Vitenskapskomiteen for mat og miljø
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VKM Report 2023: 23

Assessment of the risks posed by domestic cats (*Felis catus*) to biodiversity and animal welfare in Norway

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

VKM has evaluated to what extent keeping of cats pose a risk to biodiversity in Norway. Risks were assessed separately for threats to biodiversity from direct predation, indirect (non-lethal) effects, competition with other wildlife and spread of infectious organisms. VKM also assessed the risk of reduced animal welfare related to the keeping of domestic cats, both for the cats and their prey. In addition, VKM has assessed a range of risk-reducing measures aimed at minimizing the risk for negative impacts on biodiversity and animal welfare. Overall, VKM find that the risk of negative impact on vulnerable birds and red-listed mammalian species are high under certain conditions. VKM also find that there is a considerable risk associated with increased spread of infectious organisms from cats to wildlife and other domestic species. Some of these infectious organisms may also infect humans. With respect to mitigation measures, VKM concludes that measures focused on limiting cats' access to prey populations are likely to yield the most positive outcomes in terms of mitigating the adverse impact on biodiversity.

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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 four VKM members, four external experts and one VKM staff. Two referees commented on and reviewed the draft opinion. The Panel on Biodiversity, supplemented by one member of the Panel on CITES, 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 or the VKM Panel on CITES.

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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.

Table of Contents

Summary

Key words: VKM, risk assessment, Norwegian Scientific Committee for Food and Environment, Norwegian Food Safety Authority, Norwegian Environment Agency

Background

The domestic cat (*Felis catus*) was introduced to Norway more than a thousand years ago and has historically functioned as a useful predator of pests, such as mice and rats. Currently, the domestic cat is predominantly kept as a pet, but is also used to control populations of small rodents, especially on farms. The domestic cat is not considered a wildlife species according to Norwegian legislation and is exempt from the regulations concerning the introduction and keeping of introduced species. VKM initiated this project as part of our commitment to assess the risk to Norwegian biodiversity from species that have been introduced to Norway, regardless of such regulations. No previous complete assessment of the risk to Norwegian biodiversity from domestic cats has been conducted, although the effects on birds has been assessed previously. A large proportion of the cat population in Norway is allowed to roam freely outdoors. The potential impact on native fauna from domestic cat predation is a contentious issue in many countries globally. It is well-documented that cats prey on a wide range of animals in Norway and elsewhere, including small rodents, birds, reptiles, amphibians and various larger invertebrates. The animal welfare for the prey might also be of concern. Moreover, due to their indoor-outdoor lifestyle, cats might transfer diseases to humans, other domestic animals and wildlife populations. Many domestic cats also spend parts of their time outdoors without supervision, which might expose them to factors that represent a risk to their welfare.

In this report, VKM has assessed the risk that domestic cats represent to biodiversity in Norway and descried the role of domestic cats in the spread of infectious agents (parasites, bacteria and viruses). VKM also assessed the risk of reduced animal welfare related to the keeping of domestic cats, both for the cats and for wild animals. In addition, VKM has assessed a range of risk-reducing measures aimed at minimizing the risk for negative impacts on biodiversity and animal welfare. The assessment is based on the current climate conditions. In addition, VKM has assessed whether the risks are expected to change due to climate change.

Methods

Risks were assessed separately for threats to biodiversity from direct predation, indirect (non-lethal) effects, and competition with other wildlife. Risks related to direct predation were assessed separately for birds, mammals, reptiles, and amphibians. For birds, we also assessed the risk of negative effects on specific local areas that might be particularly sensitive to cat predation. Such areas, hereafter termed hotspots, include RAMSAR sites (wetland areas that are breeding or stop-over sites for migratory birds), as well as breeding colonies for seabirds and breeding sites for shorebirds. The risk of

negative effects of cat predation on red-listed mammal species was assessed independently from general effects on small mammal communities.

VKM has based its evaluation on publicly available information, and an extensive search for information in the scientific literature. Based on data from the literature, a model was developed to estimate the total number of prey individuals across the most important taxonomic groups that are killed annually by domestic cats in Norway. Several behavioural, physiological, morphological and life history traits and their Red List status were used to assess the relative risk for different species of birds, mammals, reptiles and amphibians. A model predicting spatial distribution of domestic cat density was established and overlaid the spatial distribution of species at risk and bird hotspots to further evaluate the risk to species and bird communities. A semi-quantitative risk assessment was performed. For each hazard, the risk is equal to the product of impact (potential adverse effects) and likelihood for the impact to occur. The evaluation of mitigative measures was based on information in published sources and supplemented by expert judgements from members of the project group. In total, 15 measures were assessed. The measures were categorized into four groups, depending on the type and scope of the measure. The four categories included: i) measures that restrict cats' access to prey populations, ii) measures that reduce hunting success of cats, iii) measures that depress hunting behaviour, and iv) measures that reduce impacts by reducing the number of cats.

Results and conclusions

VKM found that cats pose a high risk to Norwegian biodiversity under certain conditions. We estimated that the total population of 690 000 to 870 000 owned and feral domestic cats kill between 21.3 to 68.9 million (median: 33.2) prey individuals each year, of which owned cats constitute ca 75% of the predation. The annual total number of prey individual includes 3.9 to 13.8 million (median: 6.3) birds and 12.6 to 42.7 million (median: 20.3) mammals. In addition, cats kill an unknown number of insects each year. VKM concludes that direct cat predation can represent a high risk for the most vulnerable bird species living in areas with high cat densities, such as urban areas and in the bird hotspots that are most exposed to cats. The risk for common mammalian prey species is considered low to moderate. The impact of cat predation on some red-listed bat species is potentially high, but a low likelihood for negative impacts results in a Low to Medium risk. The risk of negative effects on reptiles and amphibians is mainly assessed as low, although for three species, cats pose a Medium risk. The risk of negative effects on avian and mammalian predators due to competition for shared food sources is Low in most cases, although it might be Medium in areas with high cat densities for animals that have a high dietary overlap with owned or feral cats. The risk posed by indirect effects of cats on potential prey species is Medium under certain conditions, but this is assessed with low confidence.

VKM concludes that there is a considerable risk associated with increased spread of infectious organisms from cats to wildlife and other domestic species. Some of these infectious organisms may also infect humans. A wide range of diseases and disease-causing agents, in which cats have been implicated as potential hosts, amplifiers, or transmitters to humans, wildlife or other animals as hosts, were identified and described. Cats were found to play a peripheral role in the disease transmission in most systems but may be an important contributing factor to infections with severe impacts and/or affecting a large number of individuals across multiple species of wildlife, domestic animals and humans in some disease systems. These included the eukaryotic protozoan parasite *Toxoplasma gondii,* the *Toxocaria* parasites, the bacteria *Francisella tularensis*, *Salmonella* genus bacteria. In addition, they might possibly play a role in emerging respiratory viruses, in particular influenza.

VKM also assessed the risk for negative effects on prey welfare from the keeping of domestic cats. In rural habitats, VKM found it unlikely that domestic cats significantly reduce the welfare of wild prey populations. In urban and suburban areas where cats are more numerous, VKM found it to be very likely that cats have a negative effect on prey animal welfare.

The impacts of climate change might amplify the adverse consequences of domestic cats on biodiversity. This is because climate change tends to render wildlife populations more vulnerable and less resilient against predation and disease related mortality. Simultaneously, it increases the importance of dispersal and range shifts as compensatory mechanisms in response to climate change. Domestic cats are insulated against direct effects of climate change and thus able to maintain a high hunting pressure even when local prey is scarce. Additionally, climate change might facilitate the establishment of disease agents, and milder winters may increase the survival of feral cats. Therefore, a compound or cascading effect of climate change seems likely to increase the negative impacts of cats on biodiversity.

With respect to mitigative measures, VKM concludes that measures focused on limiting cats' access to prey populations are likely to yield the most positive outcomes in terms of mitigating the adverse impact on biodiversity. These measures are expected to have major to massive effects in terms of reducing the impacts of predation and the spread of pathogens. However, keeping cats indoors only may have potential negative effects on cat welfare, especially for cats that are used to roam outdoors. The use of outdoor enclosures ("catios"), or walking the cat on a leash, has many of the same advantages, but potentially smaller negative impact on cat welfare.

Another mitigating measure would be to keep the cat indoors only in certain geographic areas or in certain time periods. Time of specific concern include the period between dusk and dawn when cat hunting success might be particularly high, as well as during the breeding season for birds in spring and early summer. Likewise, keeping owned cats indoors only in regions near bird hotspots is likely to have a significant potential for reducing the risk to these bird communities.

Measures that reduce the cats hunting success, such as marking the cats with colorful collars, bibs or bells, are also likely to reduce the predation pressure on wildlife and thus the risk of negative effects on biodiversity from keeping domestic cats. These measures are likely to have smaller effects than the measures that directly limit domestic cats interactions with wildlife. Also measures that aim to reduce the size of the cat population – and in particular the population of feral cats – were also evaluated as less efficient in terms of reducing the risk for negative effects on biodiversity. These measures included mandatory neutering of cats not used for breeding, mandatory ID-marking, culling of feral cats, and application of TNR or TTVARR methods.

In terms of cat welfare, the current practice of allowing cats to roam freely is often considered the best option for the cats. However, cats are, when roaming freely, subjected to many hazards, sometimes with fatal outcome. Free roaming cats, as opposed to cats kept indoor, in a catio, or walked on a leash, run the risk of being killed by traffic, domestic dogs or wildlife, or being harmed by humans. Free roaming also increases the likelihood of being injured in fights with other cats or becoming infected with parasites and pathogens. There is also a, albeit low, likelihood of the cat getting lost and end up as stray cats or in cat colonies.

Data gaps and uncertainty

Several data gaps and uncertainties were identified. In particular, there is a lack of studies that directly assess the impact of domestic, owned and feral, cats on biodiversity in Norway. Data gaps make the assessment of population effects more uncertain. Our assessment clearly shows that domestic cats kill a large number of prey annually in Norway. However, the assessment of population effects of cat predation is uncertain due to a lack of information on the proportion of the prey mortality from cats that is additive to other causes of mortality. There are considerable data gaps related to the extent of cat predation on wild species in Norway.

Moreover, there is a lack of studies concerning feral cats in Norway, both related to the number of feral cats and their rates of prey consumption relative to owned domestic cats. While VKM identified substantial risk associated with cat predation on bird hotspots, lack of data pertaining to the distribution of feral cat colonies precludes a direct assessment of which hotspots are most at risk. There is considerable uncertainty about the cat's role in spread of pathogens or parasites, in particular to wildlife species.

Finally, there is relatively little data on the efficacy of many of the proposed mitigative strategies, and there is substantial uncertainty related to implementation of the assessed mitigation measures (termed "implementation uncertainty"). The uncertainty influences how potential measures will be perceived and implemented by cat owners and the public.

Sammendrag på norsk

Bakgrunn

Tamkatt (*Felis catus*) ble innført til Norge for mer enn 1000 år siden og har historisk sett vært nyttig fordi den jakter på skadedyr som mus og rotter. I dag holdes tamkatt i hovedsak som kjæledyr, men den benyttes også fortsatt til å holde smågnagerbestandene nede. Ifølge norsk lovgivning er ikke tamkatt regnet som en viltart, og den er listet som et unntak i forskriften som regulerer hold og innførsel av fremmede organismer. VKM initierte dette prosjektet som en del av sitt mandat for å vurdere risiko for negative effekter på biologisk mangfold som følge av arter som er innført til Norge, uavhengig av slike juridiske forhold.

Det foreligger ingen fullstendige risikovurderinger av hold av tamkatt i Norge fra før, men effekter på fugl har blitt beskrevet tidligere. En stor andel av tamkattene i Norge oppholder seg mye utendørs uten begrensninger i hvor de kan gå. Slikt kattehold er et kontroversielt tema i mange land på grunn av effektene det kan ha på stedegen fauna. Det er godt dokumentert fra Norge og andre land at tamkatter kan skade og drepe et stort antall ulike viltlevende arter, som smågnagere, fugler, reptiler, amfibier og ulike arter av store invertebrater. Dette reiser også spørsmål ved dyrevelferd for byttedyrene. På grunn av sin innendørs-utendørs livsstil kan tamkatter også spre sykdommer til ville dyr, andre husdyr og mennesker. Siden mange tamkatter tilbringer mye tid utendørs uten tilsyn er de også eksponert for en rekke faktorer som innebærer en risiko for deres velferd.

I denne risikovurderingen har VKM vurdert hvilken risiko tamkatt utgjør for biologisk mangfold i Norge, og beskrevet rollen som tamkatt spiller når det gjelder spredning av sykdomsfremkallende agens (parasitter, bakterier og virus). VKM har også vurdert risiko knyttet til redusert dyrevelferd vedhold av tamkatt, både velferd for katten selv og for potensielle ville byttedyr. Vurderingen er basert på dagens klima, men VKM har også vurdert hvordan risiko kan endre seg som følge av et endret klima.

Metoder

Risiko for negative effekter på biologisk mangfold ble vurdert separat for direkte effekter av predasjon, indirekte (ikke-letale) effekter av predasjon, og konkurranse med andre viltlevende arter. Risiko knyttet til direkte effekter av predasjon ble vurdert separat for fugl, pattedyr, reptiler og amfibier. For fugl vurderte vi også risiko for negative effekter i spesifikke lokaliteter som kan være særlig sensitive for predasjon fra tamkatt. Disse områdene, som i rapporten omtales som «hotspots», inkluderer RAMSAR-områder (våtmarksområder som er viktige hekkeområder og rasteplasser for migrerende fugler), hekkekolonier for sjøfugl og hekkeområder for vadefugl. Risiko for negative effekter av kattepredasjon på pattedyrarter som er listet som nært truet eller truet på norsk rødliste, ble vurdert separat fra effekter på små pattedyr generelt.

VKM har basert risikovurderingen på offentlig tilgjengelig informasjon og et ekstensivt søk etter informasjon i vitenskapelig litteratur. Basert på informasjon fra litteraturen ble det utviklet en modell for å estimere antall dyr som blir predatert av tamkatt årlig, fordelt på de viktigste dyregruppene. Ulike atferdsmessige-, fysiologiske-, morfologiske- og livshistorietrekk ble benyttet for å vurdere risiko for ulike arter fugl, pattedyr, reptiler og amfibier. For å vurdere risiko for enkelte fuglearter og sårbare fuglesamfunn, ble fordelingen av slike arter og samfunn sammenliknet med antatt tetthet av tamkatt i ulike områder. En semi-kvantitativ risikovurdering ble gjennomført. For hver risikofaktor (engelsk: *hazard*) er den totale risikoen basert på produktet av potensiell negativ påvirkning (engelsk: *impact*) og sannsynligheten for at denne skal inntreffe (engelsk: *likelihood*). Evalueringen av risikoreduserende tiltak ble basert på tilgjengelig informasjon fra publiserte kilder, og ekspertvurderinger fra medlemmer av prosjektgruppa. Tiltakene ble gruppert i fire kategorier, avhengig av type tiltak og formål. Disse fire kategoriene inkluderte i) tiltak som begrenser kattens tilgang til byttedyrpopulasjoner, ii) tiltak som reduserer kattens jaktsuksess, iii) tiltak som reduserer kattens jaktlyst, og iv) tiltak som reduserer antall katter.

Resultater og konklusjoner

VKM vurderer risikoen for at tamkatt har negativ effekt på biologisk mangfold i Norge som høy under en del spesifikke forhold. Det ble beregnet at den totale bestanden av tamkatt i Norge på om lag 690 000 til 870 000 individer (både eide og eierløse katter), vil ta mellom 21,3 og 68,9 millioner (median: 33,2 millioner) byttedyr årlig. Eide katter ble anslått å stå bak omtrent 75 % av predasjonen. Av det totale antallet byttedyr ble det beregnet at fugl utgjorde 3,9 til 13,8 millioner (median: 6,3 millioner), mens pattedyr utgjorde mellom 12,6 og 42,7 millioner (median: 20,3 millioner). I tillegg tar tamkatt et ukjent antall insekter hvert år. VKM konkluderer med at det er høy risiko for negative effekter på sårbare fuglearter som lever i områder med høy tetthet av tamkatt, inkludert urbane områder og fugle-hotspots som er eksponert for katter. Risiko for negative effekter på vanlig forekommende pattedyrarter er vurdert som liten. Tamkatt kan potensielt ha stor negativ effekt på enkelte arter flaggermus som er vurdert som truet eller nært truet på den norske rødlista for arter, men siden sannsynligheten for at dette inntreffer er vurdert som lav er den totale risikoen for negativ påvirkning på disse artene vurdert som lav til middels. Risikoen for negative effekter av tamkatt på viltlevende arter som følge av konkurranse om byttedyr, er vurdert som lav i de fleste situasjoner, men kan være medium i tilfeller hvor kattetettheten er høy og for arter som har stort overlapp med tamkatt når det gjelder valg av byttedyr. Risikoen knyttet til indirekte (ikke-letale) effekter av tamkatt på potensielle arter byttedyr er vurdert til medium, men denne vurderingen har liten grad av sikkerhet.

VKM konkluderer med at det er betydelig risiko for at tamkatt kan bidra til økt spredning av sykdomsfremkallende organismer til viltlevende arter og til andre husdyr. Flere av disse organismene kan også smitte mennesker. VKM har identifisert og beskrevet en lang rekke sykdommer og sykdomsfremkallende agens der katter har blitt beskrevet som en mulig mellomvert.. I de aller fleste tilfellene spiller katter en perifer rolle, men i enkelte sykdomssystemer kan tamkatt bidra til å spre sykdommer som skader et stort antall individer av både viltlevende arter, husdyr og mennesker. Disse inkluderer den eukariotiske protosoiske parasitten *Toxoplasa gondii*, *Toxocaria* parasitten, bakterien *Franscisella tularensis*, og bakterier av Salmonella-slekten. I tillegg kan tamkatt potensielt spille en rolle i spredningen av nye respiratoriske virus, særlig influensa.

VKM har også vurdert risiko knyttet til redusert dyrevelferd for byttedyrene som følge av hold av tamkatt. I rurale områder finner VKM det usannsynlig at tamkatt bidrar signifikant til å redusere dyrevelferden for byttedyrpopulasjoner. I urbane og suburbane strøk, hvor tamkatt er tallrik og det er få andre ville rovdyr, finner VKM det svært sannsynlig at tamkatt bidrar til redusert dyrevelferd for byttedyrene.

Klimaendringer kan potensielt forsterke de negative effektene som tamkatt kan ha på norsk biologisk mangfold. Det skyldes at klimaendringer kan gjøre viltarter mer utsatt for sykdommer og potensielt mer påvirket av predasjon. Tamkatter er beskyttet mot direkte effekter av klimaendringer siden de i liten grad er nødt til å fange byttedyr for å overleve. Derfor kan de være i stand til å opprettholde høye tettheter og stort predasjonstrykk, selv om enkelte byttedyr blir mer sjeldne som følge av klimaendringene. I tillegg kan klimaendringer legge til rette for nye sykdomsfremkallende agens, og mildere vintre kan føre til at flere eierløse tamkatter overlever. I sum kan en kaskade av effekter som skyldes klimaendringer øke de negative effektene av tamkatt på biologisk mangfold.

Når det gjelder risikoreduserende tiltak vurderer VKM at tiltak som begrenser kattens tilgang til områder der det er bestander av viltlevende dyr er mest effektive for å begrense negative effekter på biologisk mangfold. Disse tiltakene, det vil si bruk av utendørs innhegning eller lufting utendørs i bånd, kan forventes å ha stor effekt på å redusere predasjon og spredning av sykdom. Det er imidlertid også potensielt negative effekter av å kun holde katten innendørs, særlig for katter som er vant til å kunne ferdes fritt ute. Bruk av utendørs innhegninger («catio») eller lufting utendørs i bånd har mange av de samme fordelene, men potensielt små negative innvirkninger på velferden for kattene.

Et annet risikoreduserende tiltak vil være å holde tamkatt innendørs kun i enkelte særlig utsatte områder og tidspunkt på året eller døgnet. Tidspunkt som vurderes som mest aktuelle er kveld og morgen når kattens jaktsuksess kan være høy, og i hekkesesongen for fugl på våren og tidlig sommer. Videre vil hold av tamkatt kun innendørs i nærheten av fugle-hotspots kunne ha en betydelig risikoreduserende effekt for disse fuglesamfunnene.

Tiltak som reduserer kattenes jaktsuksess, som bruk av fargerike krager, bjeller og smekker, kan også redusere predasjonstrykket og derfor de negative effektene på biologisk mangfold.. Effekten er vurdert til å være mindre enn effekt av tiltak som begrenser kattenes interaksjoner med viltlevende dyr. Også tiltak som har til hensikt å begrense størrelsen på kattepopulasjonen, i særlig grad antall eierløse katter, er vurdert til å ha begrenset effekt på å redusere risiko for negative effekter på biologisk mangfold. Disse tiltakene inkluderer både obligatorisk sterilisering av katter som ikke skal benyttes i avl, obligatorisk ID-merking, avliving av eierløse katter, og bruk av TNR eller TTVARR-metoder.

I rapporten har VKM også vurdert velferd for kattene ved dagens praksis med å la katter vandre fritt utendørs. Praksisen utsetter tamkatt for en rekke risikofaktorer som infeksjoner sykdommer og parasitter, skade fra andre katter, møte med hunder og ulike arter av viltlevende dyr. Det er også en lav sannsynlighet for at tamkatt forviller seg og ender opp som hjemløs eller blir del av en kattekoloni.

Datahull og usikkerheter

Det er identifisert en rekke datamangler og usikkerheter. Ikke minst gjelder det mangel på studier fra Norge som direkte undersøker effekter av tamkatt, både eide og forvillede, på biologisk mangfold. Datamanglene gjør vurderingen av negative effekter på bestandene av viltlevende arter usikker. Vår vurdering viser tydelig at tamkatt årlig dreper et stort antall byttedyr i Norge, men vurderingen av hvilken effekt dette har for populasjonene er hemmet av at vi ikke vet med sikkerhet hvor stor andel av denne predasjonen som kommer i tillegg til annen dødelighet hos byttedyrene, og hva som kompenseres via redusert dødelighet knyttet til andre dødsårsaker.

Videre mangler det studier på eierløse tamkatter i Norge, både når det gjelder størrelsen på bestanden og på hvor mange byttedyr de tar sammenliknet med eide katter. Selv om VKM identifiserte risiko for negative effekter av kattepredasjon på særlig sensitive fugleområder («hotspots»), gjør mangel på data knyttet til forekomst av kattekolonier det vanskelig å identifisere hvilke «hotspots» som er mest risikoutsatt.

Det er knyttet stor usikkerhet til rollen tamkatter spiller for spredning av patogener og parasitter, i særlig grad når det gjelder spredning til viltlevende dyr. Også når det gjelder effekter av risikoreduserende tiltak er dataene generelt mangelfulle, og det er betydelig usikkerhet knyttet til implementeringen av mange av disse tiltakene. Denne usikkerheten kan påvirke hvordan de potensielle tiltakene blir mottatt av katteeiere.

Glossary and typology

Glossary

Additive predation	Predation that causes an immediate reduction in total survival probability
Compensatory predation	Predation that does not affect the total survival probability (preying on individuals that would soon die regardless)
Predation rate	Proportion of a population killed by the predator (by cats in this case)
Kill rate	Number of prey individuals killed / time unit / individual predator (e.g., one year or one month)
Neutering	removal of gonads, i.e., testes or ovaries.

Typology of cats

In this report, the term "wildcat" is only used for the wild, original cat species (mainly *Felis silvestris* and *Felis lybica*). Domestic cats (*Felis catus*) may be owned, showing varying indoor-outdoor lifestyles and may belong to a particular breed, or having become stray or feral.

Owned cats: All cats that have an owner that is responsible for it. Includes both indoor cats, free-ranging cats and farm-cats, but not stray or feral cats.

Indoor cats: Owned cats (typically pets) that are prevented from going outdoors on its own, and thus do not interact with native wildlife. Some indoor cats may be taken out on leash or stay in an outdoor enclosure (or 'catio'). Indoor cats without such opportunities are termed *only-indoor cats*. Regarding pathogen/parasite pathways, indoor cats implies trained to use a litterbox whereas free-ranging cats defecate outside.

Free-ranging cats: Owned cats habituated to humans but allowed to roam freely outside the house. Free-ranging cats are sometimes referred to as "outdoor cats", or "indoor-outdoor cats" as they typically are outdoors for only part of the time.

Stray cats: Previously owned cats that have lost their contact with owners and have strayed some distance from their original home. Their habituation to humans is presumably reduced. They typically live only outdoors but may be found close to human settlements.

Feral cats: Domestic cats descended from owned cats but has been without an owner for more than one generation. They have become wild, with no habituation to humans and live entirely outdoors, typically more remote from human settlements than stray cats. Stray cats and feral cats may be termed *homeless cats* by animal welfare organisations.

Farm cats: Free-ranging, owned but also stray or more or less feral, cats that live in close association with agriculture, typically around barns and outhouses in contact with livestock, wildlife and peridomestic rodents etc.

Non-pedigree cats: Domestic cats that do not belong to a particular cat breed or is a mixture between a breed and a non-pedigree cat.

Pedigree cats: Domestic cats that belong to one of the around 50 well-defined cat breeds and are selected for breeding by humans.

Forest cat breeds: Pedigree breeds of Long-haired cats from the Northern hemisphere that show closely related gene-pools: Norwegian Forest Cat, Maine Coon, and Siberian/Neva Masquerade.

Background to the Terms of Reference, as provided by VKM

The domestic cat was introduced to Norway and has historically functioned as a useful predator of pests, such as mice and rats. However, in more recent times, the domestic cat has predominantly been kept as a pet and is to a lesser degree used for pest control. Several breeds have been developed more recently, especially breeds suited as pets. Despite selective breeding, the cat’s natural hunting instincts remain intact. Some breeds are well-suited for a life indoors, but many cats are kept outside to some degree, where they roam freely. The natural hunting instincts of a cat make it an important predator in the Norwegian fauna. Worldwide, both owned domestic and feral cats are among the biggest threats to local biodiversity. It is known from some islands that predation by cats has led to the extinction of a variety of endemic vertebrates. (Nogales et al. 2004). It is also well-documented that cats prey on a wide range of prey in Norway: small rodents, squirrels, birds, reptiles, amphibians, and various larger invertebrates. Several species in these animal groups are at risk of extinction in Norway and are therefore red-listed nationally. The total threat to biodiversity in Norway remains unknown.

A report by the Norwegian Ornithological Association (now BirdLife Norway) from 2018 estimated that there were about 770,000 cats in Norway in 2016, and that these together kill circa 7 million birds each year. In addition, cats prey on an unknown number of other animals. Based on the increase of domestic cats in Norway from 2011 to 2016, there is reason to believe that the number of cats kept as pets in Norway is now more than 800,000.

Cats kept partly outdoors can spread disease-causing organisms (agents) and parasites like *Toxocara cati, Salmonella* spp., *Fransicella tularensis, Toxoplasma gondii* (causing toxoplasmosis), and can potentially spread emerging viruses such as SARS-CoV-2 between humans and other animals.

Apart from the potential effects on biodiversity arising from predation and spread of agents and parasites, there are also animal welfare issues related to keeping domestic cats:

- Many wild animals are injured or frightened by cats. Disturbances and fear of cats might affect the animals’ behaviour, reproduction and survival.

- Cats are often left outside without supervision. They are therefore among the few pets in Norway that are exposed to considerable risk of death from traffic, poisoning and abuse in addition to interaction with native wildlife (badgers, foxes, etc.).

- Domestic cats that have not been neutered may reproduce in nature, resulting in feral cats. Although neutered animals can survive in the

> Norwegian nature, they are not adequately adapted to a life without supervision and care in the Norwegian climate, which reduces their welfare.

Although cats were introduced by humans, they are legally not regarded as an alien species in Norwegian nature but rather defined as pets under §29, section five of the Norwegian Biodiversity Act (see also note to §3 letter h in the Regulation on alien organisms). The Norwegian Biodiversity Information Centre (Artsdatabanken), however, regard cats as an alien species, but have they have not been risk assessed as the species had self-sustaining populations in the wild prior to the year 1800. Nevertheless, the cat is a species that has shown to have a high potential to have a negative impact on biodiversity.

Terms of Reference (ToR) as provided by VKM

The Panel on Alien Organisms and Trade in Endangered Species (CITES) initiated this project on behalf of VKM and commissioned the project group to:

- Assess the risk of negative impacts on biodiversity in Norway posed by the keeping of domestic cats, including the spread of pathogenic organisms and parasites to humans and other animals.

- Assess the risk of reduced animal welfare in relation to the keeping of domestic cats, including the reduced welfare of cats, and of wild animals.

- Identify risk-reducing measures linked to the identified hazards under points 1 and 2 above.

The assessment should be based on the current climate conditions. In addition, VKM is to assess whether the risks are expected to change due to climate change (under RCP 8.5) from now to the year 2100.

1 Introduction

1.1 History of the domestic cat

1.1.1 Origins of domestic cats

The domestic cat (*Felis catus*) resembles several small, wild cats from Africa and Asia. Currently, it is not known where and how the domestication occurred, but genetic, archaeological and historical studies provide good indications (Crowley et al 2020a). Analyses of genetic material, behaviour and appearance of various wild cats have shown that the domestic cat is closely related to both the European wildcat (*Felis silvestris,* Figure 1) and the African wildcat (*Felis lybica*, Figure 2). However, DNA analyses of 979 wild and domestic cats in Europe, the Middle East, Africa and Asia show that the domestic cat is originally derived from the African wildcat, and not the European (Driscoll et al., 2007). The analyses further indicate that the domestic cat originated in the Middle East, in the Fertile Crescent belt from the Egyptian Nile area to Palestine and Mesopotamia, where agriculture is believed to have originated. Later, the domestic cat occasionally mated with both European and Asian wildcats. All of these can have fertile offspring. The relatively new cat breed Bengal cat is derived from the Asian leopard cat (*Prionailurus bengalensis*), being crossed with domestic shorthair cats in the 1970s (Kitchener et al., 2017).

Figure 1: European wildcat, *Felis silvestris*. Photo: XTREKX, Mostphotos.com

The European wildcat still exists in Central European countries, like Germany, Belgium and France in addition to Portugal, Spain, Turkey and Italy. Wildcats also have a scattered distribution throughout Eastern Europe (Yamaguchi et al. 2015; Ruiz-Villar et al. 2023). Until recently the European wildcat was distributed in Scotland, where it was often termed Scottish wildcat. Scottish populations of the wildcat are no longer considered to be viable by IUCN, being too heavily crossed with feral domestic cats (Breitenmoser et al., 2019). The European wildcat probably never existed in Norway, but it was distributed in Denmark northwards to Mid Jutland and in Scania, southern Sweden, where European wildcats have been found in burials in Neolithic settlements, i.e., before 1700-1900 CE (Topak, 2019). The European wildcat is timid, unsocial, and aggressive if approached, and even their kittens are almost impossible to tame. The species is therefore an unsuitable candidate for domestication and live in close contact with humans (Serpell, 2014).

The African wildcat (Figure 2) is more social than the European wildcat. It has a mild temperament and lives close to villages in Northeast Africa. The African wildcat is distributed throughout the Middle East and much of Africa. It inhabits semi-arid regions but is not found in deserts. The mating system is monogamous, and males help providing food for the kittens.

Figure 2: African wildcat, *Felis lybica*. Photo: Nico Smith, Mostphotos.com

1.1.2 *Origin of domestic cats in Norway*

It is not known when the domesticated cat came to Norway. The cat has been assumed to be brought to Norway by the Vikings, perhaps from the British Isles, or from the Vikings' journeys in Russian rivers to the Black Sea and Miklagard (today's Turkey). It is believed the cat came to Norway in the 800s, but it may have occurred earlier. Language researcher and Professor Bjarne Berulfsen said that the Norwegian word "katt" must have come to Norway before the Viking age (from later latin *cattus*). It is unknown whether the term refers to the domestic cat or the European wild cat, but the latter species never occurred as far north as Norway. In Norse mythology, it is said that the goddess Frøya drove in a wagon pulled by two cats.

In the Viking Age, the cat was well-known. The Vikings kept cats as domestic animals, and in Iceland, cat skins became a valuable commodity. Among other things, the skins were used to make gloves. In the 13th century, cat skins were a valid means of payment, and a skin of an adult male cat was worth three fox skins, according to the Norwegian King Magnus Lagabøte's law from 1274.

In 1983, the Icelandic geneticist Stefan Adalsteinsson described findings that strongly suggest that it was the Vikings who brought the cat to the Northeastern America (Adalsteinsson and Blumenberg, 1983). The distribution of colour patterns of domestic cats on the East coast of the United States were remarkably similar to the colour patterns of the cats in Iceland, Orkneys, Shetland and other islands where the Vikings had lived. They probably brought live cats on their travels to Vinland (now Newfoundland) presumably as pets, to keep the ship and

BOX 1: Early history of relations between domestic cats and humans

The earliest sign that the cat lived with humans is what appeared to be an intentional burial of a young lybica-type cat in its own small burial pit just 40 cm from the human pit in Cyprus (Vigne et al., 2004). This cat skeleton is dated to about 9500-9200 years BCE.

The area in the Middle East where the domestic cat originated, is considered the cradle of civilization, where man crossed from a collector/hunting culture to cultivate the soil. The most important prey to the cat, like mice and other small rodents, lived well on stores of cereals that humans had cultivated and harvested.

