceccherelli, R. and Mancianti, F. (2019) Serological and Molecular Investigation on Toxoplasma gondii Infection in Wild Birds. *Pathogens*. 8(2):58. doi: 10.3390/pathogens8020058.

NBIC (2022). Guidelines for the Generic Ecological Impact Assessment of Alien Species, version 4.4. Trondheim: *Norwegian Biodiversity Information Centre*

Neimanis, A. S., Handeland, K., Isomursu, M., Ågren, E., Mattsson, R., Hamnes, I. S. and Hirvelä-Koski, V. (2010) First report of epizootic trichomoniasis in wild finches (family Fringillidae) in southern Fennoscandia. *Avian diseases*, 54(1), 136-141

Nentwig, W., Kuehnel, E. and Bacher, S. (2010) A Generic Impact Scoring System Applied to Alien Mammals in Europe. *Conservation Biology*, 24(1): 302-311. https://doi. org/10.1111/j.1523-1739.2009.01289.x

Newton, I. (1969) Winter fattening in the Bullfinch. *Physiological Zoology* 42:96–107.

Newton, I. (1998) Population limitation in birds. *Acade- mic Press*, London, UK.

Newton, I. (2007) Weather-related mass-mortality events in migrants. *Ibis* 149:453-467. DOI: 10.1111/j.1474-919X.2007.00704.x.

Nice, M. M. (1927). Experiences with Cardinals at a feeding station in Oklahoma. *Condor* 29: 101–103.

Oberholser, H. C. (1974) The bird life of Texas*, University of Texas Press*, Austin.

Oliveros, C. H., Field, D. J., Ksepka, D. T., Barker, F. K., Aleixo, A., Andersen, M. J. and Faircloth, B. C. (2019) Earth history and the passerine superradiation. *Proceedings of the National Academy of Sciences*, 116(16), 7916-7925.

Owen, J.C., Nakamura, A., Coon, C.A. and Martin, L.B. (2012) The effect of exogenous corticosterone on West Nile virus infection in Northern Cardinals (Cardinalis cardinalis). *Vet Res*. 43(1):34. doi: 10.1186/1297-9716-43-34. PMID: 22520572; PMCID: PMC3372427.

Pagenkopp, K.M., Klicka, J., Durrant, K.L. et al. (2008) Geographic variation in malarial parasite lineages in the common yellowthroat (*Geothlypis trichas*). *Conserv Genet* 9, 1577–1588. https://doi.org/10.1007/s10592-007-9497-6

Parkes, K.C. (1997) The Northern Cardinals of the Caribbean slope of Mexico, with the description of an additional subspecies from Yucatán, in: R. W. Dickerman (Ed.), The

Era of Alan R Phillips: A festschrift Horizon Communications, Albuquerque, New Mexico. pp. 129–138.

Peck, G. K. and R. D. James. (1987) Breeding birds of Ontario: Nidiology and distribution. Vol. 2. Passerines. Toronto: *Misc. Publ. Roy. Ont. Mus.*

Peters, J., Verhoest, N. E. C., Samson, R., van Meirvenne, M., Cockx, L., and de Baets, B. (2009) Uncertainty propagation in vegetation distribution models based on ensemble classifiers. *Ecol. Modelling* 220, 791–804. doi: 10.1016/j.ecolmodel.2008.12.022

Petit, M., Clavijo-Baquet, S. and Vézina, F. (2016). Increasing Winter Maximal Metabolic Rate Improves Intrawinter Survival in Small Birds. Physiological and Biochemical Zoology. 90. 000-000. 10.1086/689274.

Phillips, S.J., Anderson, R.P., Dudík, M., Schapire, R.E. and Blair, M.E. (2017) Opening the black box: an open-source release of Maxent. *Ecography*, 40: 887-893. https://doi.org/10.1111/ecog.03049

Pistone, J. P., Light, J. E., Campbell, T. A., Catanach, T. A. and Voelker, G. (2021) Restricted Geographic Sampling Yields Low Parasitism Rates but Surprisingly Diverse Host Associations in Avian Lice (Insecta: Phthiraptera) from South Texas. *Diversity* 13, no. 9: 430. https://doi.org/10.3390/d13090430

R Core Team (2023). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org

Ramírez Albores, J. E. (2010) Presence of the Northern Cardinal (*Cardinalis cardinalis*) in southwestern Puebla, Mexico. *Huitzil* 11(1): 42–45.