Cats and people had mutual benefit, and in the beginning, this may have been a kind of symbiosis or mutualism. The role of the cats in the lives of the ancient Egyptians is reviewed by Serpell (2014). A 4,000-year-old painting found in the grave of King Baket III depicts the cat while it faces a rat, which indicates that the cat was valued as a rat catcher. 3500-4000 years ago, magic knives of ivory were made with cat figures, to repel poisonous snakes, accidents, and illnesses. The most famous cat god is Bastet, which was associated with fertility, birth, protection and care for children. Originally, she was drawn with a lion head, but about 2700-3000 years ago this was replaced by a cat head.

The famous Greek historian Herodot described the Bastet cult when he travelled in Egypt about 2470 years ago (Herodotus, 1987). When cats that lived in houses with people died, there was great grief in the family. If someone happened to kill a cat, there was great concern. This was a serious crime, and cat murderers risked being lynched.

food supplies free from mice and rats, and when they died, the skin became a valuable commodity.

Near Uppsala in Sweden, a cat tail was found in 2011 at an excavation in a vicarage. It turned out that this was a tail from a domestic cat, and the tail was dated to 520-590 BCE. If this is correct, domestic cats may have lived in Scandinavia much earlier than previously thought. However, the cat tail may have been a gift obtained in Central Europe.

Bones of domestic cats, either *F. lybica* or *F. catus*, were found in two graves in Denmark and Sweden, dated to around 200 CE (Toplak, 2019). The Swedish site was a burial of a rich woman in Varnhem, Västergötland (near Uppsala). The grave goods indicate that the cat was kept by humans already around that time. Around 50 graves with cat bones from the Vendel period (550-790 CE) and the Viking Age have been found in Sweden, of which two-thirds of the cats were males (Andersson, 1993, cited by Toplak, 2019). The domestic cat may first have appeared in Jutland in the second century CE, then spreading to the rest of Scandinavia along with other Roman artefacts. Romans may have dispersed cats along with other gifts for diplomats and regarded cats as prestige objects during the Roman Iron Age before the cats took on other tasks, such as rodent control (Bönnemark 2020). However, there are no proof that such cats existed in Norway that early.

Today, the cat is the most popular mammalian pet in Western Europe and North America. The European Pet Food Industry (FEDIAF, 2022) estimates that in Norway, there were 783,000 owned cats and 490,000 dogs in 2021.

1.1.3 New cat breeds

Most of the domestic cats do not belong to any breed but have retained anatomical and behavioural characteristics from wildcats (Braastad, 2019). Originally, domestic cats were only found with the natural colours: tabby (ring pattern), mackerel (striped) and spotted. These

As a result of the cat being so useful, it was forbidden to export cats from ancient Egypt. Special agents were sent out to buy back and bring home cats that had been illegally exported. However, the cat gradually spread around the Mediterranean.

The domestic cat probably did not originate in Egypt. Various archaeological and historical sources show that domestic cats existed in China at least 5300 years ago (Hu et al. 2014), in the Indus Valley 4100-4500 years ago, in Palestine at least 3700 years ago and in Crete 3100-3500 years ago. The cat came later to mainland Europe, in Greece and southern Italy around 2400-2500 years ago. The Romans used ferrets to catch mice and rats and did not need the cat to catch mice and rats.

In England, cats were first described around 350 CE, and it is estimated that the cat was found throughout Europe and Asia around 900-1000 CE. Cat populations possibly spread with man along commercial trade routes.

Model of the Egyptian god Bastet. Photo: Bjarne O. Braastad

colour patterns give the cat good camouflage, similar to other large cat species, such as tigers (*Panthera tigris*) and cheetahs (*Acinonyx jubatus*). Later, the tortoiseshell cat, the tricolour (orange, black/gray/brown and white) appeared in Turkey. These colour patterns are linked to a sex-linked gene on the X chromosome, the two alleles giving either orange or non-orange (allowing black, grey or brown; Schmidt-Küntzel et al., 2009). The two X chromosomes of females can have both alleles, giving the tricolour (or sometimes multicolour) pattern. Whether the cat is also white depends on other genes. Therefore, tortoiseshells are almost always female cats. The distribution of this type in Europe suggests that the Vikings brought this colour variant on their long ships from Miklagard (today's Turkey area) to Brittany, North England and Scandinavia (Adalsteinsson and Blumenberg, 1983).

The first pedigree breeds of cats were probably the sealpoint Siamese and Persians, which developed several hundred years ago. Genetic studies suggest that the breeds originated from mutations, and not by directional breeding to change the appearance or by crosses with other cats. However, over the last hundred years, several new colour patterns have been developed in these two breeds. Several new cat breeds have emerged as a result of mutations, such as the hairless sphynx or the ragdoll, the latter typically hanging down passively when lifted by humans. Genetic defects can easily occur as a result of mutations and are maintained if the trait becomes popular. The breed standards of many cat breeds, like for dogs, often result in overtyped traits, such as a flat nose or too long coat, which can result in health problems. The Norwegian Animal Welfare Act, § 25[1], requires in its second article that '*Reproduction […] shall not be carried out in such a way that it:*

changes genes in such a way that they influence the animals' physical or mental functions in a negative way, or passes on such genes, reduces the animals' ability to practice natural behaviour, or cause general ethical reactions.

Animals with a genetic constitution as cited in the second article shall not be used for subsequent breeding.'

The popularity of cat breeds has changed over time. Persians are quite persistent, while the Siamese breed has been replaced by other oriental breeds, like the Oriental Shorthair and Balinese. In Norway, currently less than 1% of new-born pedigree cats are Siamese. Maine Coon has become the most popular pedigree breed in Norway, with 26% of the newly registered cats by Norwegian Association of Pedigree Cat Clubs (NRR)[2] in 2021. Other popular breeds include the Siberian Cat (16%), Ragdoll (11%), British shorthair (8.2%), and Sacred Birman (7.8%) of the new cats. 7.2% of new cats registered were of the Norwegian breed Norwegian Forest Cat. Less common breeds include the Neva masquerade (5.3%), Bengal (3.5%), Persian (2.6%), and Devon Rex (1.3%).

[1] https://www.regjeringen.no/en/dokumenter/animal-welfare-act/id571188/

[2] www.nrr.no/opprett_test/statistikk/

1.1.4 Relationship between the cat breeds

Genetic studies of cats worldwide show how the breeds are related (Lipinski et al., 2008; Menotti-Raymond et al., 2008). Norwegian forest cat is closely related to the American Maine Coon, but also to the Siberian Cat. All of these have long fur and are closely related to non-pedigree cats. The oriental breeds Siamese, Balinese and Oriental Shorthair are genetically close to each other, and are currently crossbred and thus considered to belong to the same gene pool. The three oriental breeds are closely related to Sacred Birman and Burmese cats.

Persian is a close relative of Exotic, which is a short-haired Persian type. Bengal is related to Ocicat, which is an American breed. Abyssinian and Somali cats are close relatives, but Egyptian Mau is genetically more distant from these other African breeds, perhaps because they have been bred separately for a long time. Abyssinians are also related to the hairless cat Sphynx, which in turn is closely related to Devon Rex.

The cat breeds can differ from each other also in behaviour, home range sizes and hunting efficiency (Eriksen, 2014; Braastad, 2019), as discussed in later sections.

1.2 Biology of domestic cats

1.2.1 Life history

1.2.1.1 Sexual maturation

Domestic cats usually reach puberty at 4-12 months of age, females usually at a younger age than males (England and von Heimendahl, 2010). Many factors influence the onset of puberty, the most important being breed. In general, Persian reach puberty late and Burmese early, and many shorthaired breeds earlier than long-haired. Timing of birth during the year is important, as kittens tend to come into puberty the following spring, both those born in spring and those born in summer or autumn. However, also body condition, nutrition status and social environment play a role. Puberty occurs when the female kitten reaches a weight of 80% of adult size, which is about 2.3–2.5 kg. During spring, both males and females become restless indicating the approaching heat or rut for males. For females, the heat might be triggered if there are male cats around. If the female is young or has a low social rank in a group, the cat may have a silent heat without the behavioural signs of oestrous but can still become pregnant. Oestrus lasts for 3–7 days and reoccurs every 14-21 days unless the cat becomes pregnant.

1.2.1.2 Fertility

Feral female cats are seasonal breeders and are in anoestrus for 3-4 months during winter (England and von Heimendahl, 2010). Cats usually have two litters per year, one in spring and one in late summer, and there is usually 5 months between the litters. Female cats may occasionally mate again 2-4 weeks after birth and thus become pregnant while still nursing the kittens from their previous litter. Second litters often occur if the first litter was small. The female is most fertile during 1.5-7 years of age but can breed until 8-10 years. Female cats that breed until they are 14 years old have been observed. The litter size is between 1-10 kittens, and most often 3-5 kittens. After 4 years of age, the litters gradually become smaller in numbers.

1.2.1.3 Mating

The male cat will start the courtship by sniffing the female’s head and hindquarter. Mating usually happens several times, and the male therefore stay near the female until a new mating can start - often after approximately 20 minutes. Cats have induced ovulation (Indrebø, 1997), implying that copulation triggers ovulation around 24 hours later. A female cat might mate with several males, and the kittens in each litter might be sired by several males.

1.2.1.4 Gestation period

The average gestation period lasts for 65 days (England and von Heimendahl, 2010), varying from 52 to 71 days. For non-pedigree cats, gestation usually lasts for 57-63 days, while gestation normally lasts for 64-69 days among pedigree cats (Indrebø, 1997). Pregnant cats can be active and hunt. A feral cat will be even more dependent on her hunting skills when she is pregnant, because her energy requirement is increased during gestation. Only towards the end of pregnancy, the female becomes calmer. She sleeps a lot and may hide where she finds it appropriate to give birth to her kittens.

1.2.1.5 Birthplace

When birth is approaching, the pregnant female will start searching for a suitable place to give birth. She favours a dark and quiet place, separate from the activities of people and other animals (Braastad, 2019; Braastad et al., 2022). As it is essential that the offspring are safe against predators and the opening of the nest should be too small for larger predators, like a dog.

1.2.1.6 Maternal behaviour

At birth, kittens weigh on average 110 g, but the newborns might weigh less in some pedigree breeds and in large litters. Growth during the nursing period (usually weeks 0-8) is lower the larger the litter size (Deag et al., 1987), indicating that mother’s milk production is a limiting factor for growth. By about five weeks, the mother may bring live prey (usually mice) to let the kittens practice prey catching. During the first three weeks after birth, the mother initiates nursing. During 3-5 weeks of age, both the mother and offspring might initiate nursing, while during weeks 5-8 milk is given only upon demand by the kittens. Weaning typically happens by week eight (Schneirla et al., 1963). Separation from the mother and the littermates should not be done before at least 14 weeks, because weeks 9–14 are important for social learning for the kittens (Ahola et al., 2017). From 2023, 14 weeks with the mother is a minimum requirement in FIFé (Fédération Internationale Féline) cat clubs including the Norwegian Association of Pedigree Cat Clubs (NRR)[3].

1.2.2 Natural behaviour and needs

In this section we will present selected aspects of the natural behaviour of domestic cats. The focus will be on the needs for activity, social behaviour and spatial behaviour, and the predatory behaviour. A fuller treatment of natural behaviour in domestic cats is presented by Braastad (2019) and Braastad et al. (2022).

The concept of *needs* is important in animal welfare legislation as it is required that the various needs are met. According to the Norwegian Welfare Act[4], § 23, '*The animal keeper shall ensure that animals are kept in an environment which is consistent with good welfare, and which meets the animals' needs which are specific for both the species and the individual. The environment shall give the animals opportunity to carry out stimulating activities, movement, rest, and other natural behaviour. The animals' living environment shall stimulate good health and condition and contribute to safety and well-being. Animals shall have access to suitable and safe shelter outside the normal grazing periods.* …'

Behavioural needs are behaviours that are necessary to (i) *maintain normal physiological and physical states in the animal,* and (ii) *maintain a normal psychological state, with its emotional and cognitive aspects* (Hughes, 1988, conclusion from a consensus meeting).

Examples of physiological/physical needs are the need to find food and water, and then eat and drink, the need to find shelter against bad weather, and the need to perform grooming and other maintenance behaviour. Examples of psychological needs are the needs to avoid adverse stimuli and achieve rewarding stimuli, perform appropriate social behaviour, perform intellectual activity, or play to avoid boredom, and perform behaviours that re-establish or maintain safety for yourself or your offspring. If needs are not met, or access to what is needed is thwarted, the animal will become frustrated. Severe frustrations of natural behaviour and needs may in the long run cause development of mental suffering and behavioural disorders like anxiety, aggression, or stereotypic behaviour.

1.2.2.1 Activity needs

Domestic cats, like most animals, need to move around to develop and maintain a good physical fitness. By motor play, kittens learn how to use their muscles and

[3] http://www1.fifeweb.org/dnld/rules/br_reg_en.pdf

[4] https://www.regjeringen.no/en/dokumenter/animal-welfare-act/id571188/

finetune neuromotor functioning to enable coordinated movements. Kittens need to perform object play, or predatory play, to learn how to hunt prey. This is most pronounced when the cats are 9-21 weeks of age (Leyhausen, 1979). Cats are well-known to perform object play during most of their life.

1.2.2.2 Social needs

Cats are often regarded as a solitary species, but this might not hold in all cases. Many cats, particularly pedigree cats, may be social and function well in multi-cat households. Solitary living may cause suffering for social cats. As a corollary, feral cats may form social colonies of 4-25 adult cats consisting of mainly females and their offspring (Macdonald et al., 2000). Within such colonies, communal breeding and shared nursing is common. Females do not hunt together, but some of them care for offspring while others hunt. Communal behaviours are suggested to be adaptive by means of kin selection, as the cooperating females typically consist of grandmothers, mothers and daughters, and reproduction in these groups is more successful than among solitary cats (Macdonald et al., 2000). Cat colonies may develop where food resources are clumped (Liberg and Sandell, 1988). Although there are aggregations of feral cats in Norway (see 1.3.3), it is unknown whether they cooperate and form such socially structured colonies.

The sociality of many domestic cats is the basis for their successful life with humans. Yet, there is pronounced individual variation in the degree of sociality among domestic cats, and Eriksen (2014) found sociality to be the most important among 22 factors explaining individual variation in behaviour in owned cats.

1.2.2.3 Spatial needs

Cats need sufficient space to perform their natural behaviour and to feel safe from interactions with neighbouring cats and predators. Therefore, cats need to be able to explore their surroundings to check for potential resting and sleeping places, various hunting areas, and to keep an eye, and the smell, of where neighbouring and unfamiliar cats are. Cats may share hunting areas by avoiding contact with each other by using a time-share system where cats learn each other's diurnal rhythm by urine marking on spots along their paths (Leyhausen, 1979). It has been suggested that cats are able to assess the time passed since urine was deposited by analysing the chemical constitution of the urine, as some components are more volatile than others (Leyhausen, 1979).

Cats usually walk in, or close to, forests and other biotopes that provide shelter and almost never in open terrain where they risk attack by foxes, dogs or predatory birds (Braastad, 1980). Cats may hide in trees or in dense vegetation when feeling threatened. In the mating season, adult males (≥ 2-3 years of age) roam across larger areas to seek up oestrus females. Thus, only neutered males, and adult, fertile, females defend territories. The home range sizes resulting from these behaviours are described in section 1.2.4.2.

1.2.2.4 Predatory behaviour

The cat's predatory behaviour has been analyzed by Paul Leyhausen (1979), including comparison with other wild cat species. A summary overview is later given by Fitzgerald and Turner (2000). Domestic cats usually hunt in relatively fixed and confined areas. During hunt, they typically stay within a radius of about 1 km from home, but there are pronounced individual variation. The cat is mainly a nocturnal hunter, but domestic cats can also hunt during daytime, particularly for birds (Figure 3).

Figure 3: Domestic cat with a small bird prey caught during daytime hunting. Photo: Zanna Pesnina – Mostphotos.com

Domestic cats are an ambush predator, patiently waiting for the sight of a prey (Leyhausen, 1979). When a potential prey is detected, the cat moves slowly closer to the prey. As the cat begins to approach the prey, it slowly crawls with its head non-moving and the eyes rigidly fixed on the prey. When the distance is appropriate and the prey is inattentive, the cat runs or jumps rapidly onto the prey and seizes it in its mouth. When the cat is hunting for avian prey, the cat might jump up and catch the bird in the air. The cat will not necessarily kill prey immediately, but might release it and then catch it again, often repeatedly. Female cats (and some males) might bring live prey home to their kittens from around five weeks of age, to give them practice at prey catching. The "kill bite" is therefore somewhat inhibited and has a higher threshold to be triggered, even in cats without kittens at home.

The cat is particularly adapted to hunting small rodents (Figure 4). The most common prey species are mice, rats, small birds, young rabbits, and insects (Fitzgerald and Turner, 2000). Less often, cats prey on large rats, squirrels, big rabbits, hares, ducks, pheasants, fish, frogs, lizards and even snakes. The frequency of prey types will vary among geographical sites and biotopes.

It is estimated that owned cats on average need two to four attacks per successful catch of small rodents and birds and five attacks per successful catch of a rabbit (reviewed by Fitzgerald and Turner, 2000).

Figure 4: Small rodents are the most common prey of the cat. Photo: Lightpoet – Mostphotos.com

1.2.3 Factors influencing variation in-cat predation

Several studies have evaluated kill rates as the number of prey items taken by an individual cat per time unit. Kill rates have often been based on surveys of cat owners from information about the number and type of prey items brought back by the cat. Other field studies have used tracking devices or mounted cameras on the cat to study their hunting behaviour. Tracking studies generally reveal that cats are killing and consuming more prey than they bring back to the doorstep, which we discuss further in later sections.

1.2.3.1 Age variation in predation

Age contributes to individual variation in predatory behaviour in cats. Some studies have reported that younger adults take more prey than older adults (Barratt, 1998; Churcher and Lawton, 1987). Churcher and Lawton (1987) reported that cats younger than 5 years old brought home most prey. Similarly, an unpublished survey of Norwegian cat owners (N = 1425 cats) showed a gradual decrease in the frequency of bird predation during summertime after a cat reached 4–5 years of age (Kulemann and Dangstorp, 2019b). A similar effect was not found for rodent prey, indicating that catching birds require higher skills than catching small rodents. In contrast to the research discussed above, other studies found no significant differences in predation behaviour for cats of different age (Calver et al. 2007, Tschanz et al. 2011). In Finland, Kauhala et al. (2015) found that the "super predators" were typically middle-aged and old cat individuals. Although there are few studies on predation that separate cat-age, age-specific variation in kill rates is important to consider when assessing the impact of individual cats.

1.2.3.2 Sex variation in predation

Female cats catch more prey than male cats, particularly when breeding (reviewed by Fitzgerald and Turner, 2000). When nursing a litter, the mother will need up to four times her normal prey biomass (Leyhausen, 1979). Males are typically larger than females, and it has been suggested that they are able to prey on larger prey than females, like lagomorphs and pheasants (Fitzgerald and Turner, 2000). In some studies, male cats are found to have more diverse diets than females, both because they have a larger body and larger territories where they might encounter a broader spectrum of prey (Fitzgerald and Turner 2000). Male cats also have broader heads than female cats, and Yip et al. (2014) found a correlation between diet diversity and cat head width.

1.2.3.3 Breed variation in predation

Pedigree cats are often poor or uninterested hunters, although some individuals may have excellent hunting skills. A small but significant breed variation in predatory behaviour was reported by Eriksen (2014), based on data from cat owners observing cats that had hunting opportunities. The highest frequencies of predatory behaviour were reported for Egyptian Mau, Abyssinian, Burmese, Bengal and the forest breeds Norwegian Forest cat, Maine Coon and Siberian cat. The breeds Oriental, Persian, Birman and Siamese cats engaged less in predatory behaviour. The same breeds as above were also reported by their owners to show interest in birds outside the window, while Persian, Birman and Siamese were the least interested. Many Siamese cats have a weaker stereoscopic depth vision compared to house cats, because the breed has a genetic predisposition to be cross-eyed (Guillary et al., 1974; Kaas, 2005). These cats may be expected to have a handicap when it comes to prey catching. Because Siamese and some other oriental breeds are crossed and belong to the same gene pool, the same issues with depth vision might relate to other breeds.

1.2.3.4 Time of day variation in predation

It has been reported that cats that are out during the night take more prey compared to cats that are not outside during night (Barratt, 1998). Cats were reported to catch more birds and small rodents the longer time the cats spent outdoor, both day and night (Kulemann and Dangstorp, 2019a). This is discussed further in section 1.2.4.1.

1.2.3.5 Variation in prey brought home

Many cats bring some of their prey home for later consumption or to be eaten by kittens or other cats in the household. It might also be that cats consider the prey as food for their owners. The fraction of caught prey brought home is uncertain. Several studies have found that only a few individuals bring home the majority of caught prey (reviewed in Kauhala et al. 2015). This is discussed in more detail in section 3.1.3.1.

1.2.4 Behaviour of owned cats

1.2.4.1 Average time spent outdoors

In a study of owned cats (*N* = 5129) in Europe (mainly UK), USA, Canada, Australia and New Zealand, owners reported that 59% of the cats had a combined indoor-outdoor lifestyle, while the remaining 41% were only kept indoors (Foreman-Worsley et al., 2021). An indoor-outdoor lifestyle was more likely for cats that were owned by owners who were 46 year or older, for male cats, for cats 7-14 years of age, and for cats living in rural areas. Moreover, cats in Europe have a higher probability to follow an indoor-outdoor lifestyle compared to the other countries in the survey, with 70% of the cats allowed outdoors. In a Norwegian survey (*N* = 1212 owned cats), approximately 81% of the non-pedigree cats, 42% of forest breeds and 17% of other breeds (yielding a combined estimate of 24% for all pedigree cats) were allowed to roam freely outdoors (Table 1) (Eriksen, 2014). Among non-pedigree cats allowed outdoors, 25% could freely walk in and out by a cat flap, while 75% were let in and out by the owner family. The relative frequency of cat flaps was higher among the forest breeds allowed outdoors (38% vs. 62% let in and out by owner). In households using a cat flap, cats probably go more out during night than other cats, but there is not published research on this topic.

Table 1. Percentages of Norwegian domestic cats in various indoor-outdoor lifestyles, for non-pedigree cats, forest breeds and other cat breeds (Braastad 2019, calculated from dataset of Eriksen, 2014, *N* = 1212).

Living arrangements / type of cat	Non-pedigree cats	Forest breeds	Other breeds
Number of individuals in study	*N* = 701	*N* = 173	*N* = 338
Allowed free-roaming outdoors	81%	42%	17%
In a large outdoor enclosure (> 10 m^2)	0.4%	24%	12%
In a small outdoor area (< 10 m^2)	6%	17%	22%
Outdoors with the owner only	2%	3%	18%
Outdoors on leash with the owner	3%	9%	15%
Only indoors	7%	5%	15%

Kulemann and Dangstorp (2019a) reported how many hours per day cats spent outdoors, in five-time intervals: 0, 0–3, 3–5, 5–10, and >10 hours per day. This study was made on cats that had access outdoors (Table 2). Pedigree cats were generally less outside than non-pedigree cats, particularly during winter.

Table 2. Number of hours per day cats are allowed to roam freely outdoors during summer and winter, among cats recruited to the study for being allowed outdoors (*N* = 1208 cats; data from Kulemann and Dangstorp, 2019a).

Time per day let outdoors	Summer half-year	Winter half-year
> 10 hours	44.5%	4.9%
5–10 hours	36.8%	23.3%
3–5 hours	12.5%	27.8%
0–3 hours	4.1%	39.8%
Never went out	2.1%	4.1%

In an earlier report on 585 cats in Norway, cat owners estimated that their house cats spent on average 11.0 (*SD* = 0.4, *N* = 230) hours per day outside during summer. Siamese cats were reported to spend 5.3 hours (*SD* = 0.5, *N* = 146) outside during summer, and Persian cats 5.0 hours (*SD* = 0.5, *N* = 149) (Westbye, 1998). During winter, the corresponding times spent outside were 2.9 hours (*SD* = 0.2), 0.5 hours (*SD* = 0.2) and 0.6 hours (*SD* = 0.2), for house cats, Siamese and Persian cats, respectively. Note that staying outside in this study could include cats being kept in an outdoor enclosure or walked on leash by the owner. Use of enclosures or leashes were uncommon for house cats in Norway, affecting only about 5% of house cats in Eriksen's study (2014).

1.2.4.2 Average home range size

Individual variation in home range sizes is pronounced among owned domestic cats, and the variation is related to a range of ecological factors and individual characteristics of the cat (reviewed by Liberg et al., 2000, see also Thomas et al. 2014). Intact (non-neutered) males have on average three times larger home ranges than females (range 0.72–620 hectares among study averages, individual variation: 0.08-990 ha). In rural Skåne, Sweden, with a mixture of owned and feral cats, average home range sizes were 370 ha in males and 50 ha in females (Liberg 1980, 1981, 1984a and 1984b). The large male home ranges (particularly among dominant males) overlap with that of several fertile females, and males maximize courtship and mating possibilities during the mating seasons. The home range size of neutered males is more similar to that of females, but not all neutered males have smaller home ranges (Bachmann, 2020; Bischop et al., 2022). Home ranges may overlap widely among cats of the same sex, as individuals may use the same hunting areas at different times of the day (Leyhausen, 1979).

Home ranges are often larger in rural than in urban areas. For instance, in a small Norwegian study of 111 owned cats, the average home range size was 6.2 ha in rural areas versus 2.2 ha in urban areas (Bachmann, 2020). Female home ranges vary between an average of 0.27 ha in a city (Jerusalem: Mirmovitch, 1995) to 170 ha in the Australian bush (Jones and Coman, 1982). Home ranges also vary in relation to cat population density, and Liberg et al. (2000) reported a negative relationship between home range sizes and cat densities, both in males and females. The relationship was stronger in feral cats compared to owned domestic cats. The authors believed that, in females, both factors were explained by the abundance and distribution of food or prey, although this was usually not reported in the studies reviewed. When food or prey occurred in patches on Galapagos Islands, cats moved further than when food resources were more evenly distributed (Konecny, 1983, cited by Liberg et al., 2000).

Average roaming distance (i.e., distance from home) is reported in a Norwegian study on 92 cats to be 50 m (range 4-881 m), but only three cats roamed on average more than 250 m (Prestmoen, 2022). The maximum roaming distance in this study was on average 352 m (range 48-3384 m). Owned cats typically spend most of their time outdoors in a home spot, such as the garden of the owner. In one Norwegian study on 92 cats in Ås, most cats spent 80-90% in a preferred place, and on average this was located about 60 meters from home (Prestmoen, 2022). Cats spent on average 79% of their outdoor time within 50 meters to their home (Bishop et al., 2022). A study of 111 owned cats in a wider area of Central Eastern Norway found that the cats remained stationary for 63% of the time spent outdoors and roamed for 37% of the time (Wu, 2020). Home ranges are typically smaller in older cats (7-8 years old and older), and older cats also roam across shorter distance than younger cats (Hall et al., 2016; Bachmann, 2020).

1.3 Cats in Norway today

1.3.1 Number of domestic cats

Estimates of number of domestic cats in Norway have been made by various polls during the last decades. In 2001, the poll company "Opinion" made phone interviews with 2000 people nationwide on the keeping of companion animals. They estimated that the national population of owned cats was *ca*. 535,000 animals (Mejdell, 2003). When assessing the frequency of cat keeping in Norwegian households, it must be kept in mind that the number of households is increasing. The survey from 2001 was based on a total of 2,050,000 households in Norway, while there were 2,512,000 households in Norway in 2021 (www.ssb.no/familie), which is a 22.5% increase. A corresponding increase in the number of cats from 2001 to 2021 would extrapolate to 655,000 cats in 2021.

Based on surveys made by Euromonitor, the cat population increased from 622,000 in Norway in 1999 to 683,000 in 2004 (reported by Olsen, 2005). The European pet food industry (FEDIAF) regularly publishes estimates of pet populations based on national surveys. Their estimated numbers of owned cats in Norway were 767,000 in 2014, 770,000 in 2016, 750,000 in 2017 and 2019, 770,000 in 2020 and 783,000 in 2021 (FEDIAF, 2022). DyreID, which handles the registry of microchip ID of cats and dogs in Norway, estimated the cat population in 2021 to be 620,000, based on a weighted average of TNS Gallup's Consumer & Media polls in 2016, 2019 and 2021 (Kjæledyrrapporten 2022). In this report, it was estimated that 47,200 kittens from owned cats are born annually in Norway. The report shows that there was an increase during the covid-19 pandemic but is now back to earlier rates. About 81% of the kittens are microchipped and entered into DyreIDs database.

Across different surveys, the estimated percentage of households having at least one cat differs. In 1994, a poll of 1514 persons made by SSB estimated that 17% of the households had at least one cat (Kristiansen, 1994). In the 2001 Opinion survey (see above), it was estimated that 379,000 households had cats (representing *ca*. 18% of all households). Among all households that reported having a companion animal, 50% had cats. According to DyreID's report "*Hund og katt – populasjon og grad av marking"* (2020) from 2019, 18% of Norwegian households had a cat, based on TNS Gallup's Consumer & Media poll. In 2020, FEDIAF estimated that 17% of Norwegian households kept at least one cat (FEDIAF, 2021). In contrast with these polls, in 2014, Euromonitor estimated that 36% of Norwegian households had cats (Euromonitor International, 2016). The data behind the latter estimate are unknown.

Although it appears that cat keeping in Norway has increased during the last decades, the pronounced discrepancies between estimates made by Opinion and SSB on one side, and the pet food industry on the other side, indicate that these numbers must be treated with caution. An average of the various estimates indicates about 686,000 owned cats in Norway in 2021 (Table 3), yielding an average of 0.27 cats per households. The demography of domesticated cats in Norway is further elaborated in section 1.3.4.

Table 3. Number of owned cats in Norway in 2021, as estimated by various polls and methods.

Source	Estimated number of owned cats
FEDIAF	783,000
DyreID / TNS Gallup (2021)	620,000
Opinion, 2001, extrapolated to 2021 by increase in no. of households	655,000
Average of estimates for 2021	686,000

1.3.2 Number of pedigree cats

Norwegian Association of Pedigree Cat Clubs (NRR) publishes yearly statistics of newly registered pedigree cats. In the years 2018-2021, 3710, 4332, 4592 and 4850 cats were registered, indicating an increase during the last years. The newly registered cats are mainly kittens born in Norway, but the numbers include 353, 220 and 224 (in 2019-2021, respectively) imported cats. Breed distribution is presented in section 1.1.5. To estimate the total population of pedigree cats registered in NRR, we can use age distributions of pedigree cats presented in a project report on the demography and predatory behaviour of cats, which was based on an online survey to Norwegian cat owners (Kulemann and Dangstorp, 2019a). The questionnaire link was distributed in several Facebook groups for cat owners. Responses were obtained for 1208 non-pedigree cats (85% of the sample) and 217 pedigree cats (15% of the sample) in Norway. Because the respondents probably were particularly interested in cat keeping, pedigree cats may have been heavily overrepresented in the sample. The pedigree cats were from 36 breeds with a breed distribution close to the distribution registered by

NRR. The pedigree cats were on average 5.6 years of age (*SD* = 3.9, range 1–19 years).

Calculations based on yearly numbers of newly registered pedigree kittens during 2003– to 2018, and age distribution of pedigree cats (Kulemann and Dangstorp, 2019a), reveal an estimate of 26,786 pedigree cats registered by NRR and alive by October 2019. During 2019 to 2020, the 16-year group (now 2005–2020) has increased by 7.35%, giving an estimate by autumn 2021 of 28,757 pedigree cats from 1 to 16 years of age, registered by the largest pedigree cat organization in Norway, which is the national member of FIFé. Many people have unregistered, alleged pedigree cats, or cats registered by the international cat organisations TICA, CFA or WCF. It is difficult to estimate the numbers of these cats, but a conservative estimate would imply a total number of pedigree cats in Norway to be around 40,000. The combined estimates suggest that there are around 660,000 non-pedigree cats and 40,000 pedigree cats in Norway by 2021.

1.3.3 Number of feral cats

There have been no systematic surveys of feral cats in Norway. However, a survey was sent to all 200 district veterinarians in Norway in 1999 on the magnitude and problems related to feral and stray cats in their district (Eierløse/forvillede Katter – Problembeskrivelse og forslag til løsninger, Utredning fra en tverrfaglig arbeidsgruppe oppnevnt av Statens dyrehelsetilsyn (Ownerless/Feral cats – Problems and Solutions; Report to the Governmental Animal Health Authority), 2001). The magnitude of the phenomenon was reported as "no or small" in 41% of the districts, "moderate" in 46% and "large/pronounced" in 13% of the districts (*N* = 165 of the 200 districts answered). Districts with large occurrence of feral cats included Lillehammer, Gausdal, Øvre Hallingdal, Drammen, Larvik, Porsgrunn, Nedenes, Holt, Kristiansand, Lindesnes, Mandal, Karmsund, Stavanger, Bergen, Sotra, Volda, Ørsta, Averøy, Orkdal, Trondheim, Snåsa, Bodø, Vågan, Lødingen, Målselv and Vadsø. The responses indicate that most parts of Norway were represented. Oslo and Follo did not respond.

Animal welfare organisations have scattered information of local populations of feral cats in areas of particular concern. In 2021, members of the project group for this report obtained a list of such local overviews from the Norwegian Society for Protection of Animals (Dyrebeskyttelsen), a national animal welfare organisation with 25 regional branches. During 2020 and until 1st of August 2021, 11 of the 25 branches of Dyrebeskyttelsen reported back to the project group. Numerous colonies consisting of 5-100 feral and stray cats were reported. Seven of the branches reported an estimate of the number of feral cats in their area, and the sum of these seven estimates was 24,000. The 11 branches that reported back to the project group had caught and helped about 4,370 cats in 2020 and the first seven months of 2021. In total, during 2021, Dyrebeskyttelsen Norge reported having handled (captured, treated, and rehomed or euthenized) about 5,560 homeless (including both stray and feral) cats[5]. This accounts for 88% of all homeless animals handled by this organization.

If the number of feral and stray cats was evenly distributed among those branches that report numbers and those that did not, we estimate the presence of about 54,000 feral and stray cats in the areas of these 25 branches. Nevertheless, many regions of Norway are not covered by surveillance of feral and stray cats by animal welfare organizations. These organizations typically state the total number of such cats in Norway to be 50,000-100,000. For estimates of predation of wildlife by feral and stray cats in Norway, VKM will use 50,000-100,00 such cats as a rough an estimate in this report.

According to the Dyrebeskyttelsen, colonies of feral cats consist of individuals of both sexes, but in general feral cat colonies appear to have female –biased sex ratios. The cat colonies might be self-sustaining with kittens being born regularly. The larger colonies (>20 cats) are predominantly located around waste disposal facilities and fish landing facilities, but smaller colonies (<20) are also found in private homes or farms. Regardless of size and location, the individuals living in these colonies are often characterized by poor body condition, indicating that their welfare is at risk[6].

1.3.4 Demography of domesticated cats in Norway

1.3.4.1 Sex distribution

Sandem (1998) reported 50.5% males (N = 398 cats), Westbye (1998) reported 50.6% males (N = 585), Eriksen (2014) reported 50.0% of each sex (N = 1204 cats), while Kulemann and Dangstorp (2019a) reported 52.6% males (N = 1425 cats). Combined, these studies report 51.2% males and 48.8% females (N = 3612).

1.3.4.2 Age distribution

The estimated average lifespan of domestic cats in Norway is 14 years, with estimates varying between 12–15 years among different reports (Kjæledyrrapporten 2022). A caveat with most Norwegian studies on cat behaviour is that they ask the owner with more than one cat to answer about a cat that is closest to 4 years of age. Thus, the only reliable results for age distribution for cats in Norway is from Kulemann and Drangsholt (2019a) (Figure 5). They reported an average age of 7.1 (SD = 4.4, range 0–21) years for non-pedigree cats and 5.6 (SD = 3.9, range 1–19) years for pedigree cats that were allowed outdoors. Kittens were not included in this study. Figure 5 illustrate the age distributions of males and females. 4% of the females and 2.6% of the males were ≥ 15 years of age. Among the non-pedigree cats, 42.8% were ≤ 5 years of age, while this was 60.8% among the pedigree breeds.

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[5] https://www.dyrebeskyttelsen.no/hjemlose-dyr/

[6] https://www.dyrebeskyttelsen.no/2021/10/13/hjemloshet-offentlige-utredninger-tomme-ord-og-brannslukning/

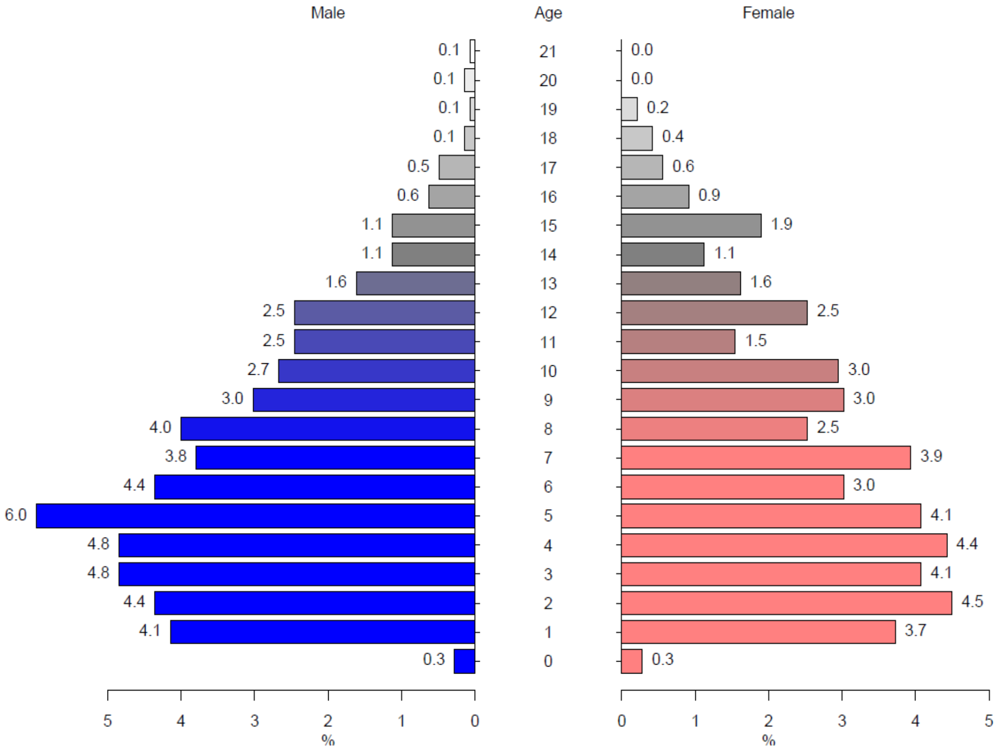

Figure 5. Age distributions of male and female Norwegian cats, among those that are allowed outdoors (*N* = 749 males and 674 females, percentages shown). Source: Kulemann and Dangstorp, 2019a.

1.3.4.3 Proportion of intact and neutered cats

A survey of Norwegian cat owners revealed that 81% of cats (*N* = 1204) were neutered in a survey consisting of 61% non-pedigree cats and 39% pedigree cats (Eriksen, 2014). In another survey restricted to cats allowed outdoor access (*N* = 1425), 96% were reported neutered and 4% were intact (Kulemann and Dangstorp, 2019a). In the latter study, 3.1% of non-pedigree cats and 7.8% of the pedigree cats were intact. An earlier study (*N* = 405), of which 22.7% were non-pedigree cats and 77.3% pedigree cats, reported only 48.9% of the cats to be neutered, although an unknown number of females were given contraceptive pills (Sandem, 1998). These results indicate that an increasing proportion of cats have been neutered during the last two decades (1998-2019).

1.3.4.4 Urban-rural gradient and house type in cat demography

There is regional variation in cat ownership within Norway. In 2001, it was estimated that 23.7% of households in Southern Norway had cats, 20.0% of the households in Western Norway, 19.2% of the households in Northern Norway, 18.1% of the households in Trøndelag, 13.7% of the households in Oslo and Akershus, and 17.8% of the households in other parts of Eastern Norway (calculations based on figures in Mejdell, 2003; N≈370 cat owners).

Table 4 presents data on the frequencies of cats in various urban/rural areas, house types, and whether the cats have access to indoor cat toilets (Braastad, 2019).

Table 4. Living conditions and environmental factors among non-pedigree cats, forest cat breeds (Norwegian Forest Cat, Maine Coon and Siberian Cat) and other breeds (*N* = 1212 cats). The figures are percentages within the breed groups. (Braastad 2019, calculated from updated dataset of Eriksen, 2014).

Living arrangements / type of cat	Non-pedigree cats	Forest breeds	Other breeds
Number of individuals in study	*N* = 701	*N* = 173	*N* = 338
Area type			
Living in a city	26%	32%	49%
Living in a village	37%	41%	31%
Living in rural areas	37%	27%	20%
Housetype			
Living in a block apartment	13%	13%	31%
Living in a villa	38%	53%	36%
Living in a terrace house	18%	19%	12%
Living on a farm	13%	7%	7%
Other	18%	8%	14%

1.3.4.5 Number of cats in the household

In a survey of cat owners from 2014 (*N* = 1204 cats), it was reported that 29% of the cats lived without other cats, 32% of the cats lived with one other cat, 16% of the cats lived with two other cats, while 22% lived with ≥ 3 cats (Eriksen, 2014). Among the non-pedigree cats, the number of cats in the household was on average 2.15 (*SD* = 1.4) cats. A study from 1997 on 405 cat owners reported an average of 2.4 cats per household when two extreme outliers were excluded (Sandem, 1998). A survey made in 2001 by Opinion involving 370 cat owners among 2000 random households, reported an average of 1.4 cats per household that had at least one cat (Mejdell, 2003). Sandem's (1998) study showed that 29% of households that had cats also had other pet species. In Eriksen's study (2014), the percentage of cat households that also have dogs were 25% for non-pedigree cats, 27% for forest cat breeds and 22% for other cat breeds.

1.3.4.6 Owner attitude of cat lifestyles and predation

In a Norwegian study by Kulemann and Dangstorp (2019a), 1425 cat owners were asked about their attitudes to wildlife hunting by their indoor-outdoor cat, indicating their agreement with four different statements. A slight majority (54.6%) reported a positive attitude to hunting by cats: 33.7% agreed that '*Predatory behaviour is important to the welfare and natural instincts of the cat, and should therefore not be regulated*', while 20.9% agreed that '*It is important that the cat catches pests (small rodents). Birds that are caught have little impact on Norwegian bird populations*.' On the other hand, 21.0% agreed that '*I dislike that the cat hunts, but I do not know how to limit it*.' And 14.0% agreed that '*I try to keep the cat indoors in the early morning, at night, and in the birds' breeding season (May/June) to minimize hunting opportunities on birds*.'. The remaining 9.8% were unsure. These responses are in line with what is reported by Crowley et al. (2019), based on qualitative interviews with 48 English cat owners.

As shown in an international study, middle-aged or older cat owners are more prone to let their cat have a combined indoor-outdoor lifestyle, compared to those under 45 years of age (Foreman-Worsley et al., 2021). Foreman-Worsley et al. also found that road traffic accidents were the major concern for owners of cats kept only indoors in Europe, USA or Canada, Australia or New Zealand, while protecting the cat from unfamiliar people was the second most important concern. North-American cat owners kept cats indoors mainly to protect them from wildlife, while Oceanian cat owners kept cats indoors more often to prevent them from hunting wildlife. Owners who provided outdoor access did so mainly for the mental well-being of their cat. These owner attitudes show that cat owners are a highly diverse group in terms of their attitude to cat predation of wildlife species. Owner attitudes are important to keep in mind when considering implementation of mitigating measures.

1.4 Impact of cat predation on biodiversity

1.4.1 Mechanisms behind negative impacts on biodiversity from cat predation

Predation can affect populations of wildlife species through two main mechanisms. First, direct or lethal effects from predation is defined by the process of capturing and killing (and often consuming) the prey. Such direct lethal effects have received considerable attention in ecological literature. Second, indirect or non-lethal effects from predation can occur when the prey population change behaviour and/or demography as a response to the predation risk associated with presence of predators.

Direct lethal effects from predation have been a focal point for research in ecology for decades. Seminal work in the 1940s and 1950s by C.C. Holling (Holling 1959) made clear how the impact of predation relies both on the *functional response* or the relationship between prey density and kill rates, and the *numerical response* in the predator population to changing prey density. Because owned cats are generally fed cat food, changes in the number of cats in response to changing prey density is not relevant. In such a system where the predator population can survive, persist and even expand at low prey density, the potential for a negative impact is very high (Nilsen et al. 2009 and Maeda et al. 2019). In such cases, the impact will depend on the number of prey each individual captures and kills per unit time, mechanisms that determine prey selection and the density of prey. The impact can be expected to be highest on prey species with low density, unless they are actively avoided as prey species by the cats. When evaluating the potential impact on biodiversity due to cat predation, knowledge about the cat density, the number of prey captured by one individual cat allowed free-roaming, their prey selection, as well as the density of the focal prey species must be considered.

When evaluating the effects of direct predation on prey populations, a key aspect is the extent to which losses to predation are additive or compensatory to other sources of mortality. If cat predation has additive effects on mortality, survival probabilities will be suppressed by predation, potentially reducing the population growth rate (Errington 1967; Peron 2013). Conversely, if the predation mortality is compensatory, mortality from other sources will decrease as predation mortality increases so that overall survival probabilities do not change (Errington 1967; Peron 2013). In such cases, predation is not expected to effect prey population dynamics and abundance. Several different mechanisms can increase the chances that predation mortality is compensated, including density dependent effects, heterogeneity among individuals in the prey population and prey abundance (Peron 2013). In addition, compensation is more likely for prey species with fast life histories (high reproduction and low survival) (Peron 2013). In addition to direct compensation caused by compensatory mortality, predation can also be compensatory if increased predation mortality results in increased reproductive output and recruitment, often caused by density dependent factors. While it is well known from ecological literature that knowledge about such mechanisms is pivotal when making assessment of the effects of predation in natural systems, the nature of the predation is still a contentious issue in the cat literature (Beckerman et al. 2007; Baker et al. 2008; van Heezik et al. 2010). For example, Selås (2011) argued that cat predation has little effect on most Norwegian bird populations because bird numbers are limited by habitat availability, food and climate, and not by predation. This would result in compensatory predation. On the other hand, Loss and Marra (2017) argued that there is unequivocal evidence that cats can affect population sizes of many vertebrate species across the world, implying that predation is (mostly) additive.

Although there has been much focus on number of birds killed by cats, cats can also affect birds and other prey species through indirect effects, such as risk-mediated behavioural effects, sub-lethal effects, and a range of non-consumptive effects of predators (Perkins et al. 2021). Due to evolved responses to reduce predation risk, prey individuals may alter their behaviour in the presence of predators (Lima and Dill 1990; Eggers et al. 2006; Fontaine and Martin 2006; Cresswell 2008), and predator avoidance may also have consequences for reproductive rates (Eggers et al. 2006; Fontaine and Martin 2006; Zanette et al. 2011). Simply by observing cats in their territories or home ranges, birds may for example increase anti-predator behaviours, such as vigilance and alarm calling, reduce feeding rates of offspring, or change habitat use or abandonment of a nest to reduce predation risk (Bonnington et al. 2013; Medina et al. 2014; Loss and Marra 2017). While behavioural effects are well documented, there is a lack of studies documenting non-lethal effects and potential reductions in population growth rates in vertebrate populations (Beckerman et al. 2007). A review of predator-prey interactions mainly focusing on invertebrates indicated that non-lethal effects may even be greater than direct mortality (Preisser et al. 2005). On the other hand, the role of non-lethal effects of predators on vertebrate population dynamics remains controversial and inconclusive (Sheriff et al. 2020).

Cats may also affect wildlife populations through competitive interactions, mainly induced by competition for shared food resources (George 1974; Medina et al. 2014). In cases where food is a limiting factor for wildlife species, such intraguild competition might directly affect the demography, population dynamics and abundance of wildlife populations (Wiens 1993). When competition occurs directly over food, it is termed *exploitation competition*, whereas *inference competition* occurs when one competitor limits another species' use of the resource (Wiens 1993). There are currently few direct assessments of competition between cats and wildlife species in the published literature (McDonald et al. 2018, Roshier and Carter, 2021, but see Biró et al. 2005 and Germain et al. 2009 for dietary overlap with the European wild cat in Hungary and France, respectively). Exploitation competition is most likely to occur among species with overlapping niches. Thus, competition between domestic cats and wildlife is most likely to occur among species that share prey preferences with the cat, and in cases where cats suppress abundance of the shared prey species. Competition is addressed further in section 4.1.7.

Finally, cats can potentially reduce predation by other species by preying on potential predator species, known as trophic cascade effects. For instance, Dickman (2009) found a strong negative relationship between predation rates on artificial nests and cat densities in Victoria (Australia) with less nest loss where cats were abundant. Dickman argued that cats reduces nest predation by removing introduced rats and other nest predators. A similar conclusion was reached by Courchamp et al. (1999), that used theoretical models to show that cats could potentially protect birds by keeping other nest predators, such as rats, at low numbers. There is little direct field evidence for these mechanisms about cats (except for a few island cases; Courchamp et al. 1999), though a study of coyotes (*Canis latrans*) documented that control of middle-sized and small predators may be beneficial for birds (Crooks and Soulé 1999).

1.4.2 An international perspective on impacts of cat predation on biodiversity

The effects of domestic cats on biodiversity have received global attention, and several studies have reported that a high number of wildlife is being killed by cats annually. For instance, it has been estimated that cats kill between 1.3 – 4.0 billion birds and 6.3 – 22.3 billion mammals annually in US alone (Loss et al. 2013). Loss states that "free-ranging cats are the single largest anthropogenic source of mortality for US birds and mammals". The total impact of cat predation on biodiversity is however a contentious issue, in part due to difficulties in establishing causal effects, as discussed in the previous section. However, it is well known that invasive predators can have dramatic effects on local biodiversity, and according to Doherty et al. (2016) thirty species of invasive predators – including domestic cats - have cumulatively been implicated in the extinction or endangerment of more than 700 species of vertebrates globally, contributing to 58% of all bird, mammal and reptile extinctions. In the Global Invasive Species Database (Invasive Species Specialist Group 2021), cats are listed among the 100 invasive species with greatest negative impacts on native animals. Globally, cats are implicated in the extinction of 40 of 87 extinct bird species, 21 of 45 extinct mammal species and 2 of 10 extinct reptile species (Doherty et al. 2016). The estimates of extinction ranked cats among the top three invasive species in terms of causing vertebrate extinctions or population declines (Doherty et al. 2016). Species living on islands were at greatest risk, but few bird species in Europe were at risk (Doherty et al. 2016)). Medina et al. (2011) reported that 123 bird species on islands around the world have been impacted by cats, and that cats contributed to the extinction of 22 bird species on islands.

Most of the compelling empirical evidence about negative impacts of free-ranging cats on wildlife comes from islands (Nogales et al. 2014, CABI 2021). For mainland ecosystems, the empirical evidence is more mixed and with less consensus. Open systems in mainland areas are often more complicated to study, and documentation of negative effects often requires substantial data on both predators (here, feral and owned cats), predator behaviour and prey abundance. In their review of the literature about cat predation in mainland ecosystems, Loss and Marra (2017) argued that ample observational evidence is available from such systems. Experimental evidence has also shown that cats can cause (local) extinctions, but because these experiments were carried out in enclosures it is unclear if the results can be directly transferred to open populations (Loss and Marra 2017, Frank et al. 2014). When discussing negative effects from cats on bird populations in UK, The Royal Society for the Protection of Birds (2021) argued that there is no clear scientific evidence that cat predation causes bird declines in UK. They argued that mortality from cat predation is mainly compensatory, and that the species that have declined most severely rarely encounter cats. Specific examples were that skylarks (*Alauda arvensis*, sanglerke), tree sparrows (*Passer montanus*, pilfink) and corn buntings (*Emberiza calandra*, kornspurv) have undergone serious declines, but rarely encounter cats.

In addition to prey individuals that are directly killed, a high number of individuals are not killed immediately in the attack but might be injured. For instance, records from the Wildlife Center of Virginia (WCV), a wildlife rehabilitation facility, identified that interactions with cats represented the fourth leading cause of admissions for wild birds, and the second leading cause of injuries for mammals admitted to the WCV over a 10-year period.

1.4.3 Impacts on birds globally

1.4.3.1 Number of birds killed by cats in different parts of the world

Across studies from different parts of the world, it has been reported that domestic cats and feral cats kill billions of birds annually (Table 5). Estimates of birds killed from these studies are based on a variety of methods. Some of the studies estimated the number of birds killed based on the number of prey items returned home and recorded by the cat owners (May 1988; Svensson 1996; Michaelsen 1998; Woods et al. 2003; Kauhala et al. 2015). However, several studies have shown that a proportion of prey killed were not brought home (George 1974; Kays and DeWan 2004; Maclean 2006; Krauze-Gryz et al. 2012; Loyd et al. 2013a; Barmoen 2016; Seymour et al. 2020). A further bias of most studies is that cats kill more animals than they consume (Loyd et al. 2013a). In addition, only a few studies incorporate mortality from stray and feral cats. Thus, the figures presented in Table 5 will in some cases underestimate the true kill rates by cats, unless such biases are accounted for.

Table 5. Estimates of number of birds killed (95% CI in brackets) by cats per year in different studies across the world, ranked according to number of birds killed.

Country	Number of birds killed	Type of cats	Source
China	2.7–5.5 billion	feral and owned	Li et al. 2021

Country	Number of birds killed	Type of cats	Source
US	2.4 (1.3–4.0) billion	feral and owned	Loss et al. 2013
Australia	272 (169–508) million	feral	Woinarski et al. 2017
Canada	204 (105–348) million	feral and owned	Blancher 2013
Poland	136 (104–171) million	owned	Krauze-Gryz et al. 2018
Colombia	7 (3-12) million	owned	Sedano-Cruz 2022
Australia	118 (58–248) million	owned	Legge et al. 2020
Netherlands	35 million	feral and owned	Knol 2015
Sweden	10 million	domestic	Svensson 1996
Norway	7 (2–20) million	feral and owned	Heggøy and Shimmings 2018
Norway	3.3 million	owned	Michaelsen 1998
Norway	1.2–4.8 million	owned	Braastad 2011
Switzerland	1.2–3.6 million	owned	Tschanz et al. 2011
Finland	> 1.7 million	owned	Kauhala et al. 2015
South Africa[1]	0.45 million	owned	Seymour et al. 2020

[1] Only in Cape Town

1.4.3.2 Diversity and characteristics of birds killed by cats

Many bird species are killed by cats in Europe (Table 6). However, some species are more at risk than others. Species that are most vulnerable to cat predation include those that (Blancher 2013, Woinarski et al. 2017b) feed on the ground (Blancher 2013; Woinarski et al. 2017b; Pavisse et al. 2019), sing close to the ground (Møller et al. 2010), live solitarily (Møller et al. 2010), weigh less than ca. 100 g (i.e., small and medium-sized birds; Møller et al. 2010; Bonnaud et al. 2011; Woinarski et al. 2017b), and use habitats close to humans, including bird feeders (Blancher 2013; Mori et al. 2019). Based on three European studies, the house sparrow (*Passer domesticus*, gråspurv) was the most common species taken by cats (Table 7).

Table 6. Number of bird species recorded killed by cats across Europe, listed alphabetically by country. Studies differ widely in relation to how data were collected (prey returned to owner, ringing recoveries), how many cats were studied, and the time cats were studied.

Country	Number of bird species reported killed	Source
Finland	29	Kauhala et al. 2015
France and Belgium	37	Pavisse et al. 2019
Italy	99	Mori et al. 2019
Netherlands	33	Knol 2015
Norway	113	Heggøy and Shimmings 2018
Norway	2+	Barmoen 2016
Sweden	21	Liberg 1984a
Switzerland	5	Tschanz et al. 2011
UK	44	Woods et al. 2003
UK	22	Churcher and Lawton 1987

Country	Number of bird species reported killed	Source
UK	16	Baker et al. 2008

Table 7. Overview of the most common bird species killed by cats in Europe (UK: Woods et al. 2003, Baker et al. 2008, Germany: Borkenhagen 1978), listed alphabetically by the scientific name.

Species	Latin name	Norwegian name
European greenfinch	*Chloris chloris*	Grønnfink
Feral pigeon	*Columba livia*	Bydue
Blue tit	*Cyanistes caeruleus*	Blåmeis
European robin	*Erithacus rubecula*	Rødstrupe
Chaffinch	*Fringilla coelebs*	Bokfink
Great tit	*Parus major*	Kjøttmeis
House sparrow	*Passer domesticus*	Gråspurv
Dunnock	*Prunella modularis*	Jernspurv
European starling	*Sturnus vulgaris*	Stær
Common whitethroat	*Sylvia communis*	Tornsanger
Eurasian wren	*Troglodytes troglodytes*	Gjerdesmett
Common blackbird	*Turdus merula*	Svarttrost

1.4.3.3 Predation rates and potential negative effects of cats on bird populations

Few studies have estimated the proportion of birds in a population being killed by cats annually. In Sweden, Svensson (1996) estimated that 3% of all birds were killed annually by cats. In southern Canada, 2–7% of birds are killed annually (Blancher 2013), and cat predation was suggested to be the largest human-related source of bird mortality in Canada. Churcher and Lawton (1987) estimated that 30% of house sparrow (*Passer domesticus*) mortality in an English village was due to cats. Pavisse et al. (2019) reported that 13–26% of mortality of garden birds in France and Belgium could be assigned to cat predation. For Norway, no such estimates exist. However, considering the cause of mortality among all recoveries of birds ringed in Norway, 6.2% were reported as killed by cat (Heggøy and Shimmings 2018). For ground-nesting birds on islands, high rates of bird mortality and nest or colony abandonment has been reported due to cat predation (Kirkpatrick and Rauzon 1986, Fitzgerald et al. 1991, Winter and Wallace 2006, Hughes et al. 2008, Ratcliff et al. 2009, Greenwall et al. 2019).

There have been mixed results from studies attempting to evaluate population consequences of bird mortality due to cats. Thomas et al. (2012) suggested, based on simulation modeling, that cat predation rates could significantly reduce the size of local bird populations for common urban bird species. In a case study from New Zealand, van Heezik et al. (2010) found that total predation on six bird species by cats in a city was close to or even higher than total urban population sizes, indicating a low likelihood of population persistence and that urban populations may act as sinks with source populations located on the city fringe. On the other hand, Perkins et al. (2021) found no clear effect of cat density on bird richness or abundance in a large study involving 58 urban areas in Ottawa, Canada. Further, Malpass et al. (2018) found no difference in nest survival for two common bird species (robins and cardinals) when comparing developed land (matrix habitats) and forest parks in and around Columbus, Ohio (USA), despite much higher cat predation in the developed land.

The extent of cat predation on islands varies greatly, depending on season and on availability of alternative prey (Nogales and Medina 2009; Hervias et al. 2014). Cat predation on islands is greatest on ground nesting seabirds (Hughes et al. 2008, Greenwall et al. 2019). In a case study from Ascension Island, an isolated tropical island, Hughes et al. (2008) investigated effects of cat predation on ground-nesting sooty terns. The breeding population size of sooty terns averaged 368,000 in the 1990s, a time in which cats were estimated to killing 33 adult terns per night. Cats were eradicated from the island during the period from 2001 to –2004. By 2007, the breeding population of sooty terns had increased by 14% to 420,000— despite significant predation on eggs and nestlings by rats and common mynas. The rapid population increase in sooty terns after cat eradication is a clear example of the importance of cat mortality on island seabird populations where feral cats are present. In addition, four other species of seabirds recolonized areas previously accessible to cats, once cats had been removed from Ascension Island (Ratcliff et al. 2009).

1.4.4 Impacts on mammals globally

Most studies that have evaluated the composition of prey items of free-roaming cats have reported that mammals are more common than birds among prey (see section 1.4.2). A considerable number of species from several mammalian orders have been reported as killed by free-roaming cats, although most studies find only a few species (Fitzgerald and Turner 2000). The main orders of mammals depredated by cats include Rodentia (rodents), Lagomorpha (hares, rabbits, pikas), Chiroptera (bats), Marsupialia (pouched mammals), Carnivora (carnivorous mammals), and Insectivora (insectivorous mammals) (Andersen et al. 1995, Fitzgerald and Turner 2000, Woods et al 2003, Murphy et al 2019, Oedin et al. 2021).

Loyd et al. (2013a: table 1) summarized the results from eight studies conducted in UK (2), USA (3), Switzerland (1), Austria (1), Australia (1) and New Zealand (1). Across these studies, mammals constituted an average of 65% (SD: 16.7) of food items. Among the studies, the proportion varied between 34% (New Zealand) to 86% (New York, USA). Similar conclusions, with a dominance of mammalian prey species, were reached by Fitzgerald and Turner (2002), who provided an extensive literature overview. Loss et al. (2013) distinguished between owned free–roaming cats and feral cats in their study. For owned cats, they report a range of 11.1–29.5 prey items brought back annually across 7 studies in USA and Europe, and a range of 8.7–21.8

across 13 studies including other continents and ecosystems. They assumed that the number of prey items was 1.3–3.3 times the return rate. In contrast, feral cats had a much higher kill rate; on an annual basis it was estimated to be in the range 139–329 mammals per cat per year across 7 studies in USA and Europe, and in the range 177–300 across 13 studies from other continents and ecosystems. Importantly, the number of mortalities caused by individual cats and their individual prey selection is remarkably heterogenous (Dickman and Newsome 2015), contributing to the uncertainty and variation in estimates from individual studies. Such heterogeneity also contributes to the uncertainty when upscaling from individual studies to local effects on biodiversity. As is common in the mammalian predator-prey literature, hunting success might also vary between open and closed habitats (McGregor et al 2015).

In a review of 44 studies identifying bat species preyed upon or threatened by cats, Oedin et al (2021) concluded that predation by cats has been underrated as a threat to the world's bat species and that there is a pressing need for better estimates of mortality rates from cat predation. They documented that both owned and feral cats kill or injure bats. Members of the family Vespertilionidae were shown to be more exposed to predation by cats than members of other families. This was, however, likely due to the higher abundance of this bat family. All bat species found in Norway are in the Vespertilionidae, all of which are insectivorous. Cats hunt bats emerging from roosts either by sitting on their hind legs or by jumping and catching bats in the air resulting in either death or injury to the bat (Rodríguez-Durán et al., 2010, Ancillotto et al., 2013). Bats may also be caught by cats while foraging close to the ground (Rodríguez-Durán et al., 2010).

1.4.4.1 Total number of mammals killed by cats

There have been several attempts to calculate the total predation on mammals across various spatial scales. Such calculations rest on several assumptions, that might or might not be supported with more detailed empirical data. Most calculations are based on previous studies reporting predation rates upon mammalian prey species, as well as calculations of number of free-roaming cats. In addition, some studies have made a correction for the fact that not all prey items might be brought back by the cat (Loss et al. 2013). Considerable uncertainty in the estimates is related to the poorly known size of the feral cat population (Loss et al. 2013). Feral cats have higher kill rates than owned free-roaming cats (see sections 1.3.3 and 3.1.5), and they typically contribute substantially to the overall estimated number of mammal prey killed by cats. The number of mammals killed by free roaming cats have been evaluated in USA, Canada, Australia, UK and Polish farmsteads. A list of studies that have attempted to estimate total mammalian mortalities caused by free-ranging cats are listed in Table 8.

Table 8. Estimated number of mammalian prey items killed by free-roaming cats in previous studies.

Location	Number of mammalian prey	Comments	Reference
Contiguous USA (2014)	12.3 (6.3-22.3) billion	All relevant mammalian species	Loss and Marra (2013)
Polish farmsteads	583 (505 – 667) million	Numbers eaten. Estimated that 48.1 are brought home	Krauze-Gryz et al. 2018
China	3.6-9.8billion		Li et al. 2021
Australia	1.1 billion	Of which 60% were non-native species	Murphy et al. 2019

1.4.4.2 Effects of cats on mammalian populations

Small mammals (>100g) typically include the main prey taken by domestic cats (Fitzgerald and Turner 2002; Cecchetti et al. 2021a). However, a study from southern Scandinavia reported a high proportion of wild rabbits (*Oryctilagus cuniculus*) in addition to small rodents in the cat diet (Lidberg 1984). It was estimated that cat predation corresponded to ca. 4% of the annual production of rabbits, but ca. 20% of the annual production of small rodents.

Some studies suggest negative effects of cats on mammal populations (Loss and Marra 2017). For instance, the densities of wood mouse (*Apodemus sylvaticus*) were lower in suburban areas with higher densities of cats in the UK (Baker et al. 2003). Moreover, in Australia, range declines in tropical marsupials were attributed to cat predation (Fisher et al. 2014). Such observational studies should be treated with caution, as teasing out causal effects from correlational data is challenging. In an experimental setting, Frank et al. (2014) measured the effect of a low-density cat population on native small mammals. Introducing a native species of long-haired rat *Rattus villosissimus* to large enclosures with or without cats, the authors observed that the prey species persisted longer in compartments where cats were excluded (1.5 years) than in compartments where cats were allowed (2 months). Evidence is lacking from most ecosystems, but the available information from observational and experimental studies suggests that cat predation might exert considerable impact on mammalian populations when cat density is high.

1.4.5 Impacts on reptiles and amphibians globally

Reptiles and amphibians (collectively 'herptiles') form a varying component of the diet of cats globally (Read and Bowen 2001, Woods et al. 2003, Bonnaud et al. 2011, Medina et al. 2011, Kutt and Kichener 2012, Woinarski et al. 2018). Reptiles and amphibians were long neglected in estimates of the impacts of cats on wildlife (Loss and Marra 2013). Herptiles are more important prey at subtropical latitudes at 20–40° N, both on continents and on islands (Fitzgerald and Turner, 2000). The proportion of reptiles and amphibians as prey of domestic cats is highest in areas with hot and dry climates. Domestic and feral cats might have particularly large effects on the herpetofauna on islands (Bonnaud et al. 2011, Medina et al. 2011, Smith et al. 2012, Medina et al. 2014, Carrión and Valle 2018, Hernandez et al. 2018). Cats and other invasive mammalian predators have been implicated in extinctions of 10 species of reptiles (Doherty et al. 2016).