Reed, K.D, Meece, J.K, Henkel, J.S and Shukla, S.K. (2003) Birds, migration and emerging zoonoses: west nile virus, lyme disease, influenza A and enteropathogens. *Clin Med Res*. 1(1):5-12. doi: 10.3121/cmr.1.1.5. PMID: 15931279; PMCID: PMC1069015.

Ridgeway, R. (1885) Description of some new species of birds from Cozumel Island, Yucatán. *Proceedings of the Biological Society of Washington* 3:21–24.

Ridgeway, R. and Friedmann, H. (1901) The birds of North and Middle America, part 1. *Bulletin of the United States National Museum* 50.

Ridgeway, R. (1919) The birds of North and Middle America. *Bulletin of the United States National Museum* 50, Part VIII.

Ritchie, B. W., Harrison, G. J. and Harrison, L. R. (2013) Avian medicine: principles and application. *Wingers Publishing.*

Robb, G.N., McDonald, R.A., Chamberlain, D.E. and Bearhop, S. (2008) Food for thought: supplementary feeding as a driver of ecological change in avian populations. *Frontiers in Ecology and the Environment*, 6: 476-484. https://doi.org/10.1890/060152

Robbins, M. B., and D. A. Easterla (1992) Birds of Missouri: Their Distribution and Abundance. *University of Missouri Press*, Columbia, MO, USA.

Robinson, S. K., and Robinson, W. D. (2001) Avian Nesting Success in a Selectively Harvested North Temperate Deciduous Forest. *Conservation Biology*, 15(6), 1763–1771. http://www.jstor.org/stable/3061277

Rogers, K.H, Girard, Y.A., Woods, L., Johnson, C.K. (2016) Avian trichomonosis in spotted owls (Strix occidentalis): Indication of opportunistic spillover from prey. *Int J Parasitol Parasites Wildl.* 5(3):305-311. doi: 10.1016/j.ijppaw.2016.10.002.

Root, T. (1988a) Environmental factors associated with avian distributional boundaries. *Journal of Biogeography* 15:489–505.

Root, T. (1988b) Energy constraints on avian distributions and abundances. *Ecology* 69:330–339.

Root, T.L. (1994). Scientific/Philosophical Challenges of Global Change Research: A Case Study of Climatic Changes on Birds. *Proceedings of the American Philosophical Society*, Vol. 138,3: 377-384. https://www.jstor.org/stable/986743

Rozek, J.C., Camp R.J. and Reed, J.M. (2017) No evidence of critical slowing down in two endangered Hawaiian honeycreepers. *PLoS One* 12:e0187518. DOI: 10.1371/journal.pone.0187518.

Ruiz, M.O., Walker, E.D., Foster, E.S., Haramis, L.D. and Kitron, U.D. (2007) Association of West Nile virus illness and urban landscapes in Chicago and Detroit. *Int J Health Geogr*. 6:10. doi: 10.1186/1476-072X-6-10.

Samuel, M. D., Woodworth, B. L., Atkinson, C. T., Hart, P. J., and LaPointe, D. A. (2015) Avian malaria in Hawaiian forest birds: infection and population impacts across species and elevations. *Ecosphere*, 6(6), 1-21.

Sandvik, H, Hilmo, O., Finstad, A.G. et al. (2019) Generic Ecological Impact Assessment of Alien Species (GEIAA): the third generation of assessments in Norway. *Biological Invasions*, 21, 2803–2810. https://doi.org.10.1007/s10530-019-02033-6

Shirley, S.M. and Kark, S. (2009) The role of species traits and taxonomic patterns in alien bird impacts. *Global Ecology and Biogeography* 18:450-459. DOI: 10.1111/j.1466-8238.2009.00452.x.

Simberloff, D. (2013) Invasive Species: What Everyone Needs to Know. *Oxford University Press*, Oxford.

Simberloff, D. and Boecklen, W.J. (1991) Patterns of extinction in the introduced Hawaiian avifauna: A reexamination of the role of competition. *American Naturalist* 138:300–327.