Woinarski et al. (2018, 2020) found that two variables were predictors of the frequency of reptiles and amphibians in feral cat diet samples in Australia: mean annual rainfall with a higher frequency of reptiles in the cat diet in areas of lower rainfall and mean annual temperature with a higher frequency of in the cat diet occurrence in areas of higher temperature. Dietary studies indicate that feral cats prey on a wide taxonomic range of Australian mainland reptile species and are capable of switching prey if preferred species are depleted (Dickman and Newsome 2015; Doherty et al. 2015). Cats prefer reptiles in the size ranges from 10 to 50 g and 50 to 100 g (Kutt and Kitchener 2012).

Studies of prey of domestic cats returned home underestimate total prey captures since some prey are consumed or abandoned away from home. In Krauze-Gryz et al. (2012), reptiles were mainly brought home (90%), while for amphibians roughly 2/3 were eaten and 1/3 brought home. Studies using animal-borne video cameras have demonstrated that the numbers of returned prey are lower than numbers caught and killed (Loyd et al. 2013a; Seymour et al. 2020), and that even studies based on faeces and stomach contents underestimate numbers of animals killed by cats since not all are eaten (Loyd et al. 2013a, Hernandez et al. 2018).

The proportion of prey that is reptiles or amphibians (or of any group of prey organisms), and differences in returned prey vs not-returned prey, will depend on both types of animals and the local faunal composition (Li et al. 2021). Seymour et al. (2020) found that reptiles constituted 50% of prey and only 17% of returns in South Africa, but Krauze-Gryz et al. (2012) reported that reptiles were 7% of prey and 8% of returns in rural Poland. For cats on a small marshy island off the coast of Georgia, USA, reptiles included 17% of the animals killed but frogs made up 30%, which is the highest proportion of amphibians in any study that we have found.

In an inquiry of the prey brought home by free-ranging house cats in Finland, reptiles accounted for 8 percent of prey for younger cats and 2 percent for older cats (Kauhala, Talvitie, and Vuorisalo 2015). Young cats brought home insectivores, amphibians and reptiles more often than old cats. In total, Kauhala, Talvitie, and Vuorisalo (2015) estimated the number of reptiles and amphibians brought home by cats to be 33,000 annually in Finland.

A questionnaire of the numbers of animals brought home by domestic cats in Great Britain concluded that there were 4% amphibians 1% reptiles (Woods, McDonald, and Harris 2003). A minimum of four species of reptiles and three species of amphibians were recorded (Table 9).

In another English survey of the numbers of animals brought home by domestic cats, 495 prey animals were returned, including 20 individuals of amphibian (4%) and 25 individuals of reptiles (5%) (Baker et al. 2008). This study included 275 cats from 186 households.

In southern Europe, with a warmer and drier climate than in Norway, reptiles can make up a large proportion of cat prey. Mori et al. (2019) collected data for Italy on the impact of cats both through a citizen science approach based on irregular reports of prey brought home over four years by 145 domestic cats belonging to 125 owners and by tabulating all prey for 21 of these 145 cats for 1 year. Of 2042 animals reported by citizen scientists, reptiles accounted for 24% and amphibians for 2%. Six genera of lizards and nine genera of snakes were represented, in addition to one tortoise; amphibians comprised three genera of frogs and one genus of toads. About 3/4 of the prey were brought home in spring and summer. The most frequently killed reptiles included the common wall lizard (*Podarcis muralis*, 37% of reptiles brought home), the Italian wall lizard (*Podarcus siculus*, 16%) and the common wall gecko *Tarentola mauritanica,* 11%). Most amphibians brought home included the agile frog (*Rana dalmatina*, 61%).

Table 9 lists European studies of domestic cat predation on amphibians and reptiles. Similarly, Table 10 lists species of amphibians and reptiles that have been documented as prey for domestic cats in Europe. The most important prey animals are lizards and slow worms as a burrowing group of legless lizards.

Table 9. Frequency of reptiles and amphibians in the diet of domestic cats (DC) or feral cats (FC) in Europa.

Country	% frequency of occurrence of reptiles in diet (N)	% frequency of occurrence of amphibians in diet (N)	Sample type	Source
Norway	0%	0%	camera (DC)	Barmoen 2016
Sweden	0%	0%	scat (DC/FC)	Liberg 1984a
Finland	Reptiles and amphibians together 3% (45)		questionnaire survey (DC)	Kauhala et al. 2015
Great Britain	1% (147)	4% (587)	questionnaire survey (DC)	Woods et al. 2003.
Great Britain	5% (25)	4% (20)	questionnaire survey (DC)	Baker et al. 2008.
Poland	eaten: 3% (12) brought: 8% (112)	eaten: 5% (18) brought: 1% (11)	stomachs and scat and prey brought hom (DC)	Krauze-Gryz et al. 2012
Poland	4% (12)	0%	stomachs and scat and prey brought hom (DC)	Pinotek et al. 2020.
Italy	21%	4%	questionnaire survey (DC)	Mori et al. 2019.
Switzerland	0%	0%	questionnaire survey (DC)	Tschanz et al. 2011

Table 10. Frequencies (%) or occurrence (x) and number of individuals (N) of reptile and amphibian species captured by cats in Europe.

Common name	Scientific name	Kauhala et al. 2015	Woods et al. 2003	Baker et al. 2008	Mori et al. 2019	Piontek et al. (2020)	Comment
Lizards							
common lizards	*Zootoca vivipara*	x	6% (45)			x	
sand lizard	*Lacerta agilis*		0.2% (2)			x	
Bedriagas lizard	*Archaeolacerta bedriagae*				2% (1)		
European green lizard	*Lacerta viridis*					x	
Filfola lizard	*Podarcis filfolensis*				23% (12)		
Tyrrhenian wall lizard	*Podarcis tiliguerta*				6% (3)		
slow worm	*Anguis fragilis*	x	12% (87)	55% (25)			
Italian Slow Worm	*Anguis veronensis*				19% (10)		
Snakes							
vipers	*Vipera berus*	x					
grass snake	*Natrix natrix*		1% (10)			x	
four-lined snake	*Elaphe quatuorlineata*				11% (6)		
green whip snake	*Hierophis carbonarius*				19% (10)		
Montpellier snake	*Malpolon monspessulanus*				2% (1)		
Amfibians							
(agile frog)	*Rana* sp.	x					Mainly *Rana dalmatina*
common frog	*Rana temporaria*		75% (545)	44 % (20)			
(common toad)	*Bufo* sp.		3% (23)		4% (2)		Mainly *bufo bufo*
European tree frog	*Hyla arborea*				8% (4)		
Italian agile frog	*Rana latastei*				2% (1)		
Italian crested Newt	*Triturus carnifex*				2% (1)		
(smooth and crested newt)	*Triturus ssp*		3% (22)				Both *Triturus cristatus* and *Lissotriton vulgaris*
Turtles							

Common name	Scientific name	Kauhala et al. 2015	Woods et al. 2003	Baker et al. 2008	Mori et al. 2019	Piontek et al. (2020)	Comment
Hermann's tortoise	*Testudo hermanni*				2% (1)		

1.4.6 Impacts on fishes globally

In China, the total amount of fishes caught by both owned and unowned free-roaming cats in both urban and rural areas made up 12% of the prey, where mammals made up 29% and birds 21% (Li et al. 2021). In this study, the combined amount of water-dependent prey items (fishes and amphibians) made up 22% of the prey.

In most studies of cat prey selection, fish are rarely reported as being frequent prey, and when they do it is mainly domesticated fish from private ponds. For instance, in the survey-based, UK owners reported 31 instances of their cats bringing goldfish (*Carassius auratus*) home, out of 14,370 prey items in total (Woods et al. 2003). Similarly, cat owners reported only 7 fish killed "in confined environments" in Italy, out of 2042 records of vertebrate prey (Mori et al. 2019). For cats hunting in central Australian grassland habitats, Yip et al. (2014) recorded fish from 5 of 73 cat stomachs (5 fish total, of 251 prey items identified).

1.4.7 Impacts on macroinvertebrates globally

House cats catch and eat invertebrates, and small-bodied invertebrates are regularly recorded in studies based on owners' observations of prey items brought home (Woods et al. 2003; van Heezik et al. 2010, Tschanz et al. 2011, Krauze-Gryz et al. 2012, Kauhala et al. 2015, Hernandez et al. 2018, Li et al. 2021). Prey remains found in stomach contents or cat faeces come from a surprisingly wide range of invertebrates, ranging in size from springtails, flies, spiders, and wasps to cicadas, stag beetles, scorpions, and large orthoptera such as grasshoppers, wetas and katydids. Most small surface-crawling terrestrial invertebrates can be found in the detailed prey lists based on stomach contents or faeces (Medina and Garcia 2007, Bonnaud et al. 2011, Kutt 2011, Woolley et al. 2020). A similarly large variety of invertebrates are killed in video studies using cat-borne cameras (Loyd et al. 2013a, Hernandez et al. 2018). Even crabs and crayfish have been found in cat faeces (Konecny 1987, Yip et al. 2014). Results from several studies suggest that large-bodied members of the insect orders Orthoptera, Coleoptera, and Lepidoptera are preferred by cats as prey (Medina and García 2007, Nogales and Medina 2009, Bonnaud et al. 2011).

A few studies of feral or owned cats have focused specifically on the role of invertebrates as prey. Woolley et al. (2020) studied the consumption of invertebrates by feral cats in Australia and found that invertebrate remains occurred in 39% of dietary samples, roughly a third of which were from Orthoptera. They estimated that over one billion invertebrates are consumed yearly by feral cats across the continent.

In studies of predation of invertebrates by feral cats on the Canary Islands, insects occurred in 1/6 of cat faeces, which is similar to values reported in other studies of cat diets on islands (Nogales and Medina 2009, Millán 2010, Medina et al. 2012). On La Palma, insects made up 91% of invertebrate occurrences in faeces and 94% of invertebrate prey biomass (Medina and García, 2007). The main insect prey groups included Orthoptera, Lepidoptera and Coleoptera. Other groups of arthropods and molluscs included centipedes, millipedes, woodlice, and snails.

Most of the data on invertebrate consumption by cats originate from investigations of cat diets. Most of these studies are of cat predation on islands (reviews: Nogales and Medina 2009; Bonnaud et al. 2011). Bonnaud et al. (2011) reviewed 72 studies encompassing 40 islands worldwide and found that invertebrates comprised 28% of the prey. Most orders of insects were recorded, and the most common groups were again Orthoptera, Coleoptera and Lepidoptera. In a more recent island study, Hernandez et al. (2018) filmed prey hunting using small video cameras on cat collars (Creaturecams). In numbers, invertebrates made up nearly half of all animals killed by cats.

In a study of free-ranging cats in suburban and rural environments of southeastern Brazil based on analysis of cat scats, invertebrates were the most common prey item (Campos et al. 2007). Invertebrates were captured nearly three times as often as mammals.

Li et al. (2021) surveyed the Chinese public for records both of prey brought home and of observations of predation, by both owned and feral cats in both urban and rural areas. Invertebrates made up 14% of 23,105 total prey items. From these records, and from data on patterns of cat ownership, proportions of owned cats allowed outdoors, and an estimate of rates of predation by unowned cats, Li et al. estimated that between 1.6 and 4.8 billion invertebrates are killed annually in China by owned and unowned cats.

Gillies and Clout (2003) conducted a questionnaire-based year-long survey of prey brought home by 80 owned cats in two suburbs of Auckland City, New Zealand. Of the invertebrates caught, over 90% were in the most urbanized suburb, where invertebrates were the largest class of prey items (by number), and 2/3 of these prey were captured by just four cats. The main invertebrate prey were crickets and other Orthoptera, cicadas, and lepidoptera. These are common and large-bodied insects that move frequently in the landscape.

A conclusion from dietary research on cats is that, though many invertebrates are found in scat or stomach samples (or reported as brought home), they usually constitute only a small part of the animal biomass that is consumed. Given the large size of most terrestrial invertebrate populations, it is not believed that owned cats or feral cats have significant impacts on local biodiversity of invertebrates (Woolley et al. 2020 but see Eisenhauer 2018 for a dissenting opinion). However, predation on concentrated populations of large-bodied insects, such as the endemic wētā orthopterans of New Zealand, could be an exception (Fitzgerald and Karl 1979, Gilllies and Clout 2003, Woolley et al. 2020).

1.4.8 Indirect effects of cat predation behaviour

Most focus has been on the number of prey killed by cats, but cats can also affect birds through a range of indirect effects, including risk-mediated behavioural effects, sub-lethal effects and a range of non-consumptive effects of predators (Perkins et al. 2021). Due to evolved responses to reduce predation risk, wild birds may alter their behaviour in the presence of predators (Lima and Dill 1990; Eggers et al. 2006; Fontaine and Martin 2006; Cresswell 2008), and predator avoidance may also have consequences for reproductive rates (Eggers et al. 2006; Fontaine and Martin 2006; Zanette et al. 2011). By observing cats in their territories or home ranges, birds may increase anti-predator behaviours, such as vigilance and alarm calling, reduce feeding rates of offspring, or change habitat use or abandon a nest to reduce predation risk (Medina et al. 2014; Loss and Marra 2017). Bonnington et al. (2013) found that brief presentations (15 min) of taxidermy mounts of cats close to nests of blackbirds (*Turdus merula*) caused a one-third reduction in nestling feeding rates during the next 1–1.5 hours, and increased nest defense behaviour towards the cat model caused a large increase in corvid nest predation rates during the next day, presumably because the intense nest defense attracted corvids and enabled them to locate nests. Thus, exposure to the cat models had direct, but non-lethal effects on reproduction of blackbirds, as well as indirect effects through third-party predation mediated by increased anti-predator behaviour. This study is one of the few that have studied non-lethal effects of cats in detail. Using a simulation modeling approach, Beckerman et al. (2007) suggested that when cat densities were high and even when direct predation mortality was low (<1%), a small reduction in fecundity due to sub-lethal effects (<1 offspring $year^{-1}$ cat^{-1}) could result in marked decreases in bird abundances (up to 95%). Negative effects were manifested when the density was around 500 cats pr km^2.

Hunting by cats does not only lead to successful kills; small mammals that escape cats can still suffer from sub-lethal effects including physical injury, stress effects, loss of energy and time, and having to use suboptimal territories of other resources (Hernandez et al. 2018, Sheriff et al. 2020). Several studies have found that predation risk reduces fecundity in mammals (Sheriff et al. 2020, Voznessenskaya, 2014), at least partly because of an increase in stress hormones (Sheriff et al. 2009). In an experimental study on pest rodents in Swaziland, the rodents spent less time and were less likely to exploit food resources under the simultaneous presence of domestic dogs and cats (Mahlaba et al. 2017). A study of New York City rats documented shifts in the rodent's space use when feral cats were present (Parsons et al., 2018). Bats, too, suffer from non-lethal attacks by cats. A study from the UK found that 2/3 of wing tears in bats were due to cats (Khayat et al. 2020). There are still unresolved questions related to non-lethal effects or the non-consumptive effects of predation, and their relevance in mammalian predator-prey systems (Hernandez et al. 2018, Sheriff et al. 2020). The phenomena of non-lethal effects have not yet been studied extensively in relation to cats and their potential effects on mammalian prey.

1.4.9 Effects of cat predation on biodiversity in Norway

1.4.9.1 Effects of cats on Norwegian birds

Previous estimates of the total number of birds killed by cats annually in Norway vary from approximately 1 million to 7 million per year, with the highest figure being the most recent estimate and with the most thorough calculations (Table 5). Heggøy and Shimmings (2018) calculated that 67% of the variance in their estimates of total annual kill rates was due to variation in individual kill rates, followed by correction factors for undetected prey (16%), and only small contributions from variation in the estimates of total number of domestic and feral cats, and the proportions of domestic cats that were free-ranging and hunting.

Cats may take a wide variety of bird species (Table 6). The extensive list of 113 species for Norway was based on ringed birds returned to the Norwegian Bird Ringing Centre and reported as killed or scavenged by a cat (Heggøy and Shimmings 2018). Among 93 species with at least 20 ring recoveries (dead for any reason; range 21–3842, median 194), there were 74 species for which at least 1% were reported as killed by cats, and 39 species for which at least 10% were reported as killed by cats (Heggøy and Shimmings 2018). Among the latter group, most species were small and common passerine bird species breeding in forest or close to humans, and many were migratory (Heggøy and Shimmings 2018) (Figure 6).

Figure 6: Domestic cat with passerine prey. Photo: FurryFritz, Colourbox.com

The impact of cats on bird populations is a debated and contentious issue in Norway. Michaelsen (1998) expressed concerns that cats could have negative effects on birds based on personal observations, in particular that cats killed many shorebirds in some Ramsar-sites and bird protection areas. Selås (2011) concluded that the cat is not a threat to biodiversity in Norway as their total predation rates were low. Braastad (2011) also concluded that there was little evidence that cats are a serious threat to populations of birds or other animals in Norway. Heggøy and Shimmings (2018) concluded that there is a lack of data to evaluate whether cats can affect population sizes of birds but emphasized that their finding of approximately 7 million birds killed per year by cats in Norway suggest that authorities should consider the issue.

1.4.9.2 Effects of cats on Norwegian mammals

While much of the research conducted on the effects of cats on biodiversity in other parts of the world is relevant and potentially transferable to Norwegian ecosystems, local data will nevertheless be important when calibrating and tailoring the evidence to assess the impact of cats on Norwegian biodiversity. Some research exists on the potential effects on birds, but research focusing on effects on mammalian prey species is limited. In Norway, as in most other parts of the world, small rodents are expected to be among the main prey items. The only systematic assessment of the potential impact on mammalian prey in Norway is Kulemann and Dangstorp (2019a), who assessed the composition and number of prey items brought home by owned cats based on questionnaires sent out to cat owners. They found that the cats on average brought home 11 (SD: 38) prey items each year, of which ca. 39% were small rodents. In addition, the sample of cats brought home at least one red squirrel (*Sciurus vulgaris*, Norw: ekkorn) and stoat (*Mustela erminea*, Norw: røyskatt). As reported from other parts of the world, there was a considerable heterogeneity among individuals, with some cats returning no prey items whereas other cats returned up to 400 prey items in a year. Not all prey individuals killed by cats are brought home and the total kill rates are likely higher. For instance, from the USA, Loss and Marra (2013) found that the total number of prey killed is 1.3 to 3.3 times the number of prey items brought home.

1.4.9.3 Effects of cats on Norwegian amphibians and reptiles

Few studies have been conducted in Norway that include data on domestic cats' predation on amphibians and reptiles. A study of 11 cats equipped with a camera conducted by Barmoen (2016) in Akershus, documented no amphibians or reptiles among 83 prey animals captured or brought home. Although this study was conducted in a residential area, both smooth newt and common frog were potential prey in this area but the sample size was limited. A study by Liberg (1984a) in Sweden and Tschanz et al. (2011) in Switzerland came to the same result as the Norwegian study. A Finnish study found that 2.8% of the prey of cats consisted of reptiles and amphibians (Kauhala et al. 2015). However, the proportion of reptiles as prey for cats in rural areas was somewhat higher (5.4%). Other European studies that have documented reptiles and amphibians among the prey of domestic cats have found relatively low frequencies in the north, compared to southern and warmer countries (Baker et al. 2008, Kutt 2012, Krauze-Gruze et al. 2017, Mori et al. 2019). Almost all the naturally occurring reptiles and amphibians in Norway have been documented as prey for cats in the European studies, although the frequency is relatively low (Woods et al. 2003, Baker et al. 2008, Kauhala et al. 2015, Pionte et al. 2020).

Documentation on reptiles and amphibians as prey for cats in Norway is lacking in the scientific literature, but anecdotal observations indicate that reptile and amphibian species have been taken by cats. The salamander blog[7] received two emails in 2020 with a description of a cat that had taken up to several smooth newts (*Lissotriton vulgaris*) home and two emails with a description of a cat that had taken a common lizard (*Zootoca vivipara* – norfirfisle) home (4 of 150 emails received). It is also documented with photos that the cat has taken home smooth snake (*Coronella austriaca* – slettsnok) (Aanensen pers com.). Researchers working with the moor frog *(R. arvalis* – spissnutefrosk) and the common frog (*R. temporaria* – buttsnutefrosk) have also observed that cats have taken these two species (Jeroen von der Kooji, pers comm.). Thus, all the naturally occurring species of reptiles and amphibians are potential prey for cats in Norway.

1.4.9.4 Effects of cats on Norwegian fishes

Norwegian freshwaters are species poor compared to most other countries with 32 native species of fish, and 12 non-native species (Vøllestad 2023). There are no data on fish predation by cats in Norway. Cats can catch and eat fish, but most studies of cat predation did not find fish among the prey of cats. For the studies showing that cats have brought fish home, these show predation largely is on fish being raised for food in small ponds or goldfish (*Carassius auratus*) (see section 1.4.6). All these studies showed that fish constituted a very small proportion of the prey. No studies show predation by cats on marine fish. In Norway, widely distributed freshwater fish mainly include salmonid species, or other relatively fast swimming fish that might be more difficult to catch for a cat than cyprinids. However, there are some cyprinid fish in Norway with a limited distribution, like roach (*Rutilus rutilus*). Only three freshwater fish in Norway are red- listed, which includes Atlantic salmon (*Salmo salar*), sea lamprey (*Petromyzon marinus*) and Arctic lamprey (*Lethenteron camtschaticum*). These species are anadromous and perform marine migrations. None of these are regarded as vulnerable to predation by cats because of their habitat use and behaviour, and they are not shown to be the prey of cats in studies referred to in this report. Therefore, predation by cats is not likely to have any detectable population level impact on native fish species in Norway. The unusually high proportion of fish in diets of hunting Chinese cats (Li et al. 2021) may reflect the widespread ancient practice of integrating fish farming in small ponds in China (Chen et al. 1995). This is a practice that would greatly increase the relative availability of fish as prey.

1.4.9.5 Effects of cats on Norwegian macroinvertebrates

Little is known about invertebrate predation by cats in Norway. Kulemann and Dangstorp (2019a) found that insects made up 19% of prey items reported by cat

[7] www.forskning.no/salamanderblogg

owners, in line with data from other parts of the world, and Barmoen (2016) observed that cats take night-flying moths and other insects. Given the high abundance and large population fluctuations of most insects it seems unlikely that cat predation will have any negative impacts on their populations. One possible exception might be macroinvertebrates that are red listed due to low population sizes, but there are no information that suggest that this is the case.

1.5 The epidemiological role of cats

Transmissible diseases are an important component in any ecosystem, and the epidemiological role of a species is part of its indirect impact on the biodiversity of a community.

Free roaming cats are in an intermediary ecological position: they live in close contact with humans to the point of being allowed indoors in kitchens and bedrooms and remain at fairly constant numbers even when prey is scarce due to disease, predation or food. At the same time, they are active predators in contact with a wide range of environments and species from domestic (farm animals and other pets), peridomestic (animals that live in close contact with humans but on their own accord, rats being a typical example) and wild fauna.

Their role as a free-ranging companion pet means they are in a unique position ecologically and epidemiologically, potentially being capable of carrying disease agents back and forth between host domains otherwise not in close contact (Figure 7). Cats are therefore potentially ecologically important for (i) zoonoses (diseases that transmit from animals to humans), (ii) reverse zoonoses (diseases that transmit from humans to animals), and (iii) animal diseases (diseases that do not involve humans but may transmit between livestock, pets and/or wildlife).

Historically, the main reason for keeping cats was to control rodents that damage crops and carry diseases. However, as a result of improved sanitation and construction in large parts of the world, cats now have a decreased role as controlling rodents and thereby disease reservoirs in rodents. Whereas this changing role seems likely to have reduced the incidence of transmissible diseases in cats, they are still in close contact with humans and some potential disease reservoirs in peridomestic rodents and wildlife. The current net effect of cats on disease dynamics is unclear, and likely to be highly context specific (Chalkowski et al. 2019; Badenes-Pérez 2023).

Cats may carry and transmit a considerable number of pathogens, depending on the cat's lifestyle and surroundings. Examples include zoonoses, like rabies, toxoplasmosis, toxocariosis, bartonellosis and salmonellosis, that can comprise health risks to humans and animals including wildlife (Chalkowski et al. 2019; Wilson et al. 2021). At the same time, their place in the human-dominated ecosystem makes them a potential reservoir for zoonotic pathogens to humans and other domestic animals, and a possible bridge species for emerging infectious diseases. However, they are also potential sentinels and biological control agents limiting the danger of transmission of diseases to humans from the numerous reservoirs of rodent diseases. As many parasites and pathogens use multiple host species, either opportunistically or sequentially, managing disease risk frequently requires a broader understanding of the ecological community.

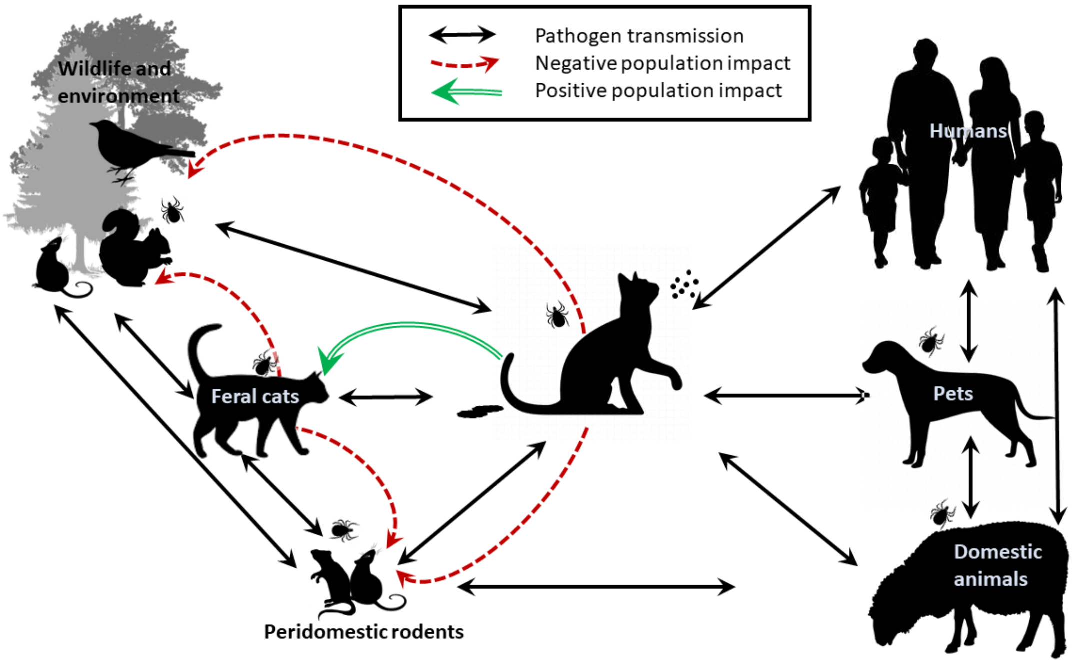

Figure 7: Simplified transmission network for pathogens (dots) and parasites (ticks), highlighting the key position domestic cats potentially have as a link between different reservoir domains, in addition to the interaction between cats and their effects on prey populations.

Another aspect of cats with regards to zoonoses is their propensity for frequenting multiple households. Thus, they have a noteworthy role as unsupervised connectors and transmission pathways that can bypass quarantines and known contact points. Moreover, their space use also gives them a frequently overlooked potential for reverse zoonoses by infecting other pets, (peri)domestic animals or wildlife by human pathogens they would not otherwise be exposed to, as noted during the SARS-CoV-2 pandemic (Bosco-Lauth 2020, Nagy 2022) and for antibiotic-resistant *Staphylococcus aureus* (MRSA) (Abdullahi 2023).

1.6 Animal welfare issues related to keeping of cats

1.6.1 Definition of animal welfare

Animal welfare considers the quality of life of the individual animal. The focus is on the animal itself, rather than what we do (animal care) or ought to do (ethics). According to Fraser (2008), see also Duncan and Fraser (1997), animal welfare encompasses three main dimensions:

1. *Natural life* – the extent to which the animal can perform a broad repertoire of behaviours typical of the species, with freedom of choice and ability to adapt to the environmental conditions in which it is living.

2. *Biological function* – how well the body functions to keep the animal alive, healthy, and that breeding animals can reproduce successfully.

3. *Subjective experience* - how the animal itself mentally experiences or perceives its situation or quality of life, which depends on the balance between positive and negative emotions.

Based on this, the Research group on Ethology and Animal Housing at the Norwegian University of Life Sciences has defined animal welfare as an elaboration of the well-known definition given by Donald M. Broom (2014), and explained by Braastad et al. (2022, Chapter 9):

"Animal welfare is the individual animal's subjective experience of its mental and physical state as regards its attempts to cope with its environment."

Mental states include emotional and cognitive states. Mental states imply *sentience* – the ability to consciously experience feelings and thoughts. *Physical states* include physical and physiological conditions that affect mental processes. *The environment* includes the social, physical, and biological environment.

1.6.2 Potential hazards to cat welfare related to outdoor roaming

Studies from UK showed that most cat owners, including those who were concerned about the potential environmental effects of free ranging cats, highly valued the freedom related to outdoor roaming for their cats (Crowley et al. 2019, 2020a and 2020b). Although there are positive effects for the cat to be allowed to roam freely, outdoor cats also face potential hazards. Risks are relating to fights or attacks by other cats (Loyd et al. 2013b), domestic dogs (Olsen and Allen, 2001) or native wildlife (Lukasik and Alexander, 2011). Further, outdoor cats are frequently injured or killed in traffic (Olsen and Allen, 2001; Rochlitz et al, 2001), and they are susceptible to a range of parasites and disease-causing agents (Gerhold and Jessup, 2013, Chalkowski, Wilson, Lepczyk, and Zohdy, 2019).

1.6.2.1 Cats as prey

While there has been considerable research on predation by cats on wild prey species (reviewed in section 1.4), there are no systematic data about predation on. From Norway, anecdotal evidence of cats being killed by various predators can be found in local newspapers and on social media. For some of these, documentation (such as in form of videos or photographs) is included. For others, the causality between a dead cat and the observation of a predator is less clear. Based on available information, we suggest that the following wild predators may present a hazard to outdoor cats in Norway.

Among avian predators, most reported cases concern the golden eagle (*Aquila chrysaetos* – kongeørn), for which there are documented cases from various parts of the country. Also, some cases of predation on cats are documented for the Eurasian eagle-owl (*Bubo bubo* – hubro). In addition, it is assumed that the northern goshawk (*Accipiter gentilis* - hønsehauk) is likely to catch at least kittens.

Particularly in urban environments, encounters between the red fox (*Vulpes vulpes* - rødrev) and cats are regularly reported. However, UK cats were 40 times more likely to be injured by another cat than by a fox[8]. There are cases of cats being killed by Eurasian lynx (*Lynx lynx* - gaupe) in Norway but encounters between the two felids are probably rare. Similarly, wolves (*Canis lupus* - ulv) can kill cats, although the likelihood is fairly low given the low number of wolves. Moreover, the European badger (*Meles meles* - grevling) and the pine marten (*Martes martes* - mår) have been proposed as possible cat hunters. While some cases have been reported for the badger, we are not aware of documented case of pine marten predation on cats.

1.6.2.2 Domestic dogs

Attacks by dogs occur, but the extent is unknown. Some incidents of cats killed by dogs are described in Norwegian newspapers and on various social media for pet owners, but no statistics exist. Cats are also at risk of being injured or killed in traffic accidents when chased by dogs. In Norway, stray dogs are rare and are culled if disturbing sheep or reindeer, but many people walk their dog unleashed.

1.6.2.3 Cats injured and killed by humans

Traffic accidents are the major hazard for severe injuries or death of cats if they are allowed outdoors, representing an important welfare issue for animals that are injured and not killed instantly. There is no official data on the number of cats that are killed, but several animal welfare organisations, including NOAH, report that the number is 400-600 per year. Some cats will seek the warmth from a car or tractor engine and seek shelter inside the vehicle during cold weather, which can have lethal effects once the vehicle starts.

Cats are sometimes accidently poisoned by glycol as a commonly used anti-freeze solution or rodenticides (Soleng et al. 2022). In Norway, there has recently been several cases of intoxication due to alphachloralose (Bernhoft et al., 2020), which is a rodenticide that became popular after the restrictions on sale and use of anticoagulant rodenticides. The use of alphachloralose was banned in 2020. As all poisoning may

[8] https://vethelpdirect.com/vetblog/2013/02/14/urban-foxes-attacks-on-cat/

result in pain and suffering, exposure to toxins represents a severe welfare issue to feral and free-roaming cats.

Anecdotal evidence suggest that cats are tortured and killed, or simply mistreated, by people more frequently than other domestic species, such as dogs. Cases reported in newspapers include wounds from firearms or arrows, burns, knife cuts, strangulation and poisoning.

1.6.3 Cat health and welfare in Norway

1.6.3.1 Physical health

The physical health of owned domestic cats in Norway is generally good (Falk et al. 2021). According to the diagnostic database Pyramidion, the top five treatments of cats by Norwegian veterinarians in 2022 included tartar scaling, bite injuries, tooth resorption, entangled fur, and abscesses (Kjæledyrrapporten 2022). The rate of vaccination of owned domestic cats is high compared to other countries, and many owners follow the recommendation to vaccinate their cat against common viruses, such as parvovirus/Feline Panleukopenia virus and calicivirus and herpesvirus causing respiratory disease (Dyrehelserapporten 2021). During recent decades, cat owners have become increasingly likely to bring a sick cat to the veterinarian, and they are willing to pay for veterinary care for illnesses that previously commonly resulted in euthanasia. An increasing proportion of owned cats are also health insured (Kjæledyrrapporten 2022).

Cats can be infected by a wide range of infectious agents: viruses, bacteria, fungi and parasites (Sykes et al. 2022). Cats may be infected with internal and external parasites including ear mites, ticks, intestinal worms and more. Many owners of hunting cats regularly treat their cat against internal parasites, including tapeworms arising from the ingestion of rodents, and use repellent agents against ticks. However, there are some infectious viral diseases with a potential to spread among cats and for which there are no efficacious vaccine or treatment (Sykes et al., 2023). Feline immune deficiency virus (FIV, also known as "Cat AIDS") attacks the immune cells compromising the immune system, and the cat will eventually die from various infections. The virus is spread through saliva and blood, for example when cats fight. There is no cure. Feline leukemia virus (FeLV) also attacks the immune system (bone marrow and white blood cells). Virus spreads via urine, saliva, blood, and during mating, thus more easily among intact (non-neutered) cats. Not all infected cats become ill, but if they do, the disease is fatal. Feline infectious peritonitis (FIP) is caused by a coronavirus that mutates in the cat. FIP is manifested clinically in two version or a mix thereof; acute disease with ascites or hydrothorax (i.e., fluid in the abdomen or thoracal cavity, respectively), or a more prolonged disease with symptoms from the liver, kidneys, eyes, CNS, eyes and/or liver and kidneys, caused by inflammatory lesions around blood vessels. The virus spreads via faeces, and mainly affects young cats (<2 years). Some of the chronic infections, for example respiratory infections like chlamydia and herpesvirus, are commonly observed in multi-cat households or in boarding houses or breeding facilities (Hannah Jørgensen, the Norwegian Veterinary Institute, personal communication). However, also singly housed cats with outdoor access will encounter other cats and are thus prone to acquiring infectious diseases. The notifiable disease that is most frequently diagnosed in cats in Norway is salmonellosis (Dyrehelserapporten 2021).

The lungworm *Aelurostrongylus abstrusus* is prevalent in many countries and was recently diagnosed in 23 of 79 cats presented with respiratory disease to a veterinary clinic in the Bergen area (Røssland et al. 2022). This nematode parasite is dependent on a slug as intermediate host, which is infected by eating larvae in cat faeces. Cats are infected by ingesting infected slugs or its slime, or via a paratenic (non-obligatory) vertebrate host, such as a small rodent, a bird or reptile. The parasite may be an important cause of respiratory disease in feral cats and owned cats with outdoor access.

A review related to various lifestyles of cats suggests that uncontrolled outdoor access is associated with several welfare concerns for companion cats, including increased risks of disease and parasites, injury, or death due to traffic, predation, or ingestion of toxic substances, and becoming permanently separated from their owner (Tan et al., 2020). Outdoor cats are also at risk for being poisoned by rodenticides (anticoagulants or alphachloralose), directly by ingesting the poison or by ingestion of poisoned rodents (Walton et al. 2018; Windahl et al. 2022). However, there are also welfare challenges associated with indoor housing, such as lack of stimuli and boredom in single-cat households (see sections on behavioural needs, 1.2.2 and 1.6.3.3), whereas there may be a high infection pressure in multi-cat households.

1.6.3.2 Breed-related health issues

Pedigree cats often come from highly inbred lineages, and close inbreeding has produced several heritable problems (Matsumoto et al. 2021). Breeds, such as Main Coon, Ragdoll and Sphynx, suffer from heritable heart disease (Silverman et al. 2012). Hereditary retinal atrophy (an eye disease) is found in several breeds, including Abyssinian and Persian cats (Narfström 1983, Rah et al. 2005). Polycystic kidney disease is particularly prevalent in Persian cats and is usually found in nearly half of cats screened, regardless of country of origin (Cannon et al. 2001). Both Persian and Birman cats are genetically susceptible to feline infectious peritonitis (Golovko et al. 2013). Inbreeding effects can be characteristic of an entire breed or only of a subpopulation of a breed: Australian-bred Burmese have four times more type 2 diabetes than Burmese cats bred in the United States (Balmer et al. 2020).

Some physical problems are due to side effects of preferred conformation traits. Cats with a flat face (brachycephaly), such as the Persian cat, may experience breathing difficulties and impaired draining of tears (Farnworth et al. 2016). Hairless breeds, such as the sphynx cat and Devon Rex, have difficulty regulating body temperature (Overgaauw et al. 2020), and are prone to other genetic disorders related to heart disease and muscular dystrophy.

In 1995, the Standing committee under the Council of Europe's Convention for the Protection of Pet Animals adopted a resolution on the breeding of pet animals. They urged for a new breeding policy towards healthier dog and cat breeds and indicated that prohibition of certain breeds might become necessary if breeding could not be done to reduce health problems (Cannon et al. 2001; Farnworth et al. 2016; Balmer et al. 2020). As of spring 2022, it has been determined by court in Norway that breeding of Cavalier King Charles Spaniels and English Bulldogs conflicts with, § 25 of the The Norwegian Animal Welfare Act, and therefore banned[9].

According to Dyrebeskyttelsen, the health situation and body condition of feral cats is often poor (See section 1.3.3). Contagious and transmissible diseases spread easily in dense cat populations. Feral cats are dependent on irregular food sources and must catch prey or find food sources. In addition, many are infested with internal- and external parasites. Poor body condition and lack of feed make them extra vulnerable to low ambient temperatures. Most feral cats do not receive veterinary care, and they are not vaccinated nor treated against parasites. Nevertheless, animal protection organizations take care of several thousand homeless feral cats each year, and they bring sick cats to the veterinarian for treatment or euthanasia. Dyrebeskyttelsen reports that infectious diseases of the respiratory tract and eyes and internal parasites and ear-mites are common among these cats. Further, veterinarians commonly find dental problems (broken teeth and infected teeth/root abscesses), wounds and subcutaneous abscesses caused by bites/claws. Feral cats also suffer from harsh weather conditions, freezing, malnourishment and hunger. Long-haired cats often have entangled fur. Females suffer from frequent litters and the kittens from consequences of inbreeding.

1.6.3.3 The cat's mental health and behaviour needs

The house cat is one of few domestic species that is allowed almost full behavioural freedom. Many cats can go in or out of the house as they please, receive food regularly, and may still hunt outdoors as they please. Freedom of choice and freedom to display most natural behaviours, like exploration, climbing and hunting, indicating good mental health (Tan et al. 2020). Pedigree cats and house cats in urban areas are more often kept indoors only, sometimes with access to an outdoor veranda or yard. The indoor life makes the cat highly dependent on the knowledge and actions of the owner to supply it with care and various items to stimulate activity. The indoor life may thus be less stimulating, and some cats become inactive and overweight. See more on behavioural needs in section 1.2.2.

1.6.4 Welfare of potential prey

Animal welfare originally focused on animals kept by humans. However, most definitions of animal welfare emphasize the state of the animal as perceived by the animal (1.6.1). Welfare includes the affective state or feelings, such as hunger, pain,

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[9] https://www.nrk.no/norge/domstolen_-forbudt-a-avle-disse-hunderasene-1.15805353

fear or distress on the negative side and the feeling of safety, control, or happiness on the positive side of the scale. Further, many definitions include the biological functioning of the animal, and whether it is healthy and fit, rather than sick or injured. The last approach often included in definitions of animal welfare is "natural living", based on the degree of natural elements in the life of the animal and whether the animal can display highly motivated behaviour. Thus, animal welfare focuses on the animal and not the care from humans, although the stockmanship is an important factor ensuring good welfare in kept animals. Human behaviour affects even wild animals, and it is relevant to consider the welfare for wild animals. One important difference between population conservation and animal welfare is that the former is concerned with the status of populations and ecosystems (Soulé 1995), whereas animal welfare focuses on the welfare of individuals.

The prey animals of cats are usually of small body size. The cat's deadly bite is placed on the back of neck and severs the spinal cord close to the prey's head, efficiently killing the prey (Leyhausen 1979 reported by Fitzgerald and Turner 2000). However, it may take a considerable amount of time before the cat decides to kill its prey. Sometimes, the prey is carried alive to the cat's home, probably a behaviour evolved as a mean to teach kittens to hunt and kill. Often, the cat "plays" with the prey before killing it (see 1.2.2.4). It has been suggested that play stems from cautiousness, to avoid being bitten by rodent prey which can defend themselves. Leyhausen (1979) report that hungry cats kill their prey more quickly than well-fed house cats.

Cats can kill small prey with one precise bite. However, the common play behaviour of catching and releasing it several times, sometimes resulting in freeze reactions in the prey, will undoubtedly cause stress, fear, and pain to the prey animal, which may last for substantial time (Figure 8). With larger prey, the killing process may be less efficient, causing more suffering.

Figure 8: Domestic cat showing characteristic play behaviour with rodent prey. Photo: Deyan Georgiev – Mostphotos.com

1.7 Regulations regarding keeping of cats

1.7.1 Legislation in other countries

There is no EU legislation on the keeping of cats (except when used in animal research), but some member states have national legislation. Many countries have legislation that restricts who (veterinarians or others) may euthanize cats and/or restricts the methods allowed for euthanasia. Some European countries have national Animal Welfare Acts, which state that animals cannot be killed without due reason. For example, in Italy, it is not allowed to euthanize healthy cats, and homeless cats are left where they are or placed in animal shelters, often funded by governmental bodies.

In some areas of Australia, cats born after July 1st, 2022, must by law remain on the owners property[10].

Trouwsborst and Somsen (2020) suggested that the European Nature Conservation Act, and in particular the EU Birds and Habitats directives, should have implications for the Member states' management of cats. The authors interpret the legislation so that stray and feral cats should be removed when they pose a threat to protected bird species and/or sites. They also claim that this legislation requires that the Member States ensure that owned cats do not roam outdoors.

Under the Swedish Animal Welfare Act from 2019, there is a directive on the keeping of dogs and cats (SJVF 2020:8, Saknr L 102). Among the many provisions, cats shall be allowed to display hunting behaviour. If cats are kept permanently indoors, the hunting behaviour must be satisfied using toys. Further, it is recommended that cats that are allowed outdoor access should be neutered or otherwise prevented from uncontrolled breeding.

Legislation on mandatory registration and ID-marking (microchipping) of cats are put into force in Sweden and Denmark from 2023 and will be put into force in Finland from 2027.

1.7.2 Regulations in Norway

1.7.2.1 Animal welfare legislation

Both owned and feral cats are protected by the Norwegian Animal Welfare Act (Dyrevelferdsloven, Norwegian Ministry of Agriculture and Food, 2009). The intention of the law is to promote good animal welfare and respect for animals (§ 1). The law states (§ 3) that animals have an intrinsic value irrespective of their usable value for humans, and that animals must be treated well and be protected from danger of

[10] https://www.cityservices.act.gov.au/pets-and-wildlife/domestic-animals/cats/cat-containment

unnecessary stress and strains. The law applies in general to mammals, birds, reptiles, amphibians, fishes, decapod crustaceans, octopuses and squids, and honeybees, irrespective of whether they are owned or wild. However, most paragraphs address the duties of humans who oversee animals. Although the law attributes intrinsic value to animals, it is explicitly stated in the preparatory documents that the value does not include a right to life. Legally, kept animals are regarded as the owner's property, and in Norway the owner has the right to terminate the life of his/her animals, whatever reason and independent of the age or health status of the animal. The only exception is that it is illegal to kill animals as an independent form of entertainment or competition (§12). Further, the animal must be handled, stunned, and killed in a proper, welfare friendly manner, as described in §12. The owner must have the competence necessary to care for the animals and secure their welfare (§ 6) according to the provisions given in the law and directives issued under the law. See also section 1.1.3 on breeding in relation to The Norwegian Animal Welfare Act, § 25.

Specific directives regulating animal welfare are made for most production animal species, as well as horses. The directives give more detailed provisions on how to keep and care for the animals. In contrast, this is no provision on the keeping of pet animals. For instance, identity marking is allowed according to the law (§ 10) and made mandatory in specific directives for some production species, but not for cats. For cats, mandatory identity marking has been proposed several times in Norway as a measure to find the owner of lost cats more easily, thus improving cat welfare and increasing owner responsibility. However, these proposals have to date not been implemented.

Surgical procedures or removal of healthy body parts are only allowed for justifiable health reasons (Animal Welfare Act, § 9), but neutering of animals is permitted if necessary due to animal welfare reasons or for other specific reasons. For many years, castration of cats and dogs was illegal according to the former Animal Protection Act. However, Dyrebeskyttelsen argued that neutering would largely benefit the welfare of cats by reducing the number of unwanted kittens. In 1994, the ban on castration of cats was abolished.

In a new version of a directive giving provisions on the euthanasia of dogs, cats and rabbits, which was sent for consultation the winter/spring of 2021, it is clearly stated that the directive includes feral cats. Feral cats and feral rabbits are not considered as wildlife but are controlled by the Animal Welfare Act § 12 regarding rules for killing of kept animals. The terms of the legislation mean that feral cats cannot be shot from a distance or caught in traps with a mechanism that kills the animal.

1.7.2.2 Nature Diversity Act

The purpose of the Nature Diversity Act (Norwegian Ministry of Climate and Environment, 2009) is to "protect biological, geological and landscape diversity and ecological processes through conservation and sustainable use, and in such a way that the environment provides a basis for human activity, culture, health and well-being, now and in the future, including a basis for Sami culture" (§ 1). The act states a duty for persons to act with care and take all reasonable steps to avoid causing damage to biological diversity (§ 6). Although the act focuses on the protection of species/populations and not the welfare of individual animals, there are some passages where animal welfare concerns are stated. According to § 15, unnecessary harm and suffering to wildlife and their nests and burrows, and unnecessary chasing of wild animals, shall be avoided. The precautionary principle, in case of lack of knowledge, is stated (§ 9).

Wildlife not specifically stated as game species are protected all year around. Game species can be hunted within a specific time of the year, and for some species (e.g., large cervids) there are restrictions both on the size and the age and sex-distribution of quota. Most wildlife species are protected during the breeding season, but invasive species, such as American mink (*Neovison vision*), may be hunted/trapped all year around. Further, small rodents and reptiles can be killed at any time to prevent damage to people or property (§17). According to the Wildlife Act (Viltloven[11]), traps designed for small rodents are exempt from rules on approval, which apply to traps meant for other species. Also, the use of poison is legal, although no longer for private persons. Still, also small rodents are protected by the Animal Welfare Act.

The domestic cat is exempt from the list of alien species mentioned in the directive on invasive species (Forskrift om fremmede organismer) because it is considered a domesticated animal, whereas crosses with non-domesticated Felidae species are included. Feral and stray cats are not considered as wildlife.

Earlier, the wildlife legislation included rules on keeping dogs on a leash or fenced, to protect wildlife from being disturbed or chased during the breeding season (from April 1st to August 20th). The provision was later transferred to the Dog Act[12] (2003). Requirements for use of leashes are valid irrespective of the dog's size, breed type or age, with exemptions only for some utility dogs. Similar restrictions on outdoor access for cats do not exist in Norway.

1.8 Mitigation measures used to prevent damage to biodiversity

There are two main approaches to reducing cat predation on small vertebrates; (1) through controlling the size of cat populations or (2) by restricting the individual cats' predation success (Cecchetti et al. 2021b). The population of cats can be controlled through either lethal-, or non-lethal measures. Reducing predation of outdoor cats can be achieved either through reducing the cats' access to prey via restricted outdoor access, reducing the hunting success of outdoor cats with various devices that make the cat more detectable, or that inhibits aspects of hunting behaviour, or through enrichment that reduce motivation to hunt by play objects or high-quality feed.

[11] https://lovdata.no/dokument/NL/lov/1981-05-29-38

[12] https://lovdata.no/dokument/NL/lov/2003-07-04-74

Measures used to avoid recruitment to-, and control of, feral cat populations include:

- Neutering and contraception
- Mandatory ID tagging and registration
- Legal restrictions on keeping cats as pets
- Culling of feral cat colonies/populations
- Different variants of the TNR (Trap, Neuter, Return) approach

Measures that reduce the individual cat's predation include:

- Keeping the cat indoors (full or part time)
- Use of outdoor enclosures
- Walking the cat outdoors on a leash
- Using collars with bells or other sound producing devices
- Use of plastic bibs that reduce the cats hunting success
- Use of colourful collar covers that make the cat more visible

Additional measures that can reduce the motivation to hunt include:

- Keeping cat breeds that have reduced hunting instincts
- Compensate for, or replace the stimulus for, hunting by playing or play objects
- Providing high-quality feed

These measures are described in more detail and evaluated for effectiveness under Norwegian conditions in section 5.

Implementation of new measures to reduce the negative impacts on biodiversity from cat predation might potentially benefit from information campaigns to cat owners and the general public about the rationale, implementation and efficiency of the measure. Informing about the potential negative effects from keeping free-ranging cats on biodiversity, in particular close to areas and habitats housing vulnerable prey species, might also affect the motivation in the general public to keep or purchase free-ranging cats. However, it is unclear if information campaigns as such will change the behaviour of cat owners: many cat owners report that they view cat hunting behaviour as normal and not something they would like to depress (Crowley et al. 2019 and 2020). Likewise, many cat owners value outdoor access for their cats (Crowley et al. 2020). These latter surveys were carried out in UK, but to the extent that Norwegian cat owners share similar values, information campaign might not have the preferred short-term outcome. Another survey from several large cities in UK, Australia, the USA, China, New Zealand and Japan showed that cat owners differed from non-owners both in terms of concerns over cats killing wildlife, but also their view on (stronger) regulations and legislations (Hall et al. 2016). Moreover, a survey contrasting "conservationists" and animal welfare professionals indicated contrasting priorities concerning cat welfare vs biodiversity conservation, but also agreement on several areas (Crowley et al. 2022).

1.9 Cats as predators of vermins/pests

Domestic cats might negatively affect the biodiversity through predation and indirect effects (section 3). This also potentially concerns several species of small mammals, such as bats, lagomorphs and certain small rodent species. Nevertheless, some of the small rodent species (e.g., brown rat *Rattus norwegicus* and house mouse *Mus musculus*) might may cause considerable harm on food and property (Stenseth et al. 2003), and they may carry pathogens that pose a threat towards humans (zoonotic agents or rodents as vectors). Historically, cats were considered utility animals due to their ability to catch small rodents (Crowley et al 2020a). This aspect is also discussed in section 1.5 and assessed in section 3.6. Even today, the ability of cats to kill or scare away rodents from farms and houses should not be underestimated (Figure 9). The widespread use of poison for rodent control has severe side-effects. Second and third generation anticoagulants, the most used rodenticides, have a long half-life. Thus, these substances have the potential to accumulate in body tissues of non-target animals that eat from the bait by accident, or that eat dead or sick rodents. High levels of anticoagulants have been found in dogs (Seljetun et al. 2020). Alphachloralose has been found to poison cats and dogs (Bernhoft et al. 2020). Further, anticoagulant rodenticides are found in many wildlife species in many countries, including Norway. The affected species include raptors and predators, such as eagles, owls, red fox, lynx, wolverine and wolf, sometimes in concentrations that might impact the condition of the animal (Seljetun et al. 2019; Madslien et al. 2019).

Figure 9: Cats still play a role as predators of vermins on farms, thus reducing the use of rodenticides that can have negative effects on biodiversity. Photo: https://www.flickr.com/photos/texaseagle/8261268337 (no changes made to the photo)

1.10 Effects of climate change

1.10.1 On potential prey species

A key conclusion of the UNEP Emissions gap report 2022 (UNEP 2022), is that there is currently no credible pathway to the Paris Agreement goals of restricting global warming below 1.5 to 2 degrees. For Norway, current forecasts indicate 3 to 5 degrees C increase, as higher latitudes are disproportionally warmed due to high latitude amplification. Temperature changes will entail rapid and drastic impacts to major Norwegian ecosystems that increasingly find themselves outside of the climate region to which they are adapted but with little time to move.

Birds are highly mobile and capable of adjusting their range and habitat to changing climate, but their food sources or habitats may not be as mobile (Van Doren 2022). Small mammals, many invertebrates and reptiles are expected to have great problems with range shifts, especially in fragmented landscapes dominated by land use change where roads, farmland, urban and suburban areas create barriers to animal movements (Wan et al. 2022).

Cats are contributing to making human habitation into a barrier for species range shifts. Moreover, with increasing climate stress and environmental stochasticity impacting the population dynamics of whole species assemblages, the ability to tolerate hunting pressures is likely to decrease for many species (Hilty et al. 2019, Harfoot et al. 2021, Lees et al. 2022, VKM 2022). Thus, climate change will likely decrease prey species' ability to tolerate disturbance and mortality from cats.

In short, climate change should be expected to interact negatively with cat presence in two ways. First, climate change may make wildlife *more vulnerable to the impacts* of cats, as stressed species become less able to compensate for the demographic impacts of predation and disease. Second, the presence of cats *amplifies the effect* of climate change since cats contribute to making human habitation into barriers to dispersal for species that need to shift their range in accordance with a changing climate.

1.10.2 On the survival of feral cats

Little is known about survival of feral cats in Norway. It can be assumed that if winter temperatures are a limiting factor, the survival prospects could be increased in a warmer climate. In addition, climate-induced changes in the distribution of potential prey species might affect the survival prospects of feral cats.

1.10.3 On change in pathogen fauna

In general, climate change in Norway allows a greater range of zoonotic pathogens to occur in Norway. Zoonotic pathogens and vectors tend to be opportunists with good dispersal ability and short generation times, and many are limited in distribution by winter cold, and/or thrive on weakened and stressed hosts (Nnadi and Carter 2021; Kubelka et al. 2022; Mora et al. 2022). While there are exceptions, we should expect a larger diversity and abundance in the protozoan, viral, bacterial and eukaryote parasites in Norway with warmer winters and increasing climate mismatch between current ecosystems and their climate conditions. Some known examples are listed in section 3.6.

2 Methodology and Data

2.1 Risk assessment methodology

2.1.1 Biodiversity

For the questions outlined in the ToR, hazards were identified and assessed separately. VKM assessed each potential hazard in four standardized steps: hazard identification, hazard characterization, likelihood, and risk characterization, as judged by the project-group experts. Table 11 describes the ratings for the level of confidence associated with each assessment.

Table 11. Qualitative scale used for describing the level of confidence in an assessment.

Rating	Confidence 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 is 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 predation on-, or competition with native species or spread of disease-causing organism. The known effects of the hazard are presented and referenced examples of the known impacts from other countries are usually included.

Under "**Hazard characterization**" the specific potential effects of the hazard in question are described under current Norwegian conditions. Examples include which species the focal species could compete with or predate on. The potential magnitude of the specific hazard is then characterized from "Minimal" to "Massive" as described in Table 12.

Table 12. Rating of the potential magnitude of impact on biodiversity in Norway

Rating	Impact descriptors
Minimal	Impact on biodiversity is limited to occasional deaths of individuals. No expected effects on the local-, regional-, or national population size.
Minor	Impact on biodiversity 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	Impact on biodiversity can result in moderately reduced abundance of one or more species, with potential implications on population viability on a regional level.
Major	Impact on biodiversity may cause severe reductions in the abundance of one or more species, including potential extinction of local or regional populations. Consequences may also affect ecosystem functions and services. The consequences are likely reversible should the assessed species be eradicated.
Massive	Impact on biodiversity may cause detrimental reductions in the abundance of more than one species, including extinction of local populations and potentially threaten the survival of the national population. Consequences are likely to affect ecosystem functions and services and are likely 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 13. In most cases (unless otherwise stated explicitly), the likelihood is based on expert judgement rather than specific modelling that estimate the likelihood.

Table 13. Rating of the likelihood of the specific impacts in the assessment.

Rating	Likelihood 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 potential impact of that hazard and the overall likelihood of this occurring (Figure 10).

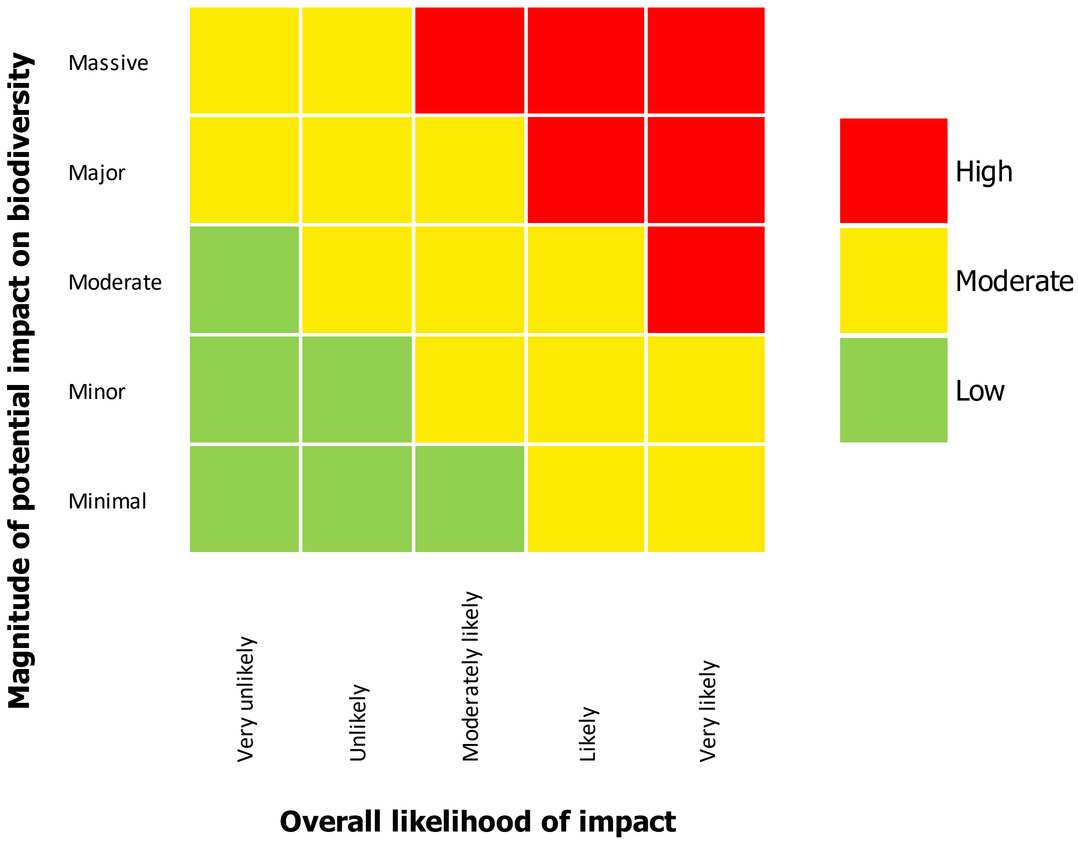

Figure 10: The conclusion of the risk assessments (low, moderate, or high) is based on the overall likelihood of the impact and the magnitude of the potential consequences of that impact on Norwegian biodiversity.

2.1.2 Animal welfare

The concept of animal welfare is defined in section 1.6.1. We assume that the presence of cats in an area will be noticed by most prey animals in question, either by smell or sight, and that awareness of predation risk will have a negative effect on the welfare of the prey animals. Prey animals may feel unsafe and become anxious. Usually, cats will be one among several predator species posing a threat to the prey animals. Thus, the effect of cats will be relatively small compared to other predators in areas with low density of cats. In urban and suburban areas, cats are more numerous and may be the most important predator for some prey species. There is likely variation among prey species regarding their emotional responses to seeing a cat or being disturbed or chased by a cat. Heterogeneous responses are probably even the case within a species due to age effects, previous experience, and individual stress coping ability. However, we will not consider such differences further. We assess that the welfare of the prey is affected similarly irrespective of whether an individual is hunted by a cat or a fox or a hawk. One exception is that cats, and in particular if they are fed at home, often play with the prey, catching, and releasing it repeatedly over some time before eventually killing it. In the welfare risk assessment, we evaluate the negative effects on the living prey animals. The effects on prey animals can vary from a transient feeling of fear to a prolonged post-capture period with pain and distress. Thus, strains on the prey animals may include negative emotions, such as anxiety, fear, pain, hunger, thirst, distress, frustration, lethargy, and malaise. Prey animals may become physically injured by the cat's claws or teeth. Small prey animals that the cat plays with may sometimes escape. Injuries caused by cat bites or claws are often painful and may become infected. Injuries may hamper important functions, such as motion/flying ability. When assessing the effect on animal welfare, both the intensity and time aspect of the negative experience or consequence must be considered. Mortality *per se* is considered among the population effects, however, suffering before death because death is not instantaneous, is included. Table 14 list the impact categories and the description of these, for assessments used on animal welfare.

Table 14. Rating of the magnitude of impact on prey animal welfare when exposed to cats.

Rating	Impact descriptors
Minimal	The prey animal perceives the cat as a threat and reacts towards it by being attentive and alert but has control of the situation.
Minor	The prey animal feels anxious and distressed, adjusts its behaviour to avoid the cat by changing feeding area or nesting site. It spends more energy on being alert and ready to flee/hide, but fitness remains relatively unchanged.
Moderate	The prey animal is disturbed or chased to an extent where it does not dare to feed itself or its offspring properly. The prey animal may permanently move to another location.
Major	The prey animal is injured by the cat so that physical functions, such as running or flying ability, are reduced. The prey animal suffers from anxiety and/or sustained pain from the injury and experiences long-lasting reduced fitness. If the animal has dependent offspring, the offspring might suffer from hunger and reduced care.
Massive	The prey animal is caught by the cat. The prey animal suffers from pain, fear, and distress for a prolonged period during the cats play before eventually being killed, or it escapes with fatal injuries. If the animal has dependent offspring, the offspring might suffer from hunger and reduced care.

2.2 Literature search and selection

The experts in the project group performed individual searches in the main scientific databases to elicit key information on the broad range of relevant topics. For literature on prey selection, hunting preferences and home ranges, studies were selected based on relevance to Norwegian conditions. For studies involving diseases not currently described in Norway, global climate change and general cat behaviour, literature was selected based on relevance for Norway.

The assessment was not based on the formal principles of systematic literature reviews, as the aim was not to survey a body of literature for evidence on a specific topic.

2.3 Data and information gathering

Data on number of cats were extracted from many sources, outlined in section 1.3.

Data on population sizes of breeding birds in Norway were based on Shimmings and Øien (2015). The bird species occurring regularly in urban and rural habitats in Norway were taken from Dale et al. (2015) and Smeby (2019), supplemented by Gjershaug et al. (1994) and Svorkmo-Lundberg et al. (2006).

Information regarding reproductive rates (mean clutch size, annual number of clutches, fledging rate) of birds were taken from Ricklefs (1969) and Haftorn (1971). General information on distribution, habitat preferences, nest site selection, foraging habitats and body size of Norwegian birds were based to a large degree on Haftorn (1971), supplemented by Gjershaug et al. (1994) and Svorkmo-Lundberg et al. (2006).

Data on kill rates and proportion prey brought home, number of hours active hunting per day, and other relevant factors were extracted from the literature and cited where used.

RAMSAR area geodata were downloaded from the Norwegian Environment Agency's database (https://kartkatalog.miljodirektoratet.no/Dataset/Details/1026?lang=en-us) in September 2022.

GBIF and Artsdatabanken species observation data were downloaded from the respective observational databases for each species using searches on the respective scientific names (and their known synonyms) in September 2022. Searches were constrained to Norway and with valid geolocation data. Search portals https://www.gbif.org/occurrence/search and https://www.artsdatabanken.no/)

Red List status for Norwegian species is based on the 2021 version from the Norwegian Biodiversity Information Centre (Artsdatabanken).

2.4 Estimation of uncertainty in total number of animals killed by cats in Norway annually

We estimated the total number of prey individuals killed by cats in Norway annually, based on values of extracted from the cited literature. We used a parametric bootstrap procedure (Efron and Tibshirani 1993) to estimate uncertainty in the estimated parameters. Uncertainties in the total kill rates in categories of cats (feral cats, and owned cats in urban and rural areas) were based on the bootstrap simulations, sampling from the ranges given in Table 19. For each iteration, we sampled a random number for each parameter from the range given in the table for the respective parameter (assuming a uniform distribution) and calculated the total kill rate for the respective cat category. We repeated the procedure 100,000 times and used the 2.5 and 97.5% quantiles of the bootstrap distribution as a measure of uncertainty. When estimating the total kill rates for the main taxonomic categories of prey (Table 21), we augmented the uncertainty with an additional uncertainty pertaining to the proportion of that taxonomic group among prey items. For each taxonomic group, we assumed a uniform distribution between 0.8 times mean value given in Table 20 as a lower limit and 1.2 times the value as an upper level. The resulting estimates are presented in Table 21. Again, we used the 2.5 and 97.5% quantiles of the bootstrap distribution as a measure of uncertainty.

3 General assessments

3.1 Background for the assessment of impact of cats on animal populations in Norway

3.1.1 Assessment of the total number of cats in Norway

The total number of owned cats in Norway is estimated to be in the range 646,000 – 770,000 (Table 3). Their relative distribution in rural versus urban areas (urban areas include residential and other built-up areas), and the numbers that are free-ranging are shown in Table 15.