Sgueo, C., M. E. Wells, D. E. Russell, and P. J. Schaeffer (2012) Acclimatization of seasonal energetics in Northern Cardinals (*Cardinalis cardinalis*) through plasticity of metabolic rates and ceilings. *Journal of Experimental Biology* 215: 2418–2424.

Smith, B.T., Escalante, P., Hernández Baños, B.E., Navarro-Sigüenza, A.G., Rohwer, S. and Klicka, J. (2011) The role of historical and contemporary processes on phylogeographic structure and genetic diversity in the Northern Cardinal, *Cardinalis cardinalis*. *BMC Evolutionary Biology* 11:136–147

Smith, B.T. and Klicka, J. (2013) Examining the Role of Effective Population Size on Mitochondrial and Multilocus Divergence Time Discordance in a Songbird*. PLoS ONE* 8(2): e55161. doi:10.1371/journal.pone.0055161

Soos, C., Padilla, L., Iglesias, A., Gottdenker, N., Bedon, M. C., Rios, A., and Parker, P. G. (2008) Comparison of pathogens in broiler and backyard chickens on the Galapagos Islands: implications for transmission to wildlife. *Auk* 125, 445–455. doi:10.1525/auk.2008.06235

Speer, C. A., Baker, D. G., Yamaguchi, A., and Dubey, J. P. (1997) Ultrastructural characteristics of a Lankesterella-like coccidian causing pneumonia in a Northern Cardinal *(Cardinalis cardinalis*). *Acta Protozoologica*, 36(1).

Sperry, J.H., Barron, D.G. and Weatherhead, P.J. (2012) Snake behavior and seasonal variation in nest survival of northern cardinals *Cardinalis cardinalis*. *Journal of Avian Biology* 43:496-502. DOI: 10.1111/j.1600-048X.2012.05632.x.

Stanback, M. and Powell, E. (2010) Predator Vocalizations Affect Foraging Trade-offs of Northern Cardinals. *Wilson Journal of Ornithology*. 122. 168-173. 10.1676/09-052.1.

Stelzer, S., Basso, W., Silván, J. B., Ortega-Mora, L. M., Maksimov, P., Gethmann, J. and Schares, G. (2019) *Toxoplasma gondii* infection and toxoplasmosis in farm animals: Risk factors and economic impact. *Food and Waterborne Parasitology*, 15, e00037

Stokke, B.G. and Gjershaug, J.O. (2018). *Cardinalis cardinalis*, vurdering av økologisk risiko. Fremmedartslista 2018. *Artsdatabanken*

Stutchbury, B., Catuano, B. and Fraser, G. (2005) Avian frugivory on a gap-specialist, the red elderberry (*Sambucus racemosa*). *Wilson Bulletin*. 117. 336-340. 10.1676/04-115.1.

Swanson, D.L. (2001) Are summit metabolism and thermogenic endurance correlated in winter-acclimatized passerine birds? *J Comp Physiol B Biochem Syst Environ Physiol* 171: 475–481.

Swanson, D., Zhang, Y., Liu, J.S., Merkord, C.L. and King, M.O. (2014) Relative roles of temperature and photoperiod as drivers of metabolic flexibility in dark-eyed juncos. *J Exp Biol* 217: 866–875.

Tuanmu, M.-N. and Jetz, W. (2015) Global habitat heterogeneity. *Global Ecology and Biogeography*, 24: 1329-1339. https://doi.org/10.1111/geb.12365

Thompson, F. R., III. (2007) Factors affecting nest pre- dation on forest songbirds in North America. *Ibis* 149:98-109.

Valkiunas, G. (2004) Avian Malaria Parasites and other Haemosporidia (1st ed.). *CRC Press*. https://doi.org/10.1201/9780203643792

Van Doren, B. M. (2022) How migratory birds might have tracked past climate change. *Proceedings of the National Academy of Sciences*, 119(3), e2121738119.

Van Riper III, C., Van Riper, S.G., Goff, M.L. and Laird, M. (1986) The epizootiology and ecological significance of malaria in Hawaiian land birds. *Ecological monographs*, 56(4), pp.327-344.

Vanrompay, D., Harkinezhad, T., Van De Walle, M., Beeckman, D., Van Droogenbroeck, C., Verminnen, K., Leten, R., Martel, A. and Cauwerts, K. (2007) *Chlamydophila psittaci* transmission from pet birds to humans. *Emerg Infect Dis*. 13: 1108-1110. 10.3201/eid1307.070074.