Table 15. Total number of cats in Norway, and numbers depending on distribution (rural versus urban, where urban includes cats in residential and other built-up areas), whether they are free ranging with access to outdoor areas or remain indoors, and type of cat. Based on Eriksen (2014) and associated data. Numbers are rounded to nearest 1000.

Category	Mean	Range
Owned cats		
Non-pedigree cats	660,000	
Pedigree cats	40,000	
Total	700,000	646,000–770,000
Owned cats in rural areas		
Non-pedigree cats (37.9%[1])	247,000	
Pedigree cats (22.4%[2])	9,000	
Total	256,000	234,000–285,000
Owned cats in urban and residential areas		
Non-pedigree cats (62.1%[1])	405,000	
Pedigree cats (77.6%[2])	31,000	
Total	436,000	407,000–485,000
Owned free-ranging cats		
Non-pedigree (81.8%[1])	533,000	
Pedigree cats (27.0%[2])	11,000	
Total	544,000	508,000–605,000
Owned free-ranging cats in rural areas		
Non-pedigree (90.7%[3])	224,000	
Pedigree cats (35.7%[4])	3,000	
Total	227,000	212,000–253,000
Owned free-ranging cats in urban and residential areas		
Non-pedigree (76,3%[5])	309,000	
Pedigree cats (24,5%[6])	8,000	
Total	317,000	295,000–352,000
Feral cats		
Total number – based on expert opinion	75,000	50,000-100,000

[1]Of all owned house cats, [2]Of all owned pedigree cats, [3]Of all owned rural house cats, [4]Of all owned rural pedigree cats, [5]Of all owned urban house cats, [6]Of all owned urban pedigree cats

Overall, ca. 227,000 (32%) cats are free-ranging in rural areas and ca. 317,000 (45%) are free-ranging in urban areas. The remainder of the owned cats are indoor-only cats (ca. 151,000, 21%). The number of feral cats in Norway was estimated using expert opinion based on an evaluation of the available information. We assumed that there are between 50,000–100,000 feral cats in Norway (Table 15). See section 1.3.3. for a justification of the number of feral cats.

3.1.2 Assessment of the total number of animals killed by cats

To obtain a crude estimate of the total number of animals killed by cats per year in Norway across taxonomic groups, we combined information on the number of cats in Norway and an evaluation of published data on cat kill rates and prey species composition. Due to practical difficulties in observing cat predation rates without cat-borne video systems (Loyd et al. 2013a, Barmoen 2016, Seymour et al. 2020), there is little information on the total kill rate of cats. However, there is substantial information on the number of prey brought home by cats. Total kill rates (number of prey per time unit) may be estimated by correcting for the proportion of prey not brought home.

3.1.3 Assessment of the total number of prey brought home

Studies that have recorded number of prey brought home by owned cats have widely been used in assessments of the number of prey taken by cats per time unit. One potential bias in these studies is that the estimates might include cats that never or only rarely kill wild prey (Sedano-Cruz, 2022), but the extent of this is unknown. We included only studies from northern Europe to increase representativeness for Norwegian conditions. Kill rates might vary among seasons, and we included only studies that presented data covering a full year. Based on the nine included studies, median number of prey brought home per cat per year was 9.7 (range: 5 – 15) (Table 16). For our analyses, we used a rate of 10 prey brought home per cat per year with a range of 5 to 15.

Table 16. Number of prey brought home per cat per year in studies from Northern Europe covering a full year.

Country	Prey/cat/year[1]	Source
Germany	5.7	Borkenhagen 1978
UK	14.0[2]	Churcher and Lawton 1987
UK	4.3[2]	Baker et al. 2008
Poland	71.9	Krauze-Gryz et al. 2012
UK	5.5	Thomas et al. 2012
Finland	32.0	Kauhala et al. 2015
UK	9.7[3]	McDonald et al. 2015
Norway	11.0	Kulemann and Dangstorp 2019a
UK	5.7	Pirie et al. 2022
Mean	**17.8**	
Median	**9.7**	

[1] Values refer to free-ranging cats unless otherwise stated, [2] Not stated the proportion of the cats that were free-ranging, value based on all cats, [3] Not stated whether all cats were free-ranging

3.1.3.1 Proportion of prey brought home

Several studies have shown that cats do not bring home all prey individuals (Table 17). Two studies used radio-tracking to follow cats and record predation events, but these studies had low sample sizes. One study compared number of prey brought home with assumed true kill rates based on analyses of scat and gut contents. However, there are potential problems with this type of analyses regarding evaluating the number of prey taken due to differential digestibility and to hunting behaviour where prey are killed but not eaten. Three studies used cat-borne video cameras, and we regard this method to be the most reliable for estimating proportion of prey brought home. For these three studies (as well as for the other three studies), a median of ca. 20% of prey were brought home. Based on the available information, a reasonable range would be 10 to 30%. The estimates indicate that the observed kill rate in studies recording number of prey brought home should be multiplied by 3.3 to 10 (median: 5) to obtain an estimate of total number of prey. The proportion of prey brought home might vary for different prey taxa, but we were not able to control for this.

Table 17. Estimates of proportion of prey that is brought home by free-ranging house cats.

Country	Method	No. of prey	Prop. of prey brought home	Source
US	Radio-tracking	4	30%[1]	Kays and DeWan 2004
Scotland	Radio-tracking	25	13–28%[2]	Maclean 2006
Poland	Scat and gut samples	357	9%[3]	Krauze-Gryz et al. 2012
US	Video camera	39	23%	Loyd et al. 2013a
Norway	Video camera	83	0%	Barmoen 2016
South Africa	Video camera	62	18%	Seymour et al. 2020
Mean			**17%**	
Median			**20%**	

[1] Proportion estimated indirectly via comparison of kill rate observed during radio-tracking versus kill rate reported by cat owners (number of prey per time unit), [2] Lower value based on comparison of kill rate observed during radio-tracking versus kill rate reported by cat owners, upper value based on proportion of observed kills (n = 25) that were recorded by cat owners, [3] Proportion estimated indirectly via comparison of kill rate assumed from scat and gut analyses versus kill rate based on prey brought home.

3.1.4 Assessment of kill rates in urban versus rural areas

In total, we reviewed four studies that assessed the difference in number of prey brought home by cats living in rural versus urban areas (Table 18). Based on these studies and assumed kill rate of 10 (range: 5 – 15; Table 16), estimated kill rates are twice as high in rural versus urban areas (13.3 in rural areas (range: 6.7 – 20.0), compared to urban and residential areas (6.7 - range: 3.3 – 10.0)).

Table 18. Number of prey brought home per cat per year in rural versus urban areas.

Country	Rural rate	Urban rate	Ratio	Source
Finland	4.4	3.5	1.26	Kauhala et al. 2015
Poland	-	-	2.50[1]	Krauze-Gryz et al. 2017
Norway	13.7	8.9	1.54	Kulemann and Dangstorp 2019a
UK[2]	7.9	2.0	3.95	Pirie et al. 2022
Mean			**2.3**	

Country	Rural rate	Urban rate	Ratio	Source
Median			**2.0**	

[1] Urban rate was modelled to be 40% of rural rate, [2] The study compared cats in suburbs with cats having access to natural areas

3.1.5 Assessment of kill rate of feral cats in Norway

There is no information about kill rates or diet of feral cats in Norway, and limited information from other countries in northern Europe. Liberg (1984a) calculated that feral cats in southern Sweden had an intake rate (measured in terms of total prey weight) 4.5 times that of owned cats. Loss et al. (2013) reviewed studies of feral cats from North America, Europe and Oceania, and reported kill rates in the range of 213 to 364 prey per feral cat per year. These estimates are about 4 to 7 times higher than owned domestic cats in Europe. However, estimates likely vary substantially in relation to ecological conditions and study areas. Because of a more northerly location with poorer hunting possibilities, in particular during winter, feral cats in Norway may be more dependent on food provided by humans than feral cats in more southern countries (see section 1.3.3 for details of feral cat ecology in Norway). In their estimation of kill rates of cats in Norway, Heggøy and Shimmings (2018) assumed that kill rates of feral cats were similar to those of owned cats. In our estimation of total kill rates, we assumed that the kill rate of feral cats was 1 to 3 times the kill rate of owned domestic cats.

3.1.6 Assessment of the total number of prey killed annually

For owned cats in urban and rural areas, we calculated total annual kill rates as:

$$Annual\ kill\ rate_j = N_j * P_j * CF$$

where "Annual kill rate$_j$" is the total annual kill (for all owned free-ranging cats) rate in habitat j (urban or rural), N_j is the number of owned free-ranging cats in the respective habitat, P_j is the number of prey brought home in the respective habitat (indexed j) and CF is the correction factor. For feral cats, the calculation was somewhat simplified, as the estimate of prey brought home and the correction factor was pooled into a common estimate of individual kill rate (KR_{ferral}^{ind}):

$$Annual\ kill\ rate_{ferral} = N_{ferral} * KR_{ferral}^{ind}$$

Based on these assumptions, we estimated that domestic cats kill 33.2 million animals (95% bootstrap interval: 21.3 – 68.9 million) per year in Norway (Table 19). As is evident from the bootstrap distributions, there is substantial uncertainty in the total number of animals killed by cats in Norway.

Table 19. Parameters used to estimate number of prey killed by cats per year in Norway (i.e., total annual kill rates of cats in Norway). Numbers of cats are rounded to nearest 1,000 and prey killed to nearest 100,000

Parameter	Middle value	Range
Number of owned free-ranging cats		*Range*
Rural areas	228,000	212,000 – 253,000
Urban and residential areas	316,000	295,000 – 352,000
Number of prey brought home/cat/year	10	5–15
Rural areas	13.3	6.7–20
Urban and residential areas	6.7	3.3–10
Correction factor	5	3.3–10
Number of feral cats	75,000	50,000–100,000
Predation rate of feral cats	100	50–150
Number of prey killed annually		*95% bootstrap interval*
By owned cats in rural areas	15.1 million	7.4 – 38.3 million
By owned cats in urban areas	10.6 million	5.2 – 27.8 million
By feral cats	7.5 million	3.3 – 13.1 million
Total	33.2 million	21.3 – 68.9 million

3.1.7 Assessment of the taxonomic distribution of prey

Eleven studies from northern Europe presented data on how prey was distributed among different taxonomic groups (Table 20). Two of these studies (Kauhala et al. 2015, Krauze-Gryz et al. 2017) indicated that rural cats had a higher proportion of mammals and reptiles among prey brought home than urban cats, whereas urban cats had a higher proportion of birds. We used mean values of the eleven studies and differentiated between rural and urban proportions based on Kauhala et al. (2015), as data from Finland are considered more relevant for Norwegian conditions than data from Poland (as used in Krauze-Gryz et al. 2017).

Table 20. Distribution of prey of cats across taxonomic groups in northern European studies.

			% herptiles							
Country	**% mammals**	**% birds**	**% reptiles**		**% amphibians**	**% fish**	**% insects**	**% inverte-brates**	**% unidentified**	**Reference**
Germany	77.3	22.0	0.3		0	0	0.3	0	0	Borkenhagen 1978
UK	49.1	27.2	0		0[1]	0	0[1]	0	23.7	Churcher and Lawton 1987
UK	68.6	23.6	1.0		4.1	0.2	0.9	0.3	1.3	Woods et al. 2003
UK	66.3	24.0	5.1		4.0	0	0	0.6	0	Baker et al. 2008
Switzerland	66.2	9.2	0		0	0	17.6	0	7.0	Tschanz et al. 2011
Poland	69.8	13.1	7.2		0.7	0.9	-	8.2[2]	0	Krauze-Gryz et al. 2012
Rural	76.8	9.9	11.4		0.9	1.0	0	0	0	Krauze-Gryz et al. 2017

			% herptiles							
Urban	57.5	36.5	3.5		0.7	1.8	0	0	0	Krauze-Gryz et al. 2017
Finland	72.2	16.2		2.8[3]		0	0.4	0.1	8.3	Kauhala et al. 2015
Rural	Ca. 79	13.7	5.4		-	-	-	-	-	Kauhala et al. 2015
Urban	Ca. 70	23.6	2.6		-	-	-	-	-	Kauhala et al. 2015
UK	65.7	26.4	4.4		0.2	0	0	0	3.4	McDonald et al. 2015
Norway	12.0	7.2	0		0	0	80.7	0	0	Barmoen 2016
Norway	40.5	35.8	X[4]		X[4]	X[4]	19.8	X[4]	0	Kulemann and Dangstorp 2019a
UK	69.1	24.8	3.1		1.3	0	-	1.6[2]	0	Pirie et al. 2022
Mean[5]	**59.7**	**20.9**	**2.3**		**1.1**	**0.1**	**10.9**	**1.1**	**4.0**	
Adj values[6]										
Rural	63.7	15.5	3.7		1.1	0.1	10.9	1.1	4.0	
Urban	55.7	26.3	0.9		1.1	0.1	10.9	1.1	4.0	

[1] Reported as caught, but not quantified and not included in percentages. [2] This study did not differentiate between amphibians and reptiles [3] May also include insects. [4] Percentage not stated, the four types of other prey amounted to 3.9% in total. [5] Mean of main studies, not including values separated in rural versus urban areas. [6] Rural and urban kill rates for mammals, birds and reptiles differentiated following values reported by Kauhala et al. (2015), and adjusted to 100% for the sum of rural and urban areas.

There are indications that some taxonomic groups of prey are brought home less often than others. Maclean (2006) found that prey taken in the field had a higher proportion of mammals and a lower proportion of birds compared to prey brought home, but the field data were based on a total of only 25 predation events. Krauze-Gryz et al. (2012) did not find differences in the proportion of mammals and birds brought home but found that reptiles were brought home more often and amphibians less often than other taxonomic groups. In a study from South Africa, mammals were brought home more often than expected, whereas reptiles were brought home less often than expected (Seymour et al. 2020). Overall, these studies provided conflicting evidence for potential biases in estimated kill rates for different taxa.

A review indicated that feral cats have a prey composition fairly similar to that of owned cats (Széles et al. 2018). Their data were to a large degree from study sites in southern Europe, but they found that mammals constituted 75.5% of the prey items of feral cats, birds 9.1%, reptiles 4.5%, fish 0.5%, invertebrates 6.3% and the remainder being household food. These values are quite similar to those of rural cats reported in Table 20. Thus, we used the values for rural cats also for feral cats in Norway.

3.1.8 Total number of prey killed in Norway annually

Based on the values presented in Table 19, VKM estimates that 33.2 million prey (95% bootstrap interval: 21.3 – 68.9 million) are killed by domestic cats each year in Norway. This number include both owned free-ranging cats and feral cats. Based on the relative composition of prey species as presented in Table 20, VKM estimates that the annual predation by domestic cats includes 20.3 million mammals (95% bootstrap interval: 12.5 – 42.7 millions), 6.3 million birds (95% bootstrap interval: 3.9 – 13.8 millions), 0.9 million reptiles (95% bootstrap interval: 0.6 – 2.1 millions), 0.4 million amphibians (95% bootstrap interval: 0.2 – 0.7 millions), 3.6 million insects (95% bootstrap interval: 2.3 – 7.7 millions), 0.4 million invertebrates other than insects (95% bootstrap interval: 0.2 – 0.7millions) and a small number of fish annually. These numbers are presented in more detail in Table 21.

The estimates are based on the proportion of each taxonomic group from eleven studies in several countries in northern Europe, listed in Table 20. For mammals and birds, the variation among studies is relatively moderate, and most studies indicate that mammals constitute most prey with birds ranked second (Table 20). However, for reptiles there is substantial variation among studies, and some studies did not record reptiles as prey. The abundance of reptiles is likely to have a latitudinal gradient, and there are fewer species and smaller populations of reptiles in Norway than in the European studies we have compared with. We regard it likely that the average value of 2.3% of all prey is too high under Norwegian conditions. The proportion of insects among prey is also very variable (Table 20). We consider it likely that many insect prey are not brought home, so that the total number of insects killed may be substantially larger than reported. Underestimates of kill rates may also apply to other invertebrates. The number of fish is likely overestimated for Norwegian conditions, and the number of fish killed by cats could be close to zero based on most European studies, which has reported that cats do not prey on fish. Also, studies reporting a small proportion of fish among the prey may not be relevant for Norwegian native fish (section 1.4.9.4).

Only one comprehensive previous attempt has estimated the number of prey (birds) killed by cats in Norway (Heggøy and Shimmings 2018). They estimated that cats kill 7 million birds per year in Norway (range 2.0–19.8 million), a figure similar to our estimate of 6.3 million (range: 3.9-13.8 million).

Table 21. Estimated number of individuals killed by cats per year in Norway separated among taxonomic units. Estimations were based on the proportions of taxonomic groups among prey brought home in eleven studies from northern Europe (see Table 19). It is important to note that for e.g., reptiles and insects the proportions may have biases (see discussion in main text), specifically that the reported numbers of reptiles are too high, and the reported numbers of insects are too low. Numbers are rounded to nearest 10,000.

Taxonomic group	Rural areas	Urban areas	Feral cats	Total	95% bootstrap interval
Mammals	9,640,000	5,900,000	4,780,000	20,300,000	12,580,000– 42,670,000
Birds	2,350,000	2,790,000	1,160,000	6,300,000	3,940,000 – 13,830,000
Reptiles	560,000	100,000	280,000	930,000	600,000 – 2,140,000
Amphibians	170,000	120,000	80,000	370,900	210,000 – 700,000
Fish	20,000	10,000	10,000	40,000	20,000 – 70,000
Insects	1,650,000	1,160,000	820,000	3,620,000	2,280,000 – 7,750,000

Taxonomic group	Rural areas	Urban areas	Feral cats	Total	95% bootstrap interval
Invertebrates	170,000	120,000	80,000	330,000	210,000 – 700,000
Unidentified	610,000	420,000	300,000	1,330,000	830,000 – 2,810,000
Total[1]	**15,130,000**	**10,600,000**	**7,500,000**	**33,230,000**	21,340,000– 68,900,000

[1] From Table 19

3.2 Assessment of the impact of cat predation on birds

3.2.1 Proportion of bird populations killed by cats

Based on bird atlas data from Norway, there are between 29–55 million pairs of birds of 255 species (Shimmings and Øien 2015). However, cats mostly live in urban and rural habitats (Figure 14). Thus, many bird species live in habitats with few or no cats, in particular species breeding mostly in 'interior' boreal forests, e.g., grouse (Tetraonini, skogshøns), several woodpeckers (Picidae, spetter) and some songbirds (Passeriformes, spurvefugler), many species breeding in mountains, seabirds and wetland species. The 99 bird species that we consider occur regularly in rural and urban habitats (based on Dale et al. 2015 and Smeby 2019 and associated data), and that constitute most of the bird communities in these habitats, have total populations of ca. 37.8 million pairs in Norway. In terms of individuals, the estimated range of bird numbers is between 51-100 million. A list of bird species is found in Appendix I.

In addition to adult birds, cats probably prey extensively on recently fledged birds (Krauze-Gryz et al. 2017, Heggøy and Shimmings 2018). Note that population growth rate is typically less sensitive to variation juvenile survival, and that the potential for compensation is likely higher (Peron 2013). To assess the number of young birds produced per year, we extracted information on reproductive rates of birds in Norway from Haftorn (1971). The 99 bird species occurring regularly in rural and urban habitats have a mean clutch size of 5.51 eggs and lay on average 1.19 clutches per year. Under this assumption, the average number of eggs produced is 6.48 eggs per pair per year across species. Although cats may potentially prey on eggs or young in nests, we consider that young birds mainly become potential prey for cats when they have fledged from their nests.

There are no reviews of average fledging rate of European birds, and specific studies have been done on some, but far from all, species of interest here. The most relevant information on fledging rate is analyses made by Ricklefs (1969). Based on North and Central American bird species, he found a latitudinal gradient in fledging rate (egg success) of open-nesting passerine bird species (songbirds) from 32% in humid tropical regions, 47% in temperate regions, and to 60% in Arctic regions. This suggests an average fledging rate of 50% as an approximation for Norwegian conditions, yielding a yearly average production of 3.24 fledglings per pair per year. The 99 bird species then produce between 76.2 and 150.1 million (median value 137.6) fledglings per year, and the total number of birds that may constitute the prey base for cats is about 213 million individuals (assumed range: 127.4 – 250.3 million).

The estimated 3.9 – 13.8 million birds killed by cats annually (see section 3.1.7) will according to these calculations represent a predation rate of 1.7 – 7.4% of the total populations of bird species occurring regularly in rural and urban habitats. For perspective, adult annual survival probabilities for 123 species of North American songbirds was reported to range between 42-71% (Martin, 1995).

However, many of the bird species occurring regularly in rural and urban habitats have substantial parts of their populations in areas not affected by cat predation. This is in particular the case for many species breeding in forests. Although they are common in rural areas, and many also in urban areas, e.g., Eurasian wren (*Troglodytes troglodytes*, gjerdesmett), European robin (*Erithacus rubecula*, rødstrupe), several thrushes (*Turdus* spp., troster), warblers (*Sylviidae* and *Phylloscopidae*, sangere), tits (*Paridae*, meiser) and finches (*Fringillidae*, finker), most of their populations breeds in forest. Forest covers 37.4% of Norway, whereas built-up areas cover 1.7% and cultivated land 3.5% (Statistisk sentralbyrå; Arealressurser). Cats rarely venture far from their homes (e.g., Kays et al. 2020, Bischof et al. 2022), and mainly areas relatively close to residential houses will be occupied by cats. In a site-occupancy analyses of cat distribution based on automatic wildlife cameras in south-eastern Norway (Nyheim, 2022), cats were present at 70% and 47% of forest sites 100m and 200m from home respectively. Moreover, cat presence dropped to < 10% more than 900m from their residential houses. Based on this model, cats were present in 13% of forests in south-eastern Norway. Thus, the area of forest not affected by cat predation is several times larger than the combined area of urban and rural habitats and forest affected by cat predation. This needs to be considered when assessing the proportion of the populations of the 99 bird species that live in rural and urban habitats.

There are no available estimates of the total number of birds living in rural and urban habitats in Norway. However, as a rough approximation we excluded 50% of the population of the 23 most abundant species where we can assume that at least 50% of the population is out of reach for cats (i.e., in forested areas located far from humans). This will result in a bird population in rural and urban areas of ca 136 mill individuals (assumed range: 95 – 178 millions). The number of bird individuals killed by cats then represent 4.6% (95% bootstrap interval: 2.7 - 11.6%) of the total bird population in rural and urban habitats. This might still be an underestimation of the true proportion of the rural and urban bird populations killed by cats, because the proportion of the populations of these 23 species that are out of reach of cats is likely often much larger than 50%, and substantial parts of the populations of at least some of the other 76 species are also out of reach.

These lines of reasoning focus on the majority of cat predation taking place in rural and urban habitats. This does not mean that bird species in other habitats are not affected by cat predation. From ringing recoveries in Norway (Heggøy and Shimmings 2018), we know that cats occasionally take seabirds, shorebirds, ducks and other species not included in the analyses presented above. However, we consider that losses to cat predation outside rural and urban areas occur at low rates and likely have little population impacts on a national scale but could be important at a local scale. For example, Michaelsen (1998) suggested that cats may take several hundred shorebirds (e.g., *Charadriidae* and *Scolopacidae*, vadefugler) per year in the Ramsar site Makkevika in Møre and Romsdal. Heggøy and Shimmings (2018) mention several islands (Utsira, Fedje, Røst and Vardø) where the combined effect of large numbers of house cats and feral cats may represent a threat to seabirds and shorebirds. Cats may also be a threat to birds in wetland nature reserves, such as Østensjøvannet in Oslo (Venli 2021).

3.2.2 Assessment of bird vulnerability to cat predation

The estimations above indicated that cats annually kill 2.7% - 11.6% of the total rural and urban populations of the 99 bird species occurring regularly in these habitats. It is likely that this kill rate is highly variable among bird species. As discussed earlier (see section 1.4.3.2.), bird species with small body size, those nesting or feeding on the ground, and those living close to humans, may be much more vulnerable to cat predation than other species. To identify what species are most vulnerable to cat predation, we calculated a vulnerability index based on body size, nesting or foraging on or close to the ground, and proximity to human habitation. The index considers foraging and closeness to humans during the breeding season when much of the cat predation takes place (e.g., Churcher and Lawton 1987, Krauze-Gryz et al. 2017).

Previous studies of the relationship between the body size of birds and cat predation rate indicate that bird species vary substantially in predation risk. Møller et al. (2010) found that in Denmark predation rate decreased with increasing body size, with the highest rate of losses for species with mass <100 g. Bonnaud et al. (2011) found that on islands across the world a large proportion of the bird species taken by cats had a body mass below 150 g. Woinarski et al. (2017b) found that predation rate by feral cats in Australia was highest for bird species with intermediate body mass (60–300 g) and declined strongly for larger birds. However, they cited other Australian studies indicating highest vulnerability for birds below 100 g. Based on these studies, we classified vulnerability to predation in relation to body size on an ordinal scale from 0.1 to 5 (Table 22). Thus, a small-sized bird, i.e., < 100 g, e.g., European robin (*Erithacus rubecula*, rødstrupe), is assumed to have a predation risk 50 times higher than the largest birds > 1,000 g, e.g., Northern raven (*Corvus corax*, ravn).

Ground nesting and ground foraging increase the predation risk (e.g., Blancher 2013), but little quantitative information is available. Woinarski et al. (2017b) estimated that bird species nesting < 1 m above ground had a predation rate almost twice as high as species nesting > 1 m above ground. They also found that ground foragers had a predation rate ca. 50% higher than species not foraging on the ground. We are not aware of relevant information for Norwegian bird species, but it is likely that nesting or foraging on the ground leads to a higher predation rate than suggested by Woinarski et al. (2017b). Thus, we assume ground nesters, e.g., European robin (*Erithacus rubecula*, rødstrupe), have a predation risk twice as high as those nesting low in bushes, e.g., common blackbird (*Turdus merula*, svarttrost), and four times as high as those nesting high in trees, e.g., fieldfare (*Turdus pilaris*, gråtrost) or in cavities, e.g., blue tit (blåmeis *Cyanistes crisatus*). We assume that species foraging on the ground most of the time, e.g., European robin (*Erithacus rubecula*, rødstrupe), has twice as high predation risk as species foraging on the ground only part of the time, and 20 times higher predation risk than those rarely foraging on the ground, e.g., swallows (*Hirundinidae*, svaler) (Table 22).

Cats generally hunt at short distances from their homes, and bird species that breed some distance away from human residences, such as in the middle of large fields of farmland, were assumed to have a lower predation risk than species of garden birds that breed in or near houses (Table 22). Closeness to humans was defined as < 100 m from houses to match the hunting range of most cats (Kays et al. 2020, Bischof et al. 2022). Species that spend much of their time near humans, e.g., house sparrow (*Passer domesticus*, gråspurv), were assumed to have a predation risk twice as high as species being near humans only part of the time, and four times higher risk than species being near humans only rarely, e.g., Eurasian skylark (*Alauda arvensis*, sanglerke).

Table 22. Classification of variables affecting the vulnerability of bird species to cat predation, and their weight in vulnerability index calculation.

Variable	Categories	Weight
Body mass		
	< 100 g	5
	100–250 g	2.5
	250–500 g	1
	500–1,000 g	0.5
	> 1,000 g	0.1
Nest site		
	On the ground	2
	Low in bushes	1
	High in trees or in cavities	0.5
Foraging site		
	Mostly on the ground	2
	Partly on the ground	1
	Rarely on the ground	0.1
Closeness to humans		
	Often	2
	Sometimes	1
	Rarely	0.5

The vulnerability weights (Table 22) were used multiplicatively for the 99 bird species that occur regularly in rural and urban habitats, and this resulted in an average vulnerability index of 3.4 (range 0.003–40) (see Appendix I). There were 19 species with a vulnerability index of ≥ 10 (Table 23), of which seven are red-listed in the Norwegian Red List for species. These constitute the species that are likely to experience the highest predation rates from cats in urban and rural areas.

Table 23. Overview of the 19 bird species with the highest vulnerability index (≥ 10) to cat predation. Across all species, the index averaged 3.4. High vulnerability is related to small body size, nesting or feeding on the ground, or occurring close to human habitation.

Species	Scientific name	Norwegian name	Red List status	Vulnerability index
Common quail	*Coturnix coturnix*	Vaktel	Vulnerable (VU)	10
Wood lark	*Lullula arborea*	Trelerke	Near threatened (NT)	10
Eurasian skylark	*Alauda arvensis*	Sanglerke	Near threatened	10
Tree pipit	*Anthus trivialis*	Trepiplerke	NA	10
Meadow pipit	*Anthus pratensis*	Heipiplerke	NA	10
Yellow wagtail	*Motacilla flava*	Gulerle	NA	10
White wagtail	*Motacilla alba*	Linerle	NA	10
Eurasian wren	*Troglodytes troglodytes*	Gjerdesmett	NA	10
European robin	*Erithacus rubecula*	Rødstrupe	NA	40
Whinchat	*Saxicola rubetra*	Buskskvett	NA	10
Common blackbird	*Turdus merula*	Svarttrost	NA	10
Redwing	*Turdus iliacus*	Rødvingetrost	NA	10
European starling	*Sturnus vulgaris*	Stær	Near threatened (NT)	10
House sparrow	*Passer domesticus*	Gråspurv	Near threatened (NT)	10
Eurasian tree sparrow	*Passer montanus*	Pilfink	NA	10
Twite	*Linaria flavirostris*	Bergirisk	NA	10
Yellowhammer	*Emberiza citrinella*	Gulspurv	Vulnerable (VU)	10
Ortolan bunting	*Emberiza hortulana*	Hortulan	Critically endangered (CR)	10
Reed bunting	*Emberiza schoeniclus*	Sivspurv	NA	10

3.2.3 Assessment of population impacts for birds

The potential impact of cats on the populations of individual species is likely to depend on their vulnerability to cat predation and the proportion of the population that may be affected by cat predation. Some species may have their entire populations in areas where cats are common (e.g., house sparrows) whereas others have substantial parts of their populations in other habitats (e.g., several common forest bird species). Species that do not have potential source populations in other habitats may be more likely to suffer population declines due to cat predation than species with source populations in forest habitats. Finally, species with small or declining populations due to multiple types of threats, such as red-listed species, may have a lower potential to absorb an additional impact from cat predation.

To identify the bird species populations most likely impacted by cat predation, we combined the three criteria high vulnerability index, most of their distribution close to humans, and red-listed species). There were 10 species that had a combination of a) above-average vulnerability to cat predation, b) most of the population occurring in rural or urban habitats, and c) classified as threatened (CR, EN, VU) or near threatened (NT) on the Norwegian Red List (Stokke et al. 2021) (Table 24).

Table 24. Overview of the 10 bird species most likely to suffer population impacts from cat predation. These species had a) above-average vulnerability index (≥ 3.4) to cat predation, b) most of their populations in rural and urban habitats, and c) were red-listed in the Norwegian Red List for Species.

Species	Scientific name	Norwegian name
Common quail	*Coturnix coturnix*	Vaktel
Corn crake	*Crex crex*	Åkerrikse
Northern lapwing	*Vanellus vanellus*	Vipe
Eurasian collared dove	*Streptopelia decaocto*	Tyrkerdue
Eurasian skylark	*Alauda arvensis*	Sanglerke
European starling	*Sturnus vulgaris*	Stær
House sparrow	*Passer domesticus*	Gråspurv
European greenfinch	*Chloris chloris*	Grønnfink
Yellowhammer	*Emberiza citrinella*	Gulspurv
Ortolan bunting	*Emberiza hortulana*	Hortulan

3.3 Assessment of impact of cat predation on mammals

Studies from several countries, including Norway, have found that mammals are the prey most often brought home by cats (Table 25). The main factors determining if a mammal species will be a potential prey to cats include body size, the extent of their distribution that overlaps with that of cats, and their abundance.

All mammals recorded in Norway except introduced/alien and species that are too large to be preyed upon by cats were evaluated, (Table 26). Species inhabiting rural or urban habitats are expected to be more likely to be predated by cats (Figure 11).

3.3.1 Mammalian cat prey in Northern Europe

Among mammalian taxa, rodents are by far the most common prey across eight studies from northern Europe (Table 25). Species of shrews and lagomorphs are also relatively common among cat prey species (Table 25).

In some of the studies, shrews are reported under the taxonomic groups Soricomorpha or Insectivora, and the reported number of individuals caught may thus also include European mole (*Talpa europaea*). The lagomorphs reported in these studies are primarily rabbits (*Oryctolagus cuniculus*) and European hares (*Lepus europaeus*) (Table 20). Both species are on the list of alien species in Norway. In three of the studies, bats and mustelids were among the prey species (Table 25).

Table 25. The proportion (%) of mammalian prey items of cats in eight northern European studies, and the distribution of groups of mammals recorded as cat prey (% of all mammals).

Country	Mammals	Bats	Lagomorphs	Mustelids	Rodents	Shrews	Other	Reference
Germany	77.3	0	17.6	0	62.3	11.3	8.8	Borkenhagen 1978
UK	68.6	0.30	12.6	0.12	64.6	17.5	4.9	Woods et al. 2003
UK	66.2	0	0	0	98.5	1.5	0	Baker et al. 2008
Switzer-land	80.3	0	0	0	95.0	5.0	0	Tschanz et al. 2011
Poland	72.6	0	0.2	0.3	85.4	11.8*	2.3	Krauze-Gryz et al. 2017
Finland	79.2	1/1178	2	3/1178	90.8	6.9*	2.0	Kauhala et al. 2015
UK	65.7	0	**	0	66.6	24.3	9.1	McDonald et al. 2015
UK	69.1	0.3	4.5	0	92.0	0	7.7	Pirie et al. 2022
mean	72.4	0.08	5.3	0.05	81.9	9.8	4.4	
median	70.85	0	2	0	88.1	9.1	3.6	

* the number may include moles in addition to shrews. ** no exact number of lagomorphs was specified, but rabbit was mentioned as a non-native species caught.

3.3.2 Potential mammal prey species in Norway based on body size

Based on the reviewed literature, we assume that body size (or body mass, which often correlates with body size) and exposure to cats presumably are the main factors determining the vulnerability of wild mammals to cat predation. Based on the body mass criteria alone, we consider 37 of the 53 terrestrial mammalian species found in mainland Norway (introduced species not included) to be potential prey to domestic cats (Table 26). The list of species includes 11 bats, 1 erinaceid, 1 lagomorph, 4 mustelids and 14 rodents. Documentation of cat predation was found for 32 of these species.

All the bat and shrew species in Norway are within the size range of cat prey. For rodents, all species except the Eurasian beaver (*Castor fiber*) are within the size range also in adult life stage. Larger rats may not be among preferred prey, but juveniles and smaller individuals are known to be caught by cats (Childs, 1986). Among carnivores, two mustelids are within the size range for cat prey, including the least weasel and the stoat (Table 26). The pine marten is above the size expected for cat prey but is included as the species has been documented caught in Finland (Kauhala et al, 2015). The lagomorph is above the typical size range for cat prey. Mature mountain hares weigh about 3 kg, but the newborn weight is ca 90 g and reports of juveniles killed by cats are numerous (Dahl, 2005, Pedersen and Pedersen, 2012). In addition, cats have been reported to kill young roe deer fawns in Norway (Andersen et al, 1995 p.24). Cat predation is not considered a significant contributor to ungulate mortality and will not be assessed further.

Figure 11: Young domestic cat with small mammalian prey in rural habitat. Photo: Péter Mocsonoky – Colourbox.com

The documentation of cat predation on species of mammals was found in scientific literature, grey literature and in local newspapers that presented reliable evidence of cat predation (see list of references to Table 26).

Table 26. List of mammal species considered as potential prey to cats in Norway. RL = Status on the Norwegian Red List. Habitat types: S-N =semi-natural sites, A = artificial sites, the two habitat types with the highest density of cats. References to documentation of cat predation are given in a numbered list below the table.

English name	Scientific name	Norwegian name	RL	Body mass (g)	Habitat types	Cat predation documented
Bats						
Western barbastelle	*Barbastella barbastellus*	Bredøre	CR	8.3	S-N, A	1
Northern bat	*Eptesicus nilssonii*	Nordflaggermus	VU	11		1,2,3
Brandt's bat	*Myotis brandtii*	Skogflaggermus	LC	4-8	S-N	2,3,7
Daubenton's bat	*Myotis daubentonii*	Vannflaggermus	LC	7.6	S-N	1,2,7

English name	Scientific name	Norwegian name	RL	Body mass (g)	Habitat types	Cat predation documented
Whiskered bat	*Myotis mystacinus*	Skjeggflaggermus	LC	5.3	S-N	1,5,7
Natterer's bat	*Myotis nattereri*	Børsteflaggermus	CR	7.2	S-N	1,5,7
Common noctule	*Nyctalus noctula*	Storflaggermus	EN	28	S-N	1,7
Nathusius's pipistrelle	*Pipistrellus nathusii*	Trollflaggermus	NT	7.4	S-N	,5,7
Soprano pipistrelle	*Pipistrellus pygmaeus*	Dvergflaggermus	LC	4-7	S-N	7
Brown long-eared bat	*Plecotus auritus*	Brunlangøre	LC	6-12	S-N	1,2,5,7,8,9
Parti-coloured bat	*Vespertilio murinus*	Skimmelflaggermus	NT	15	S-N, A	1,7
Hedgehogs						
Hedgehog	*Erinaceus europaeus*	Piggsvin	NT	400	S-N	-
Lagomorph						
Mountain hare	*Lepus timidus*	Hare	NT		S-N, A	10,11
Mustelids						
Pine marten	*Martes martes*	Mår	LC	30*		12
European polecat	*Mustela putorius*	Ilder	VU	1000	S-N, A	-
Stoat	*Mustela erminea*	Røyskatt	LC	260	S-N, A	9,13
Least weasel	*Mustela nivalis*	Snømus	LC	55	S-N, A	9,12
Rodents						
Yellow-necked mouse	*Apodemus flavicollis*	Storskogmus	LC	28	S-N	9,12,14
Wood mouse	*Apodemus sylvaticus*	Småskogmus	LC	23	S-N	9,14,15
North-western water vole	*Arvicola amphibius*	Vånd	LC	150-300		12
Norway lemming	*Lemmus lemmus*	Lemen	LC	70		16
Field vole	*Microtus agrestis*	Markmus	LC	25	S-N, A	9,14,15
Root vole	*Microtus oeconomus*	Fjellmarkmus	LC	50		
House mouse	*Mus musculus*	Husmus	LC	19	S-N	9,10,12
Grey red-backed vole	*Myodes rufocanus*	Gråsidemus	LC	30-40		
Bank vole	*Myodes glareolus*	Klatremus	LC	20-40	S-N	9,12,17

English name	Scientific name	Norwegian name	RL	Body mass (g)	Habitat types	Cat predation documented
Northern red-backed vole	*Myodes rutilus*	Rødmus	LC	30-40		
Wood lemming	*Myopus schisticolor*	Skoglemen	LC	26		18
Brown rat	*Rattus norvegicus*	Brunrotte	LC	140-500	S-N, A	9,10,12,14
Red squirrel	*Sciurus vulgaris*	Ekorn	LC	330	S-N	12
Northern birch mouse	*Sicista betulina*	Bjørkemus	NT	9	S-N, A	19
Shrews						
Eurasian water shrew	*Neomys fodiens*	Vannspissmus	LC	15-19	S-N	20
Common shrew	*Sorex araneus*	Krattspissmus	LC	9	**	9,12,15
Laxmann's shrew	*Sorex caecutiens*	Lappspissmus	LC	5.4		
Even-toothed shrew	*Sorex isodon*	Taigaspissmus	NT	12		
Eurasian pygmy shrew	*Sorex minutus*	Dvergspissmus	LC	4	**	9,10,12
Eurasian least shrew	*Sorex minutissimus*	Knøttspissmus	LC	2.5	S-N, A	12

*birth weight. ** no habitat types given by NBIC.

1) Meschede and Rudolph 2004, 2) Isaksen 2007, 3) Michaelsen and Kooji 2006, 4) Isaksen 2005, 5) Mori et al. 2019, 6) Værnesbranden 2007, 7) Oedin et al. 2007, 8) Wergeland Krog 1995, 9) Woods et al. 2003, 10) Smiddy 2001, 11) Pedersen and Pedersen 2012, 12) Kauhala et al. 2015, 13) Vikebladet, 2014, 14) Pirie et al., 2022, 15) Barmoen 2016, 16) Nordlys 2007, 17) Tschanz 2011, 18) Kooji and Møller, 2017, 19) Viker 1999.

3.3.3 Potential mammal prey species in Norway based on habitat overlap with cats

The likelihood for a mammal species of being predated on by cats depends both on their abundance and on the density of cats within its typical habitat. We used the Nature Types in Norway (NiN) as defined by the Norwegian Biodiversity Information Centre (NBIC) as categories when characterizing habitat use. The habitat types 'semi-natural sites' (equivalent to rural), and 'artificial sites' (equivalent to urban) are considered most suitable for cats due to the proximity to human habitation. We found documentation of cat predation for all the Norwegian mammal species associated with semi-natural and artificial habitats (Table 26).

Among rodents, Norway lemming, root vole, grey red-backed vole and northern red-backed vole all inhabit montane areas where the density of cats is expected to be low. We note that cat predation on Norway lemming has been recorded but assume this to be a rare event due to low habitat overlap. It should be noted that there is an increasing number of holiday cabins in Norway, and that pet cats brought to the cabin could pose an increasing risk to mammalian species inhabiting montane areas. Potential stray cats in cabin villages could also potentially give rise to feral cat colonies away from typical rural and urban habitats.

3.3.4 Potential mammal prey species in Norway based on abundance, spatial aggregation and Red List status

As discussed earlier in the report, common species of small rodents that typically occur in high densities in semi-natural and artificial habitats are expected to be the most common prey species to cats. These species typically have high reproductive potential and thus high potential for population growth, indicating that they might sustain high rates of predation. There are no empirical studies from Norway on the impact of cat predation on such species. However, several of the small rodent species have large interannual variation in abundance, so any effects of cat predation on their population dynamics might be complex and non-linear. Nevertheless, cat keeping on farms has to a large extent been motivated by controlling rodent pests and support the assumption that the local impact of cat predation might be substantial. Rare species are less likely to be caught by cats, but the impact on the population could be severe in threatened species. In particular, this might be the case for species that aggregate in, e.g., communal roosts and maternity colonies, such as several of the bat species.

In total, nine terrestrial mammalian species that are red-listed are considered potential prey to cats (Table 27 – see Figure 12 for occurrence records). All the bat species listed in Table 27 have low reproduction rates and aggregate in communal roosts and maternity colonies, and some also have bachelor colonies. The western barbastelle and Natterer's bat are listed as critically endangered (CR) in Norway (Table 27). Threatened and near-threatened species of bats are expected to be particularly sensitive to cat predation in areas with high cat density.

Table 27. Nine red-listed mammal species (as of 2021) that are potential prey to cats.

Species	**Status**	**Pop size in Norway**	**Number of offspring**
Western barbastelle (*Barbastella barbastellus* – bredøre	CR	<50	1/year
Northern bat (*Eptesicus nilssonii*) – nordflaggermus	VU	Unknown	1/year
Natterer's bat (*Myotis nattereri*) – børsteflaggermus	CR	<50	1/year
Common noctule (*Nyctalus noctula*) – storflaggermus	EN	<1000	1/year
Nathusius's pipistrelle (*Pipistrellus nathusii)* – trollflaggermus	NT	<1000	1-2/year
Parti-coloured bat (*Vespertilio murinus*) – skimmelflaggermus	NT	<2000	2/year
Mountain hare (*Lepus timidusi*) – hare	NT	Unknown	2-8/year (1-3 litters)
Northern birch mouse (*Sicista betulina*) – bjørkemus	NT	Unknown	5/year (1 litter)
Even-toothed shrew (*Sorex isodon*) – taigaspissmus	NT	Unknown	Unknown

All the rodents, except for northern birch mouse, which has a restricted distribution range and therefore listed as Near Threatened, are listed as species of Least Concern. The mountain hare is found widespread in Norway but is listed as Near Threatened because of a declining population size. The even-toothed shrew is listed as near threatened because of its restricted distribution range. As no documentation of cat predation exists for this species from Norway or elsewhere, it was excluded from further analysis. See Figure 12 for approximate distributions of the red-listed mammal species in Norway that were further assessed.

3.3.4.1 Predation by cats on bats

In a review of 44 studies, Oedin et al. (2021) listed 86 bat species as preyed upon or threatened by cats. Nine of these species are found in Norway (Table 26), of which the Natterer’s bat has status as Critically Endangered on the Norwegian Red List.

In a study from Germany (Meschede and Rudolph, 2004), cat predation was reported on 15 bat species, of which 11 are recorded in Norway. The two species that were most frequently killed by cats were the common pipistrelle and whiskered bat. However, also Natterer’s bat and western barbastelle, which are listed as Critically Endangered in Norway (Table 27), were depredated.

The Norwegian Zoological Society has recorded cat predation on seven bat species: Brandt's bat, brown long-eared bat, Daubenton's bat, northern bat, parti-coloured bat, soprano pipistrelle and whiskered bat (Jeroen van der Kooij, pers. comm.). Two of these species (northern bat and parti-coloured bat) are listed as threatened or near threatened (NT) in the Norwegian Red List (Table 27).

Ancillotto et al. (2013), reported cat involvement in an estimated 28.7% of bats being brought into rehabilitation centers in Italy. Up to 90% of the wounded bats brought to a recovery center in Norway were injured by cats (Jeroen van der Kooij, pers comm.). Khayat et al. (2020) detected cat DNA on 66.7% of injured bat wings examined in the UK. In a study of bats inhabiting one specific building in Ukraine, cat predation was given as the cause of most deaths (68%, 157/231) of common noctules (Vlaschenko et al., 2019). One study from Norway reported that domestic cat predation on Brandt's bat inhabiting a barn in Trøndelag reduced the colony by at least 50% (Værnesbranden, 2007).

In contrast to small rodents, bats have slow life histories; they are long-lived and have low fecundity rates. As bats are generally long-lived with low fecundity, sudden losses of individuals may cause population decline. Bats also roost and breed gregariously (communal roosts and maternity colonies) and in buildings, i.e., close to humans and domestic cats. These traits make bats especially vulnerable to cat predation; if the (usually single) pup is killed by a cat, reproduction fails that year as they do not remate and produce a new pup in the same year. Finally, if a cat finds a colony, several bats may be killed.

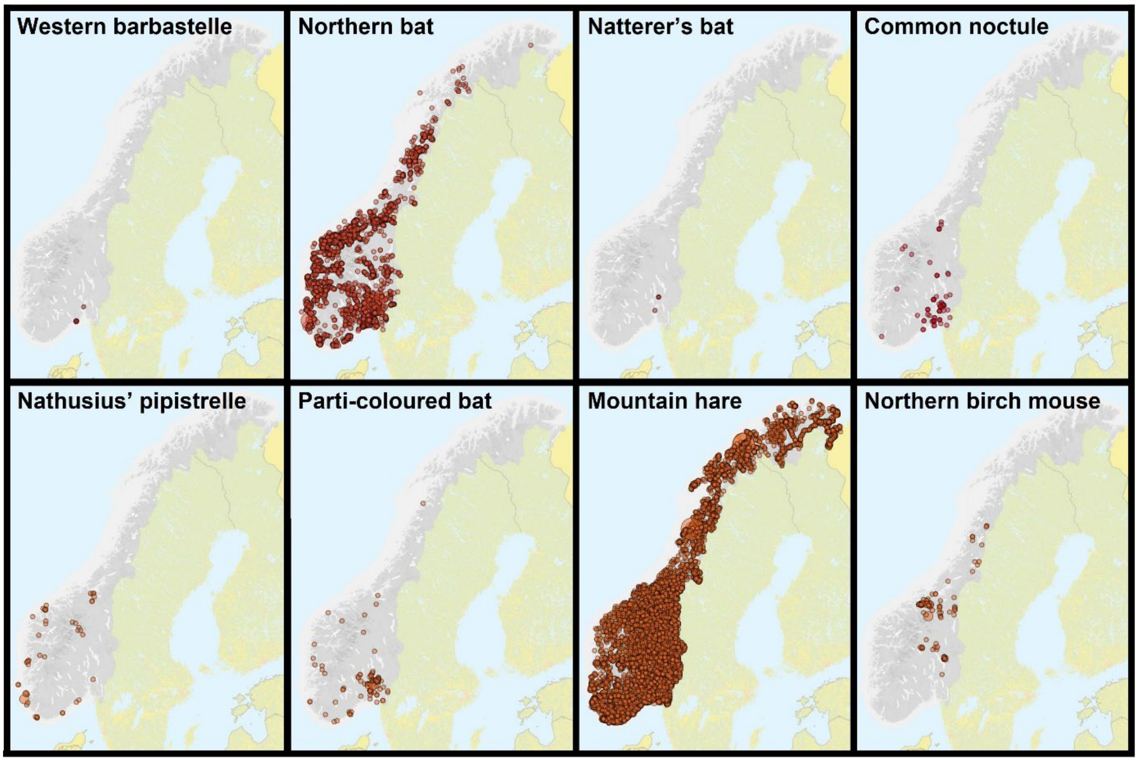

Figure 12: Occurrence records for 8 red-listed Norwegian mammal species that are susceptible to cat predation. Note that there is high uncertainty concerning bat observations and that these are not validated. Source: www.artskart.artsdatabanken.no

It has been hypothesized that cats are attracted to bat roosts by sensory cues, including sound (cats are able to hear ultrasound), smell, and vision (Ancillotto et al., 2013, Vlaschenko et al., 2019). House-roosting bat species are most vulnerable to cat predation, which will likely take place during summer when females congregate in roosts to reproduce (Ancilotto et al. 2013). Disturbance caused by cats may lead bats to leave their roosts (Welch and Leppanen, 2017). Pups losing their mothers to cat predation are expected to have lowered survival rate. All the red-listed bat species in Norway have low reproductive outputs with females producing one to two pups per year (Table 27). Some of the species have been recorded to live for more than 20 years in the wild, but the average life expectancy is around three years (Steffens et al., 2004).

When cats attack bats, they may also cause lethal harm to the bats without killing them directly. Fatal injuries can occur when the cat tears the bat's wings. In addition, bacteria transmitted to bats from cat saliva potentially cause diseases (Mühldorfer et al., 2011).

3.4 Assessment of impact of cat predation on reptiles and amphibians

3.4.1 Assessment of vulnerability to cat predation

All amphibians and reptiles and amphibians that occur naturally in Norway are potential prey for cats (Table 28). The body weight of the Norwegian species of herptiles is within what can be characterized as an optimal prey for the cat, although the smallest size categories are probably somewhat less attractive (Kutt 2012). However, when they become sexually mature at the age of 2 to 5 years, they also reach a size that makes them more attractive as prey for cats.

Amphibians live in relatively humid habitats, which makes them less suitable as prey for cats (Table 28). The amphibians will mainly be exposed to cat predation during seasonal migrations to and from the breeding ponds in the spring and autumn. Estimations of the population size of the Norwegian amphibian species are lacking. Based on registrations in the Norwegian Biodiversity Information Center and individual studies of selected populations, the number of individuals of sexually mature individuals of amphibians is estimated to be between 2 and 8 million individuals. Less than half of these individuals live in areas where cats are present. If the juveniles are included, the number will be at least 10 times as high. Smooth newt *(Lissotritin vulgaris*) and common frogs (*Rana temporaria*) will be particularly exposed during the spring and autumn migration when they are most exposed to cat predation. Both great crested newt (*Triturus cristatus*) and common toad (*Bufo bufo*) are toxic, and are therefore not suitable prey for cats, although they are killed even if they are not eaten.

A similar estimate of the number of reptiles in Norway suggest that there are between 0.2 and 0.6 million sexually mature individuals. Reptiles have much fewer offspring than amphibians and the number of juveniles can be about as many as the adults. Figure 13 shows the accumulated observations of all reptiles and amphibians as a proxy for their true distribution. The reptiles will to a greater extent than the amphibians live in areas where cats also live. Large parts of the population of slow worm (*Anguis fragilis*), grass snake (*Natrix natrix*) and smooth snake (*Coronella austriaca*) will live in areas where most cats live, while the two most common species, common lizard (*Zootoca vivipara*) and European viper (*Vipera berus*), predominantly live in areas without or with few cats. Less than half of all reptiles will therefore live in areas with a likely high density of cats.

Table 28. Reptiles and amphibians in Norway. Body weight and habitat selection in the columns to the right.

Species	Scientific name	Norwegian name	Body mass (g)	Habitat
Lizards				
Common lizard	*Zootoca vivipara*	Nordfirfisle	3-25	Cultural landscape, forest edge in slightly open sunny places (below 1,100 masl)

Species	Scientific name	Norwegian name	Body mass (g)	Habitat
Slow worm	*Anguis fragilis*	Stålorm	2-30	Vegetation-rich and slightly humid environments in the lowlands in coastal areas in S Norway, including cultural landscapes (below700 masl)
Snakes				
European viper	*Vipera berus*	Huggorm	5-150	Varied habitat throughout the country, but not so common in high mountains and in very humid areas (below 1,500-2,000 masl)
Grass snake	*Natrix natrix*	Buorm	5-180	Water-rich forest and cultural landscape with small ponds (below 500 masl)
Smooth snake	*Coronella austriaca*	Slettsnok	5-150	Sunny slopes and cliffs in coastal areas in the south (below 2-300 masl)
Amphibians				
Common toad	*Bufo bufo*	Nordpadde	2-30	Cultural landscape, coastal landscapes, and coastal forests with small ponds, (below 1,000 masl)
Common frog	*Rana temporaria*	Buttsnutefrosk	2-25	Swamp forest, mire landscape and cultural landscape with small ponds (below 1,200 masl)
Moor frog	*Rana arvalis*	Spissnutefrosk	2-25	Swamp forest, mire landscape and cultural landscape with small ponds (below 400 masl)
Pool frog	*Rana lessonae*	Damfrosk	2-25	Small forest ponds in S Norway
Smooth newt	*Lissotriton vulgaris*	Småsalamander	1-7	Cultural landscape with artificial ponds and old forest with bogs rich in small fish-free ponds (below 650 masl).
Great crested newt	*Triturus cristatus*	Storsalamander	2-25	Cultural landscape with artificial ponds and old forest with bogs rich in small fish-free ponds (below 650 masl).

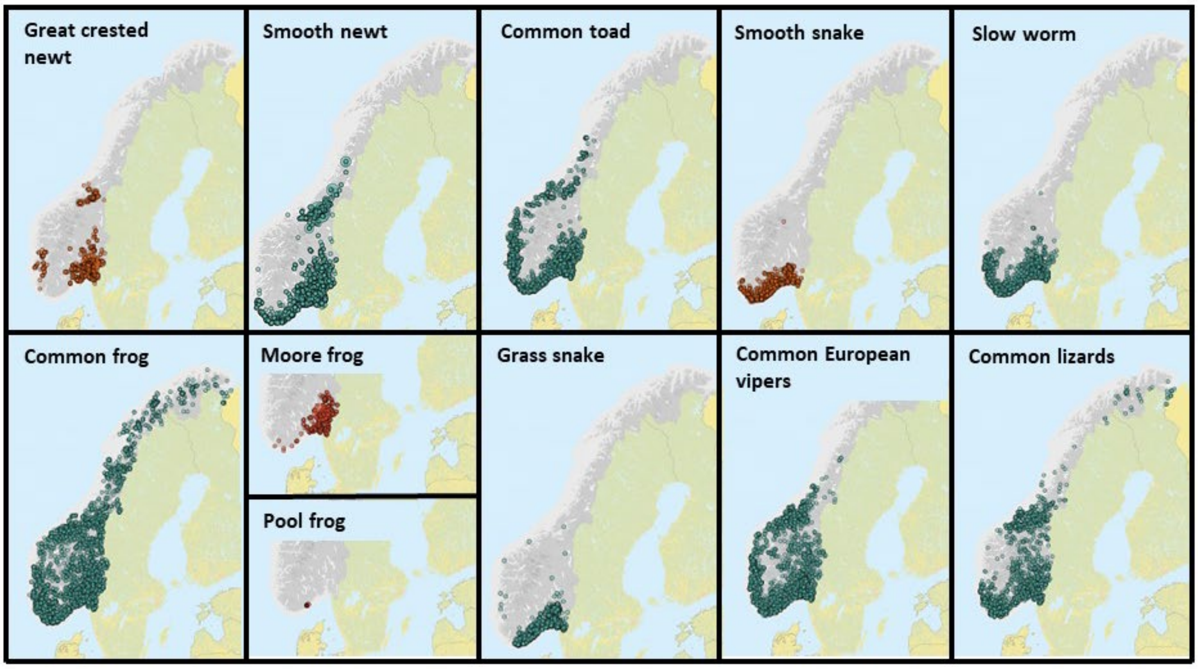

Figure 13: Distributions of the Norwegian reptiles and amphibians. Green dots are species that are classified as LC and red dots are species that at risk of going extinct in Norway (NT or higher on the Norwegian Red List). Source: https://artskart.artsdatabanken.no

3.4.2 Assessment of impact on populations of reptiles and amphibians

Cats could potentially be a population-limiting factor for the red-listed species of reptiles and amphibians that have small populations (Table 28). Smooth snake is listed as near threatened (NT) in the Norwegian Red List, mainly due to habitat loss. The species has been documented as depredated by cats in Norway (Beate Strøm Johansen, pers. comm.). The population of smooth snake is declining in Norway and cat predation can be an important contributing factor to a reduced population in urban areas. Many residential areas are close to the preferred habitats for smooth snake in Norway. Pool frog (*Rana lessonae* – damfrosk) lives in a habitat that is not favorable for cats, but there are less than 170 individuals of this species in Norway (Engmyr and Reinkind 2019, Lars Mørch Korslund, pers. comm.). Very few individuals of the species and a short distance (3-500 m) from settlements where there are cats, still make the pool frog very vulnerable. Cat predation probably has little effect on the population size of the red-listed great crested newt and the moore frog (*Rana arvalis* – spissnutefrosk). First, the great crested newt is poisonous and not a popular prey for cats. The national monitoring program that lasted from 2012 to 2017 did not document cat predation as an important mortality cause for this species (Dervo et al. 2013). Second, the habitat of the moor frog is often humid and unattractive to cats.

In the absence of Norwegian studies, we have used results from other European countries on the proportion of reptiles in the cat's prey. In addition, we lack good estimates for the size of reptile populations in Norway. It should be noted that the calculations presented in Table 20 probably overestimates the number of reptiles and amphibians killed by cats annually in Norway. The few case studies we have in Norway on reptiles and amphibians do not indicate that cat predation has any observable effects on their population sizes, although it is possible that the red-listed smooth snake is negatively affected.

Table 29. Red-listed reptiles and amphibians in Norway (NBIC 2018), with estimates of the number of populations, assessment of vulnerability to cat predation and Red List status.

Species	Scientific name	Norwegian name	Estimated no populations	Vulnerability to cat predation	Red List status
Snakes					
Smooth snake	*Coronella austriaca*	Slettsnok	400-600	The main habitat for the species overlaps with areas with many cats. The species is therefore very vulnerable	NT
Amphibians					
Moor frog	*Rana arvalis*	Spissnutefrosk	150-400	Vulnerable, but the most important habitat for the species is too wet for cats to pose a major threat	VU
Pool frog	*Rana lessonae*	Damfrosk	1-2	The most important habitat for the species is too wet for cats. Very few individuals of the species (<170) and a short distance (3-500) from settlements where there are cats still make the Pool frog very vulnerable	CR
Great crested newt	*Triturus cristatus*	Storsalamander	1 400-1 600	The most important habitat for the species is too wet for cats. The Great crested newt is poisonous and is predated to a small extent by cats, and therefore not considered vulnerable.	NT

3.5 Assessment of overlap between cats and prey species distribution

To assess the spatial distribution of cat hunting pressures, we used the estimate of total number of owned cats in Norway and assumed they were distributed proportional to human population density weighted by the rates in cat ownership in cities, towns and rural areas (See sections 1.3.4.4 and 1.3.4.5). Furthermore, we assumed a one km “hunting range” of cats from their residence (see section 1.2.4.2) and implemented this on a 1x1 km raster map of Norwegian population density and dominant housing classification (rural/ town/ city). The resulting map was also overlayed the distribution of RAMSAR and other protected areas in Norway (Figure 14), as well as the point observations of potential prey species of special interest (Figure 15).

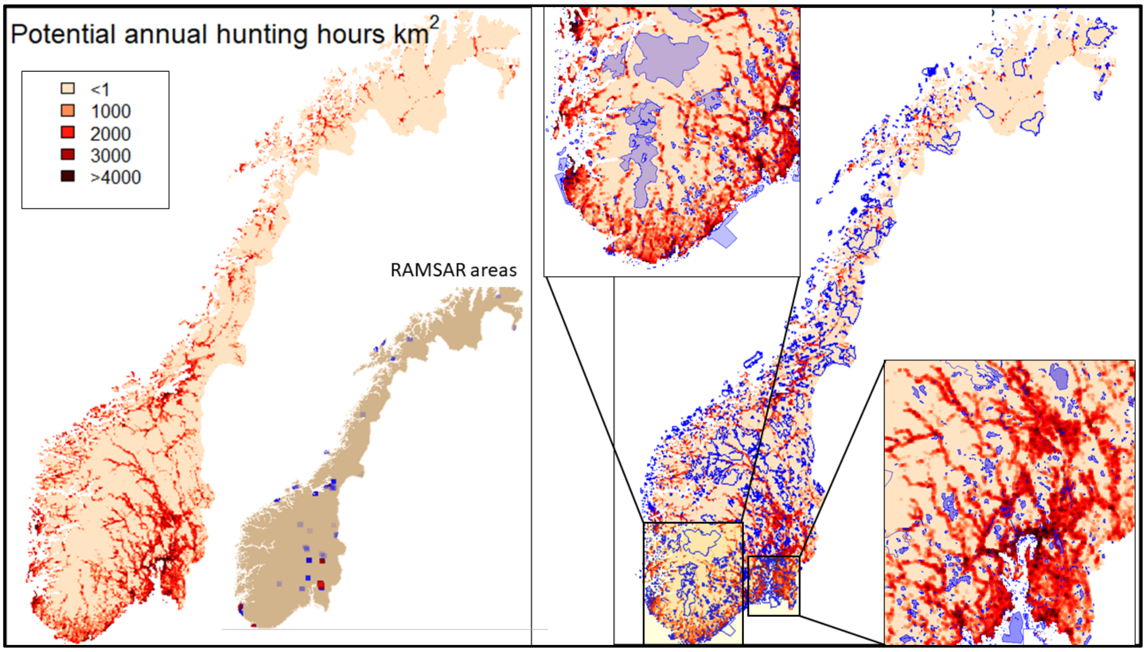

Figure 14: Estimated spatial variation in domestic cat hunting hours per km^2 in Norway (left). Hunting hours is based on the total number of owned cats and human population density. Overlap with RAMSAR areas is color-coded in map insert. On the right the same map is shown with blue polygons showing protected areas with a biological focus, (i.e., species or habitat protection, not landscape or geology), with enlarged areas inserted.

The average number of hunting hours per km^2 from the cat hunting pressure estimate were extracted from map polygons delineating the Norwegian RAMSAR areas and the means calculated, and presented in Table 30. The accessibility for cats varies on smaller scales than captured on a 1x1 km scale. Also, the willingness of cats to access dense vegetation, water and wetlands is unknown and likely to vary among individuals and among areas. Our estimates of overlap should therefore be regarded less as an estimate of ongoing hunting and more as a warning of RAMSAR areas that are most exposed to cat predation, especially in the border zones with surrounding urban, suburban and rural settlements.

Table 30. Average hunting hours per km^2 from the cat hunting pressure estimate shown in Figure 14 for the Norwegian RAMSAR areas. Open water was excluded. RAMSAR areas are arranged according to exposeure to cats.

RAMSAR area	Size in km^2	Location	Hunting hours/km$^{2/year}$
Ilene and Presterødkilen Wetland System	1.8	Vestfold	606
Åkersvika	4.3	Hedmark	576
Lovund/Lundeura	1.5	Nordland	331
Harøya Wetlands System	1.9	Møre og Romsdal	282
Trondheimfjord wetland system	2.6	Trøndelag	224
Fiskumvannet Nature Reserve	1.2	Buskerud	209
Reisautløpet	6	Troms	172
Giske Wetlands System	5.5	Møre og Romsdal	162
Nordre Øyeren	62	Akershus	162

Jæren wetland system	22	Rogaland	139
Lista Wetlands System	7.2	Vest-Agder	119
Dokkadelta	3.7	Oppland	87
Balsfjord Wetland System	17.8	Troms	66
Nordre Tyrifjord Wetlands System	3.2	Buskerud	65
Sandblåst-/Gaustadvågen Nature Reserve	2.5	Møre og Romsdal	55
Tautra and Svaet	16.5	Trøndelag	49
Øra	15.6	Østfold	46
Rott-Hostein-Kjør	107.2	Rogaland	42
Runde	13.5	Møre og Romsdal	39
Ørland Wetland System	30	Trøndelag	37
Innherred Freshwater System	1.7	Trøndelag	36
Evenes wetland system	4.3	Troms/Nordland	34
Kurefjorden	4	Østfold	23
Målselvutløpet	12.9	Troms	15
Grunnfjorden	14.7	Nordland	13
Laukvikøyene	10.8	Nordland	9
Mellandsvågen	1	Møre og Romsdal	5
Risøysundet	5	Nordland	5
Stabbursneset	15.6	Finnmark	5
Tanamunningen	34	Finnmark	4
Glomådeltaet	6.1	Nordland	3
Skogvoll	55.4	Nordland	2
Atnsjømyrene	5.3	Hedmark/Oppland	1
Bliksvaer	43	Nordland	1
Froan Nature Reserve and Landscape Protection	484	Trøndelag	1
Møsvasstangen	14.3	Telemark	1
Slettnes	12.3	Finnmark	1
Ulendeltaet	2.8	Trøndelag	1
West-Vikna Archipelago	135.9	Trøndelag	1
Fokstumyra	7.8	Oppland	0
Havmyran	40	Trøndelag	0
Hedmarksvidda Wetland System	36.5	Hedmark	0
Horta	31.6	Trøndelag	0
Hynna	15.4	Oppland	0
Karlsøyvær	49	Nordland	0
Kvisleflået	56.8	Hedmark	0
Måstadfjellet	8	Nordland	0
Øvre Forra	108	Trøndelag	0
Pasvik	19	Finnmark	0
Røstøyan	69.9	Nordland	0
Sklinna	5.9	Trøndelag	0
Tufsingdeltaet	9.2	Hedmark	0
Anda	0.5	Nordland	No data
Horsvær	170.4	Nordland	No data

In addition to RAMSAR areas, all observations with available coordinates from the Global Biodiversity Information Facility (gbif.org) were downloaded for each of three example bird species, nine red-listed mammals, four reptiles, and three species of mouse found in Norway (see map in Figure 14). For each recorded observation of the species, the value $\log_{10}$(0.001 + cat hunting hours per km^2 at location of observation/mean national cat hunting hours) are shown in Figure 15. This indicates the relative differences in the overlap between observed ranges for the species and areas with above or below average cat predation risk at a coarse (1x1 km) spatial scale.