Vignali, S., Barras, A. G., Arlettaz, R. and Braunisch, V. (2022) SDMtune: An R package to tune and evaluate species distribution models. *Ecology and Evololution*, 10(20), 11488–11506. https://doi.org/10.1002/ece3.6786

VKM (2019) Kriterier for forfatterskap og faglig ansvar i VKMs uttalelser. https://vkm.no/download/18.48566e5316b6a4910fc2dbd6/1561035075341/VKMs%20forfatterskapskriterier_revidert%20versjon%2020.06.2019.pdf

VKM (2018) Rutine for godkjenning av risikovurderinger. https://vkm.no/download/18.433c8e05166edbef03bbda5f/1543579222271/Rutine%20for%20godkjenning%20av%20risikovurderinger.pdf

VKM, Kausrud, K. L., Vandvik, V., Flø, D., Geange, S. R., Hegland, S. J., Hermansen, J. S., ... & Velle, G. (2022) Impacts of climate change on the boreal forest ecosystem. Scientific Opinion of the Panel on Alien Organisms and Trade in Endangered species (CITES) of the Norwegian Scientific Committee for Food and Environment.

Walstrom, V.W. and Outlaw, D.C. (2017) Distribution and Prevalence of Haemosporidian Parasites in the Northern Cardinal (*Cardinalis cardinalis*). *J Parasitol*. 103(1):63-68. doi: 10.1645/14-693. Epub 2016 Oct 4. PMID: 27700232.

Wan, X., Yan, C., Wang, Z. and Zhang, Z. (2022) Sustained population decline of rodents is linked to accelerated climate warming and human disturbance. *BMC Ecology and Evolution*, 22(1), 102.

Weatherhead, P.J., Gerardo, L. F. Carfagno, J. H. Sperry, J. D. B., and Robinson, S. (2010) Linking Snake Behavior to Nest Predation in a Midwestern Bird Community. *Ecological Applications* 20, no. 1: 234–41. http://www.jstor.org/stable/27797801.

Weli, S.C., Okeke, M.I., Tryland, M., Nilssen, O. and Traavik, T. (2004) Characterization of avipoxviruses from wild birds in Norway. *Can J Vet Res*. 68(2):140-5. PMID: 15188959; PMCID: PMC1142158

Weli, S.C. and Tryland, M. (2011) Avipoxviruses: infection biology and their use as vaccine vectors. *Virol J*. 3;8:49. doi: 10.1186/1743-422X-8-49. PMID: 21291547; PMCID: PMC3042955.

Williams, J.B. and Tieleman, B.I. (2000) Flexibility in basal metabolic rate and evaporative water loss among hoopoe larks exposed to different environmental temperatures. *J Exp Biol* 203: 3153–3159.

Williamson. M. (1996) Biological Invasions. Chapman & Hall, London.

Winter, K. C. (1981) Interactions between nesting Cardinals and American Robins. *Inland Bird Banding* 53: 56–57.

Winters, C. P. and Jawor, J.M. (2017) Melanin ornament brightness and aggression at the nest in female Northern Cardinals (*Cardinalis cardinalis*). *Auk* 134: 128–136.

Wittmann, M.J., Metzler, D., Gabriel, W. and Jeschke, J.M. (2014) Decomposing propagule pressure: the effects of propagule size and propagule frequency on invasion success. *Oikos* 123:441-450. DOI: 10.1111/j.1600-0706.2013.01025.x.

Woolfenden, G.E. and Rohwer S.A. (1969) Breeding birds in a Florida suburb. *Bulletin of the Florida State Museum* 13:1–83

Yates, K. L., Bouchet, P. J., Caley, M. J., Mengersen, K., Randin, C. F., Parnell, S., et al. (2018) Outstanding challenges in the transferability of ecological models. *Trends Ecol. Evol*. 33, 790–802. doi: 10.1016/j.tree.2018.08.001.

Zizka, A., Silvestro, D., Andermann, T., Azevedo, J., Duarte Ritter, C., Edler, D., Farooq, H., Herdean, A., Ariza, M., Scharn, R., Svanteson, S., Wengtrom, N., Zizka, V. and Antonelli, A. (2019) CoordinateCleaner: standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution*, 10(5):744-751. doi: 10.1111/2041-210X.13152

Zhou, L. M., Xia, S. S., Chen, Q., Wang, R. M., Zheng, W. H., & Liu, J. S. (2016). Phenotypic flexibility of thermogenesis in the Hwamei (*Garrulax canorus*): responses to cold acclimation. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 310(4), R330-R336.

Zuckerberg, B., Woods, A.M. and Porter, W.F. (2009) Poleward shifts in breeding bird distributions in New York State. *Global Change Biology*, 15(8): 1866-1883. doi: 10.1111/j.1365-2486.2009.01878.x

Appendix I

NBIC assessment scheme

Artens status i dag

- Er arten fremmed? *Ja*
- Vurderes taksonet på et høyere (artsnivå) eller lavere (underartsnivå) taksonomisk nivå? *Nei*
- Vurderes taksonet sammen med et annet takson? *Nei*
- Er arten en bruksart? *Ja*

Hvilken etableringsklasse har arten i Norge?

- Merk av den høyeste (øverste) klassen som oppfylles av arten i Norge i dag: *Arten forekommer innendørs eller i lukkede installasjoner (B1)*
- Var arten etablert per 1800? *Nei*
- Første observasjon av arten: Selvstendig reproduksjon innendørs (hvis relevant): *2005 ± 5 år*
- Individ innendørs (hvis relevant): *2005 ± 5 år*

Artsinformasjon

- Livsmiljø: *Terrestrisk*

Global utbredelse.

- Naturlig utbredelse: *Nord- og Mellom-Amerika (Temperert Boreal, Temperert Nemoral, Temperert Tørt, Subtropisk uspesifisert, Subtropisk Middelhavsklima, Subtropisk Fuktig, Subtropisk tørt, Tropisk)*
- Nåværende utbredelse: *Nord- og Mellom-Amerika (Temperert Boreal, Temperert Nemoral, Temperert Tørt, Subtropisk uspesifisert, Subtropisk Middelhavsklima, Subtropisk Fuktig, Subtropisk tørt, Tropisk). Oseania (Subtropisk uspesifisert, Subtropisk Middelhavsklima, Subtropisk Fuktig, Subtropisk tørt)*
- Kom arten til Fastlands-Norge fra: *Annet sted (utlandet)*
- Reproduksjon: *Seksuell reproduksjon*
- Generasjonstid: *1 år*

Spredningsveier

Spredningsveier til og i norsk natur.

- Spres arten utelukkende direkte til norsk natur (uten å gå veien om innendørsareal eller artens eget produksjonsareal)? *Nei, arten spres til norsk natur kun/også via innendørsareal eller artens eget produksjonsareal*

Til innendørs- eller produksjonsareal. Legg til spredningsvei.

- Hovedkategori: *Direkte import*
- Kategori: *privatpersoners egenimport*
- Hyppighet: *Ca. Årlig*
- Antall individer*: 2 – 10*
- Tidsrom: *Pågående*

Introduksjon til natur. Legg til spredningsvei.

- Hovedkategori: *Rømning/forvilling*

- Kategori: *av kjæledyr/hobbydyr eller private akvarieplanter*
- Hyppighet: *Sjeldnere enn hvert 10. år*
- Antall individer: *2-10*
- Tidsrom: *Pågående*

Videre spredning i natur. Legg til spredningsvei Hovedkategori: *Egenspredning*

- Kategori: *naturlig*
- Hyppighet: *Sjeldnere enn hvert 10. år*
- Antall individer: *2-10*
- Tidsrom: *Kun i fremtiden*

Utbredelse i Norge

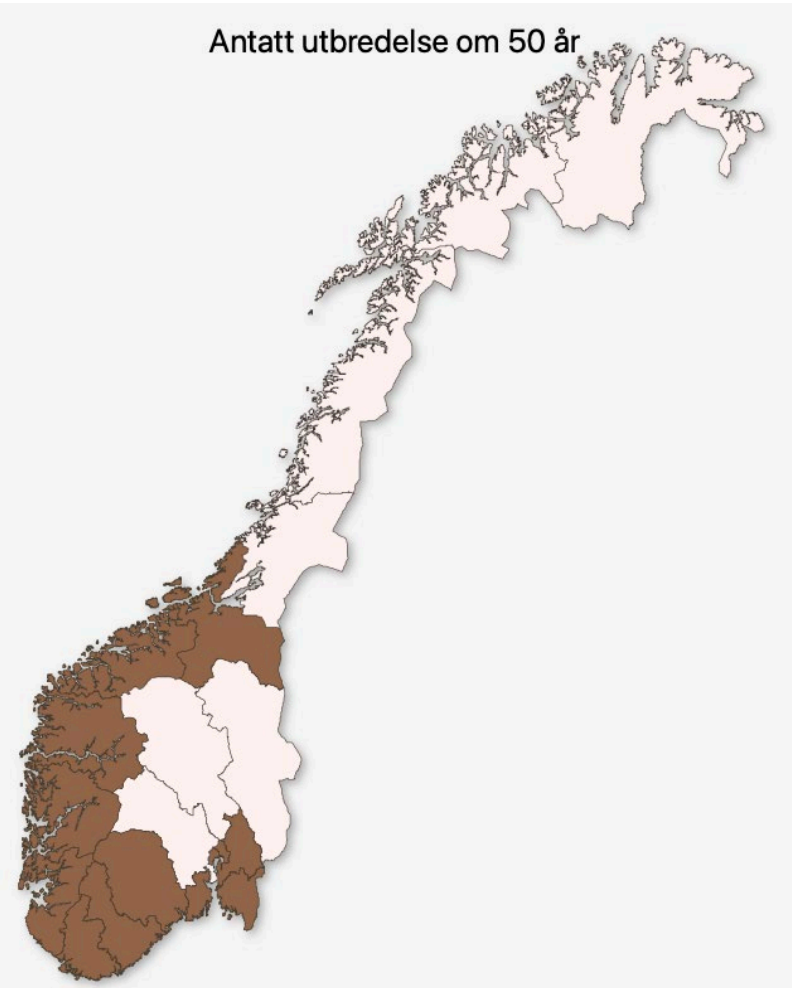
Forekomstareal. Hvor mange 2 km x 2 km-ruter kan arten kolonisere i løpet av en 10 års-periode basert på én introduksjon til norsk natur (innenfor vurderingsperioden på 50 år)?

- Lavt anslag (25-prosentil): *0*
- Beste anslag (median): *1*
- Høyt anslag (75-prosentil): *10*

Hvor mange ytterligere introduksjoner til norsk natur antas arten å få i løpet av samme 10-års periode?

- Lavt anslag (25-prosentil):
- *0* Beste anslag (median): *1*
- Høyt anslag (75-prosentil): *2*

Beskriv grunnlaget for og/eller antagelsene bak anslagene på regionvis utbredelse og forekomstareal om 50 år: *Klimaforholdene langs kysten av Norge og på Sørlandet er*



innenfor rødkardinal sin klimatoleranse Antar to kull per år, fire egg per kull, 50% overlevelse, generasjonstid på ett år, kan reprodusere hvert år.

Naturtyper

Effekter på truede eller sjeldne naturtyper fra Rødlista for naturtyper 2018.

- *Strandeng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Semi-naturlig eng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Slåttemark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Semi-naturlig strandeng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Flomskogsmark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Høgstaude edelløvskog* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Lågurtedellauvskog* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Kalkedellauvskog* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Rik vierstrandskog* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Semi-naturlig myr* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Sørlig slåttemyr (Tidshorisont: fremtidig; Kolonisert areal (%): 0.0 – 1.9; Tydelig tilstandsendring*: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).
- *Rik svartorsumpskog* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Kun obs. fra utlandet*).

Effekter på naturtyper fra NiN 2.3

- *NA T2 Åpen grunnlendt mark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA T4 Fastmarksskogsmark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA T18Åpen flomfastmark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).

- *NA T39Sterkt endret eller ny fastmark i langsom suksesjon* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA T40Sterkt endret fastmark med preg av semi-naturlig eng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA T41Oppdyrket mark med preg av semi-naturlig eng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA T45Oppdyrket varig eng* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).
- *NA V8 Strandsumpskogsmark* (Tidshorisont: *fremtidig*; Kolonisert areal (%): *0.0 – 1.9*; Tydelig tilstandsendring: *Relativ del-artsgruppe-sammensetning*; Tydelig påvirka areal (%): *0.1 – 1.9*; Vurderings-grunnlag: *Skriftlig dok. fra utlandet*).

Artens invasjonspotensial

A-kriteriet: Median levetid.

- Velg én av følgende metoder for å anslå/estimere artens mediane levetid i Norge: *Forenklet anslag*
- Basert på det beste anslaget på 1 forekomster i løpet av 10 år og 1 ytterligere introduksjon(er) i samme tidsperiode er A-kriteriet forhåndsskåret som 3 (med usikkerhet: 2–4). Dette innebærer at artens mediane levetid ligger mellom 60 år og 650 år, eller at sannsynligheten for utdøing innen 50 år er på mellom 5% og 43%: *Godtar beregnet skår.*

B-kriteriet: Ekspansjonshastighet.

- Velg én av følgende metoder for å estimere/anslå artens gjennomsnittlige ekspansjonshastighet: *Anslått økning i forekomstareal*
- Basert på det beste anslaget på 1 forekomster i løpet av 10 år og 1 ytterligere introduksjon(er) i samme tidsperiode er B-kriteriet skåret som 1 (med usikkerhet: 1–2). Dette innebærer at artens ekspansjonshastighet ligger under 50 m/år (beste anslag: 46 m/år). Skår og usikkerhet, oppsummert:
- *1< 50 m/år*
- *250 - 159 m/å*

C-kriteriet: Kolonisert naturtypeareal.

- Kolonisert naturtypeareal (%) er overført fra «Naturtyper». Skår og usikkerhet, oppsummert: *1< 5%*

Artens økologiske effekt

D- og E-kriteriet: Effekter på rødlistevurderte arter. Beskriv artens interaksjon(er) med stedegne og andre arter som har blitt vurdert for rødlisting.

- D-kriteriet: Effekter på truede arter eller nøkkelarter. Angi skår og usikkerhet: *Ingen kjent effekt*
- E-kriteriet: Effekter på øvrige rødlistevurderte arter. Angi skår og usikkerhet: *Svak styrke/Moderat styrke og begrenset omfang*

F-kriteriet: Effekter på truede/sjeldne naturtyper. Naturtypeareal (%) som gjennomgår tilstandsendring er overført fra «Naturtyper»

- Skår og usikkerhet, oppsummert: *> 0%*

G-kriteriet: Effekter på «øvrige» naturtyper Naturtypeareal (%) som gjennomgår tilstandsendring er overført fra «Naturtyper».

- Skår og usikkerhet, oppsummert: *< 5%*

H-kriteriet: Overføring av genetisk materiale

- Beskriv overføring av genetisk materiale (introgresjon) til rødlistevurdert art. *ingen overføring*

I-kriteriet: Overføring av parasitter eller patogener

- Beskriv overføring av parasitter eller patogener (bakterier og virus inkludert) til stedegne og andre arter som har blitt vurdert for rødlisting: *Ingen overføring / Begrenset til art som allerede er vert for denne parasitten*

Betydning av klimaendringer

Delkategori invasjonspotensial: 2 (usikkerhet opp mot 3).

- Ville artens delkategori for invasjonspotensiale ha blitt *lavere* i fravær av pågående eller forventede klimaendringer? *Ja*
- Delkategori økologisk effekt: 2. Ville artens delkategori for økologisk effekt ha blitt lavere i fravær av pågående eller forventede klimaendringer? *Ja*

Geografisk variasjon i risiko

Arter med en viss utstrekning i forekomstarealet kan, som en respons på ulike miljøbetingelser, ha ulik påvirkning i naturen.

- Kunne arten ha fått en *lavere* risikokategori (dvs. NK) i deler av sitt potensielle forekomstareal? *Ja*

Ettersom spørsmålet over er besvart positivt, bør geografisk variasjon beskrives nærmere: Hva kan forklare den geografiske variasjonen i risiko? (flere valg mulig):

- *Artens evne til reproduksjon og/eller spredning er begrenset til visse bioklimatiske soner eller seksjoner*
- *Artens økologiske effekter er begrenset til visse bioklimatiske soner eller seksjoner*
- *Artens økologiske effekter er begrenset til bestemte naturtyper*

Vurderingens oppsummering