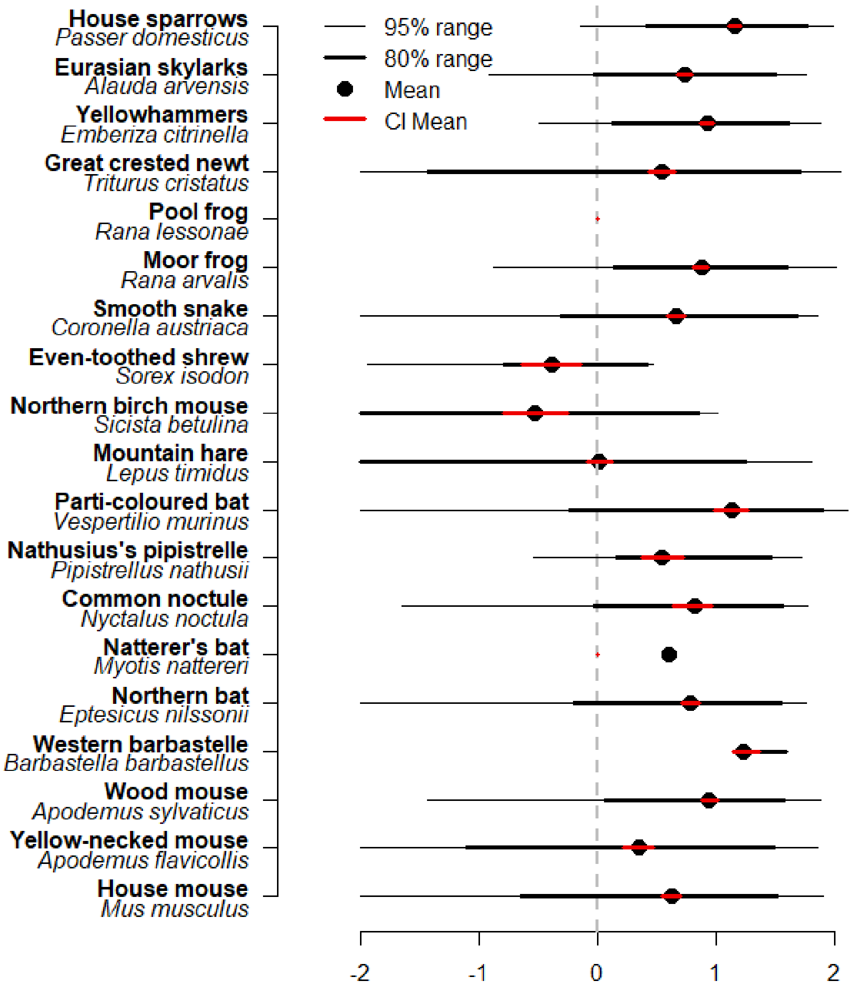

Figure 15: Overlap between cat hunting pressure (Figure 14) and ranges of selected potential prey species (see sections 3.2.4, 3.3.2 and 3.4.1). The range, mean, confidence interval of the mean estimated hunting pressure at observed locations have been extracted for each species, divided by the mean cat hunting pressure, and then log(base)-transformed. Values above zero indicate higher-than-average cat hunting pressure and observations below zero indicate less-than-average cat predation. For instance, we see that mountain hare is found over a wide range of cat densities, the house sparrows are mostly found in areas where cats are common, and the northern birch mouse is mostly found in areas with a sparse population of cats.

The wood mouse, house sparrows, yellowhammers, skylarks, great crested newts, moor frogs, parti-colored bats, common noctules and northern bats are present in areas with particularly high estimated probability of experiencing cat predation. There were too few observations for pool frogs and natterer's bats to make estimates.

These data must be interpreted with caution and are likely of limited value for comparisons among groups with very different life histories and habitat use. But between related species within comparable groups, the approach for instance suggests that cat predation might be a greater problem for sparrows than skylarks and for parti-colored bats than for common noctules.

3.6 Assessment of known cat-associated disease agents in humans, non-cat domestic animals and wildlife

Cats are potential carriers of a considerable number of zoonotic pathogens (Rahman et al., 2020). However, the role that cats have on biodiversity through disease spread is unknown for many diseases. In the following, we will address a selection of zoonoses known to occur in Norway, or that might become relevant in the next decades due to climate change or other developments. In addition to the in-text sources, we have used the published and updated overviews of the Norwegian Veterinary Institute https://www.vetinst.no/fagomrader/zoonoser) and the Norwegian Institute of Public Health (https://www.fhi.no/sv/smittsomme-sykdommer/smitte-fra-mat-vann-dyr/).

Because our understanding of the influence of cats on wildlife diseases is even more limited than our knowledge of the diseases themselves, the probability of their impact remains largely unknown. Moreover, our thresholds for considering whether an impact is serious depends on the affected species (humans, domestic animals, wildlife), and the extent of impact is likely to shift with changing climatic conditions. In this report, we present relevant knowledge in the text but do not conduct a full risk evaluation.

The degree to which specific cats are exposed to various pathogens depends on whether they roam free or not, and the local environment. Even indoor cats are exposed to peridomestic rodents, cohabiting pets and humans, while free-roaming cats are also exposed to other roaming- and feral cats, domestic animals, wildlife and the environment.

The pathogens included in this report include those found in the literature to involve cats in a role that is either (a) suspected to be relevant for wildlife, human or domestic disease transfer in Norway, or (b) may be suspected of becoming relevant in the future due to climate change and/or spread of the disease through human activity or natural processes. It does not include diseases that are of concern only to cat health.

3.6.1 Bacteria

3.6.1.1 Bacillus anthracis

Anthrax is caused by *Bacillus anthracis,* which is listed as a group 1 disease in Norway and is a target of strong control measures worldwide. The last case observed in Norway was in 1993[13], and there was a small outbreak in cows and reindeer in Sweden and Russia respectively, in 2016 (Liskova et al. 2021). Mammalian herbivores are the main hosts, but it can infect most mammals, including cats. Cats are not particularly susceptible, but may fall ill when exposed to infected meat during an outbreak in for instance cattle (Ashenefe Wassie et al. 2022), and carry a small risk of spreading the disease.

3.6.1.2 Bartonella spp.

B. henselae bacteria harboured in the saliva of infected cats and in cat fleas (*Ctenocephalides felis*) and causes the cat scratch disease and other clinical conditions. Healthy adults generally recover, but the disease may last for months. Notably, *Bartonella* spp. infection may be misdiagnosed as *Borrelia* (Lyme disease) or multiple sclerosis. Infections with emerging bacteria of the *Bartonella* genus have recently been reported in association with a range of neurocognitive and central nervous system (CNS) symptoms (Breitschwerdt 2008; Lashnits et al. 2021). This symptomatic and epidemiologic overlap with suspected effects of *Toxoplasma* is striking and one may suspect a confounding effect. Among cats, it is believed to be most transmitted by infected cat fleas, and it may also be found in the faeces of these fleas, which can serve as sources of infection if exposed to an open wound in either a cat or a human. Transmission from cats to humans is usually through scratches, but the pathogen can also be transmitted via bite wounds or by a cat licking wounds or skin lesions of a person. *Bartonella* spp. are frequently found in wildlife and domestic animals that are likely the main reservoirs and where the epidemiology and disease burden is poorly known (Breitchwerdt and Kordick 2000).

In addition to cat fleas, ticks and some other insects may vector *Bartonella* infections (Reis et al. 2011; Wechtaisong et al. 2020, Sacristán et al. 2020). Cats are thus both a source of direct infection to humans and a reservoir of *B. henselae* for adult ticks and other vectors (Regier et al. 2017), linking the European distribution of *Bartonella* to humans (Grochowska et al. 2020), wildlife, domestic animals and pets.

Cat fleas and *Bartonella* infections are rare in Norway and cat scratch disease has been little known in human medical practices in Norway (Bergh et al. 2002), but a recent study found IgG antibodies to *Bartonella henslae/Quintana* in 2/1451 (0.1%) in a survey of the human community along the south coast of Norway (Thortveit et al.

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[13] https://www.fhi.no/sm/smittevernveilederen/sykdommer-a-a/miltbrann-anthrax---veileder-for-he/?term=

2020a, b). About 1.3% of UK cat ticks have been found to carry *Bartonella* infections, likely infected from the cats on which they feed (Duplan et al. 2018).

The increasing *Ixodes* tick population (De Pelsmaeker et al. 2021, Sacristán et al. 2020, Goren et al. 2023) would then explain the finds of *Bartonella* in Norway and predict an increase in *Bartonella* incidences in Norwegian cats with climate change, and correspondingly increasing risk of transmission to humans.

3.6.1.3 Borrelia spp.

Borreliosis, caused by the *Borrelia* spp. bacterial spirochetes, is mainly vectored by the tick *Ixodes ricinus*, which feeds on a range of hosts, including cats. As the ticks are expanding their range in Scandinavia, likely partly due to climate change (Kjær, 2019, 2020), their contact rate with cats and humans increases. Cats may be exposed to *Borrelia*, but rarely display symptoms of disease. Cats are not thought to play a role in transmission of Borreliosis but may contribute to movement of ticks.

3.6.1.4 Brachyspira hyodysenteriae

Swine dysentery is caused by this anaerobic bacterial spirochete in pigs worldwide. Cats might be able to carry the bacterium in up to two months (similar to rodents, dogs and birds), but the sources are sparse, so this is highly uncertain[14] and cats seem unlikely to play any important role in disease spread.

3.6.1.5 Brucella spp.

Norway is officially free of *B. abortus*, *B. melitensis* and *B. suis* in the bovine animal populations, and of *B. melitensis* in the bovine and caprine animal population. A *Brucella* bacterial infection in humans is usually associated with unpasteurized milk, but cats are potential carriers, though not considered likely to play a significant role in disease spread (Hariharan and Hariharan 2017).

3.6.1.6 Campylobacter spp.

Campylobacter is regarded as the most frequent cause of food poisoning and gastroenteritis in humans (Goni et al. 2017, 2018). These bacteria can be found in the digestive tract of most domestic animals and birds. Contaminated poultry meat and drinking water are the most common causes of transmission to humans in Norway and worldwide (Goni et al. 2017, Zoonoserapporten 2022).

Cats may become infected with *Campylobacter* spp. without exhibiting symptoms. As *Campylobacter* is widespread in wild birds (Minias 2020), cats seem unlikely to

[14] https://www.vetinst.no/sykdom-og-agens/svinedysenteri

contribute significantly to wildlife disease, but may contribute to human transmission by bringing the bacteria into contact with people and domestic animal hosts. A French study suggests that cats and dogs may play a larger role in connecting human and livestock/ wildlife *Camphylobacter* reservoirs than earlier believed (Thépault et al. 2020).

3.6.1.7 Rickettsia spp.

The *R. felis* bacteria cause cat-flea typhus in humans and is suspected to cause many cases generally classified as fevers of unknown origin in humans in Africa (Socolovschi et al. 2010). The cat flea (*C. felis*) is considered as the primary vector, but other flea-, mosquito-, tick- and mite species, in particular the common tick *Ixodes ricinus*, have been suggested to be capable vectors (Tsokana et al. 2022, Angelakis et al. 2016). Humans and other vertebrates may become infected, but the vector and host competence of many possible hosts and vectors remain unknown (Tsokana et al. 2022). It is considered an emerging pathogen in Europe and have been reported in Sweden and 14 other European countries between 2017 and 2022, likely expanding northwards following climate-driven range expansions and abundance changes in its vectors (Tsokana et al. 2022, Angelakis et al. 2016).

As cats are competent hosts to the bacterium and its main known hosts, they may play a significant role in transmission to humans and pets in the seemingly likely event that the disease establishes in Norway.

3.6.1.8 Capnocytophaga canimorsus/ Capnocytophaga spp.

Capnocytophaga canimorsus/ Capnocytophaga spp. are most often associated with dogs. These bacteria are part of the normal mouth flora of dogs and cats, with some strains being more pathogenic or interacting with pre-existng conditions to create more severe cases (Suzuki et al. 2010, Suzuki et al. 2020). Few studies have been done on this bacterium in Norway, so the prevalence is uncertain (Fjellså and Ilbråten 2023). Clinical manifestations in humans are rare in Norway, but the bacterium also infect other vertebrates when bitten, such as rabbits (Gaastra and Lipman 2010). Cats thus seem to be an important host, but it is unlikely that the bacteria are the cause of any major impact except being one of several occasionally serious bite wound infections.

3.6.1.9 Chlamydia/ Chlamydophila spp.

Infection with *Chlamydia* / *Chlamydophila* spp. of bacterial complexes may occasionally involve cats. Avian chlamydiosis *Chlamydia psittaci* can transmit to cats and other animals from wildfowl reservoirs, but the genotypes found in cats, now mostly classified as the separate clade *Chlamydophila felis*, are rarely found in humans and not known to result in serious disease.

3.6.1.10 Coxiella burnetii

Q fever is globally distributed including southern Europe and has only been detected in Norway in humans likely to have been infected abroad. However, it is highly transmissible and has become widespread in ruminants in Denmark (Egberink et al. 2013). A possible role of ticks in transmission remains controversial (Körner et al. 2021). Transmission risk from cats and other species is high if in contact with placental tissues from animals aborting due to *Coxiella* infection (Bauer 2021). Cats can become infected by ingestion or inhalation of bacteria from infected animals, aborted material from infected ruminants, or raw milk. Cats do not play a large role in the disease cycle, but traditionally may give birth in close proximity to humans or livestock. The probability of Q-fever establishing in Norway seems to increase with climate change (Ma et al. 2021).

3.6.1.11 Clostridium tetani

Clostridium tetani is the soil-living agent of tetanus. This bacterium is common globally and infection through wound or bite causes severe disease in humans, sheep and horses, while other animals, like cats, are more resistant (Popoff 2020). However, cats can transmit the disease through bite, but probably plays no role in the epidemiology beyond these occasional infections.

3.6.1.12 Francisella tularensis

Tularemia is a zoonotic bacterial disease caused by *Francisella tularensis*, which is endemic to most of the Northern hemisphere. The bacteria can survive in water for extended periods of time and have been isolated from more than several hundreds of species whose susceptibility and morbidity vary greatly (Hennebique 2019). Tularemia in humans is rarely described in Norway, but it is an emerging disease in Central Europe with a rising incidence (Faber 2018, Yeni 2021)[15]. However, its distribution and ecology are expected to change as the climate warms (Hansen and Dresvyannikova 2022).

Transmission is mainly caused by direct contact with lagomorphs or rodents and their faeces, but it can be vectored by mosquito and tick bites. Nevertheless, water-borne transmission is most often the cause of human cases in Norway. Most Norwegian cases in pets are assumed to be dogs eating sick rodents. In a human outbreak of tularemia in Sweden in 2000, mosquito bites seemed the main infection pathway, while cat ownership was identified as one of several risk factors with an unknown causal link (Eliasson et al. 2002).

More recent research has also shown that domestic cats may play a significant role in transmission in Switzerland (Frischknecht et al. 2019), possibly through lagomorph or

[15] https://www.fhi.no/nettpub/smittevernveilederen/sykdommer-a-a/tularemi---veileder-for-helseperson/

other rodent contact (Kittl et al. 2020). Only one case of human tularemia has been found documented from a cat bite in Norway (Yaqub et al. 2004) and it has also been documented in Sweden (Petersson and Athlin 2017).

3.6.1.13 Leptospira spp.

Infection by bacteria of the *Leptospira* genus (Millian et al 2019) can result in a serious disease in humans and a wide range of mammalian hosts, notably rodents and dogs. The infection is mostly transmitted through the environment when urine-contaminated water comes in contact with broken skin, though several other pathways are possible.

The disease is mostly found in tropical and sub-tropical areas. It has been rare to non-existent among humans in Norway since the 1950s, being predominantly associated with dogs infected outside of the country. It is, however, present in Norway in rats and 10% of foxes had antibodies to *Leptospira* in a 2010 survey (Åkerstedt et al. 2010). It is on the rise in Germany, where it is expected to increase in prevalence with rising temperature and frequency of flooding events (Nau et al. 2019).

Cats are notable for having a potentially prolonged incubation period and for interacting with rodents that often form the main reservoir of the bacterium. If the disease becomes re-established in Norway, cats should be considered potential *Leptospira* carriers in public health strategies, and further investigated regarding their role in the environmental transmission cycle (Ricardo 2023).

3.6.1.14 Mycobacterium spp.

Mycobacteria can be classified into several major groups according to disease ecology, including the *M. tuberculosis* complex (MTBC) implicated in tuberculosis (as well as *M. leprae*, which causes leprosy). MTBC includes members like *M. bovis* and *M. microti*, which have similar pathogenicity, have zoonotic potential, circulate in the environment and are of importance for wildlife and domestic animals (Zhang et al. 2022).

Cats can transmit *M. bovis* and *M. microti* and can infect humans and other animals who might not otherwise have been infected (Černá et al., 2018; O'Connor et al., 2019). *M. microti* is of particular relevance to cats as rodents are its main reservoir, cats are susceptible and may transmit the bacteria to humans and other mammals (Occhibove et al. 2022, Tagliapietra et al. 2021, Ghielmetti et al. 2021, Moyo et al. 2021). However, any MTBC infection is likely to be from other environmental sources as the risk from cats just generally mirrors the background prevalence of MTBC in the environment. MTBC is relatively rare in Norway and while cats are one potential source of infection, they do not seem to have any epidemiological role beyond transmitting the bacteria to humans and other mammals. As long as MTBC remains rare in Norway, the probability of animal or human cases involving cat transmission remains low.

3.6.1.15 Pasteurella multicoda

Strains of *Pasteurella multocida* are a normal part of the oral bacterial flora of cats and to some degree of dogs, pigs and some birds. Cat bites are the most common cause when humans become infected by *Pasteurella multocida*, with outcomes ranging from minor to life-threatening. The disease is, however, currently very rare in Norway (Ujvári et al. 2019).

3.6.1.16 Salmonella spp.

Bacteria from the over 2500 variants of *Salmonella* genus are common causes of salmonellosis disease in many species, including domestic animals and humans. Vectors can include healthy carriers who can excrete the bacteria without showing signs of disease. Bacteria are excreted in faeces and can survive for months in organic material. Each *Salmonella* serovar has a different zoonotic potential, strongly regulated by stress factors including transportation, crowding, food deprivation and temperature (Drozdz 2021). Humans are most often infected through food.

While *Salmonella* passed from cats to humans (and vice versa) is well documented, several recent reports published between 2015 and 2021 have concluded that contact with healthy cats kept in homes does not constitute a major risk of salmonellosis (MacDonald et al. 2019). Multidrug-resistant *Salmonella* spp. in urban cats have been identified as a public health issue in some other countries (Dégi et al. 2021). Free-ranging and feral cats provide a link between bird-associated salmonellosis and humans and other pets (Dróżdż et al. 2021). Seasonal migration of passerines has caused *S. typhimurium* outbreaks in Sweden among cats and humans during certain years, likely via cat predation on weakened birds and environmental contamination (Söderlund et al. 2019). *S. typhimurium* seasonality in Norway may be somewhat different and dominated by a domestic reservoir as the same link has not been observed here (MacDonald et al. 2019). Thus, cats constitute a risk for salmonellosis in humans, but their relation to the wider epidemiology in Norway is currently unclear.

3.6.1.17 Staphylococcus aureus

Methicillin-resistant *Staphylococcus aureus* (MRSA) causes a range of infections in humans and animals that are hard to treat. Worldwide, farm animals are major reservoirs for livestock-associated MRSA (LA-MRSA), but Norway has a unique national strategy to prevent and combat MRSA in livestock, likely contributing to a low incidence of MRSA in animals (Elstrøm et al. 2019). Pets including cats may contribute to community-acquired MRSA (CA-MRSA) in humans or to transmission between MRSA reservoirs (Algammal et al. 2020). The incidence of MRSA cases in humans in Norway rose rapidly from the 1990's to the late 2010's but has plateaued during the last years (data from msis.no).

Although horse- and dog handling seem to carry higher risk than exposure to cats, cats may also transmit MRSA and cat handling adds to the risk of acquiring MRSA when the bacterium is common in livestock (Abdulkadir et al. 2022 and Cotter et al. 2022). However, no cases are known from Norway. Thus, cats seem unlikely to contribute significantly to MRSA infection risk if MRSA in livestock remains under control and precautions are maintained.

3.6.1.18 Yersinia pestis

The plague bacterium has caused some of the most devastating pandemics in history, including the black death. Probably emerging from rodent colonies in Central Asia, the bacterium is cosmopolitan in areas with suitable rodent hosts and has a complex life cycle. Plague is occasionally found in cats in areas where it is endemic, and cats are notable for being susceptible to all forms of plague and able to effectively transmit pneumonic plague through droplets (Evans 2022; Salkeld and Stapp 2006). However, the plague currently seems unlikely to re-establish in Norway.

3.6.2 Viruses

3.6.2.1 Feline morbillivirus

Since its discovery in 2012, Feline morbillivirus (FeMV) has been reported in domestic cats worldwide, including Hong Kong, Japan, Italy, US, Brazil, Turkey, UK, Germany, Malaysia and probably Sweden (Dahl 2018; De Luca et al. 2021). The pathogenicity of the virus is still unclear. It is most closely associated with kidney diseases in cats, but may also impact other organ systems (De Luca et al. 2021).

Evidence from other animal species suggests that it is unlikely to infect humans, but the potential for infection of other species is yet to be determined (De Luca et al. 2021). Other felines, like panthers (*Panthera pardus*) seem likely to be affected (Piewbang et al. 2020), and it has been found in white-eared opossums (*Didelphis albiventris*) (Lavorente et al. 2021). If it is introduced to cat populations in Norway, it seems relevant to our native lynx population. Choi et al. (2020) suggests a possibility for cross-species infections beyond feline health. However, it is a relatively newly identified virus and a lack of data excludes a full understanding.

3.6.2.2 Hantavirus

The haemorragic fevers caused by hantaviruses are mainly represented by *Nephropathia epidemica* caused by puumalavirus in Scandinavia and Eastern Europe. The disease is very rare in Norway but incidences may increase with warmer autumns and climate change (Ma et al. 2021; Sipari et al. 2022).

Catss do not appear to be susceptible to the relevant hantaviruses. However, they may have a role in controlling peridomestic rodent populations and bringing prey home (Guterres and de Lemos 2018), which can lead to human contact with infection.

3.6.2.3 Influenza viruses

Influenza A viruses (IAVs) infect humans and a variety of other animal species, including domestic cats and dogs. Infection of cats and dogs with both human and avian IAVs of different subtypes seems prevalent (Zhao et al. 2020). In addition to animal health implications, close contact between companion animals and humans poses a risk of zoonotic and reverse zoonotic IAV infections. Also, there is a potential for cats and other companion animals to give rise to novel (reassorted) viruses with increased zoonotic potential, including the emerging H5N1 and other avian influenza strains (Palombieri et al. 2022).

Urgent research is needed to understand the role of companion animals, including cats, in relation to potentially merging influenza viruses (Nishiura et al. 2023). Cats may serve as a link between avian influenzas in wild and domestic birds and humans (Yang et al. 2022, Bao et al. 2022).

3.6.2.4 Pox viruses

After the successful eradication of smallpox, the proportion of the human population vaccinated against the disease has decreased steadily. This decline in vaccination rates may play a role in the (re)emergence of other poxviruses that were previously kept in check due to cross-immunity with smallpox and the vaccine. This situation raises concern about the potential for zoonotic and reverse zoonotic transmission of pox viruses previously considered less significant (Kaler et al. 2022; Velavan et al. 2022). Several orthopoxviruses exist, with a complex and only partially known multi-species epidemiology (Diaz et al. 2021). There may also be effects on other non-human species by reverse zoonosis of pox viruses from humans through pets to wildlife (Afrooghe et al. 2022), and the role of domestic animals, including cats, should be kept in mind (Alakunle and Okeke 2022; Bonilla-Aldana and Rodriguez-Morales 2022).

Cowpox: Cowpox in humans is a rare zoonotic disease, likely to be confused with other pox or herpes viruses or selected bacteria due to the lack of clinical experience. Late diagnosis is one of the causes of unnecessary combined antibiotic therapy or surgical intervention. Recent cases of cowpox after cat scratches in Europe suggest that incidences have been rising and should be considered a diagnosis after cat contact (Swetaj et al. 2015; Zaba et al. 2017).

Mpox: Despite it earlier being called "monkeypox", the main reservoirs of the mpox virus are likely to be rodents and other small mammals, however the main reservoirs are currently unknown. While transmission between humans requires prolonged contact of mucous membranes or droplets, back-transmission to dogs has been shown (Seang et al. 2022). European rats and foxes and other species in occasional contact with cats have been suggested to play a potential role in the continuation of the ongoing outbreak (Blagrove et al. 2022; Bragazzi et al. 2023). However, African cats have not been infected by the virus (Haddad 2022) While susceptibility of European cats cannot be ruled out, no cases of mpox infection of domestic cats have been reported during the recent outbreak in Europe and the Americas.

Orf virus: Aa a *parapoxvirus* more distantly related to the other poxes mentioned above, orf is often confused with the much more serious *Capripoxvirus*. Both are commonly called "sheep pox" in Norwegian vernacular. But while the real sheep pox (*Capripox*) is a very serious sheep disease, it does to our knowledge not involve cats and is currently not found in Norway. Orf virus on the other hand, can give a (usually mild) disease in humans and a range of other animals, including cats (Spyrou and Valiakos 2015). However, apart from their general linking role, cats seem to play no role in transmission and epidemiology of orf.

3.6.2.5 Pseudorabies virus

The virus causing pseudorabies (Aujeszkys disease) is lethal to cats, and may be transmitted by cats to other animals, including cattle, sheep, pigs, rats, mice, rabbits and pigs. Pigs are the only species capable of sustaining a latent infection since the other species have a short and lethal disease progression (Sehl, and Teifke 2020). Humans are likely immune to the virus, yet some controversy remains on the issue as humans may have symptoms and carry the virus. Transmission happens through multiple routes, likely involving contaminated objects.

Both domestic and feral cats are part of the common host assortment for the virus (Liu et al, 2022), and as such they may bridge domestic and wildlife host reservoirs in an outbreak. Nevertheless, the pseudorabies virus seems to fade from an area once eradicated in pigs, which has been achieved in many Eurpean countries during the last few decades, and the virus has never been observed in Norway[16]. However, as wild boar is re-establishing in Scandinavia due to climate and other environmental changes (Casades-Marti et al 2019, Markov et al 2022), this situation may change, and pseudorabies become relevant.

3.6.2.6 Rabies virus

Rabies is caused by a Lyssavirus. Globally dog-bites are the cause of 99% of rabies cases in humans. Rabies is currently present in Svalbard, but not in mainland Norway (Wolff et al. 2020) and all imported dogs and cats are required to be vaccinated against rabies.

No cat-to-cat rabies transmission has been recorded, and no feline strain of rabies virus is known. However, cats are the most reported rabid domestic animal in the

[16] https://www.vetinst.no/sykdom-og-agens/pseudorabies-aujeszkys-disease

United States as they are considerably less often vaccinated than dogs (Brunt et al. 2021; Crozet et al. 2020). The virus is present in the saliva of rabid cats, and they can transmit the virus to humans through bites or scratches. Thus, if rabies becomes re-established in Norway, cats would be a source of potential exposure.

3.6.2.7 SARS-CoV-2

The Covid-19 pandemic is in an endemic phase globally, with long-term interactions between population immunity and emerging variant strains (Ying et al. 2021). SARS-CoV-2 from infected humans can spill over to other animal species within the *Mustelidae, Felinae* and *Caninae*. Also, some deer, bats, rodents and primates have been experimentally infected, with at least some strains shown to back-transmit to humans (Zhou and Shi 2021). Emerging surveillance programs have identified potential non-human host- and reservoir complexes internationally where the virus may accumulate changes, but the role that non-human hosts play in current and future developments of SARS-CoV-2 is still unclear and controversial (Escudero-Perez et al. 2023; Markov et al. 2023; Liu 2022; Hill et al. 2022; Carabelli et al. 2023; Ni et al. 2023; Borremans et al. 2019).

Deer mice (*Peromyscus maniculatus*) can be a competent host and potential reservoir species for SARS-CoV-2 (Griffin et al. 2021; Lewis et al. 2022). Unmodified common lab mice (*Mus musculus*) are not seroconverting hosts, while Syrian hamsters are (Bednash et al. 2022; Fan et al. 2022; Shou et al. 2021). Variation in antibodies suggest that some rodent species that interact with cats in human-dominated environments can vary greatly in host competence and infectivity. Interestingly, the first coronavirus-related disease recorded was likely a case of feline infectious peritonitis described as early as 1912 (Lin et al. 2021).

Even though the symptoms in house cats are rarely severe, they can infect other cats and experimental animals (Hosie et al. 2021; Murphy and Ly 2021). Infections from cats back to humans are suspected (Sila et al. 2021) but are believed to be rare and not a major driver of the current pandemic (Bessière et al. 2021; Decaro et al. 2021; Klaus et al. 2021; Lauzi et al. 2021). It is likely that cats only rarely pass the SARS-CoV-2 virus back to humans, but rare events may still be a concern in variants that have accumulated mutations affecting immune evasions and/or pathogenicity and transmissibility. This seems to be an unresolved situation (Ferasin et al. 2021; Fritz et al. 2022: Jairak et al. 2022; Kang et al. 2022). Adding further complexity, potential cross-immunity with feline coronavirus has been suggested to potentially either limit COVID-19 fatalities in humans or trigger reactions that facilitate infections, but the results are so far inconclusive (Decaro et al. 2021; Ghai et al. 2021).

3.6.2.8 West Nile virus

The agent of West Nile fever, a flavivirus, is typically vectored by Culex spp. mosquitoes in a bird-mosquito-bird cycle. A wide range of vertebrates may be infected when an infected mosquito bites another vertebrate, but humans and horses have been observed to be most susceptible to serious disease (Bosco-Lauth et al. 2019).

The West Nile virus has been moving northwards in Europe with climate change and is found in animals and humans in central Germany since 2018 (Farooq et al. 2022, Farooq et al. 2023). Cats at peak viremia may be capable of infecting mosquitoes, but their efficiency in doing so is so low that they are unlikely to contribute significantly as amplifying hosts (McNamara 2020). Furthermore, cats do not transmit the virus directly, so they are unlikely to play any important role even if West Nile virus were to establish in Norway.

3.6.3 Fungi

3.6.3.1 Dermatophytes

Fungal skin infections in animals can be caused by many fungi and have varying degrees of severity. In Norwegian cats, the most common are *Microsporum canis* and *Trichophyton mentagrophytes.* Cats may or may not show symptoms of spores in their fur or skin that can infect other animals or humans. However, the dermatophytes mostly found in cats generally only cause mild or no infestations in other host species[17]. Cats can of course also carry more serious infections from other species, like cattle ringworm (*T. verrucosum*) (Segal and Elad 2021), but the role of cats seem limited to rare vectoring of these more serious cases and more frequent vectoring of mild, self-limiting fingal skin infections.

3.6.3.2 Sporothrix spp.

Sporotrichosis is an emerging fungal infection of *S. schenkii / S. brasiliensis,* where a lineage of *S. schenkii* that is more pathogenic to humans has been reported as spreading out of South America[18,19]. It has so far not been seen in Norway but may be noted for its emerging status and poorly understood environmental persistence (Rabello et al. 2022).

3.6.4 Eukaryotic parasites

3.6.4.1 Helminths

Echinococcus multilocularis : This tapeworm is a parasite of domestic dogs and foxes that can infect cats, but the parasite produces few if any viable eggs in cats, and

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[17] https://www.vetinst.no/sykdom-og-agens/ringorm

[18] https://www.cdc.gov/fungal/diseases/sporotrichosis/pdf/Sporothrix-brasiliensis-Vet-508.pdf

[19] https://www.cdc.gov/fungal/diseases/sporotrichosis/brasiliensis.html

they are not an important part of its epidemiology in Germany (Conraths and Maksimov 2020).

Strongyloides stercoralis: This seems to be a somewhat poorly resolved cluster of closely related parasites on carnivores (Ko et al. 2020). Infection is common in temperate and sub-tropical areas, and while seemingly not established in Norway, the disease has been reported in other European countries, including Poland and Russia[20]. It is mostly associated with dogs, however, cats can also be infected and spread the parasites through faeces. Thus, cats may be of relevance should the parasite establish.

3.6.4.2 Nematodes

Dirofilaria spp. nematodes, known as heartworms, are zoonotic parasites vectored by mosquitoes, and have canids as main mammal reservoirs. Cats are less suitable hosts than dogs, and usually harbor a low number of adult worms, and patient infections are rare. Heartworrms are not present in Norway. The ongoing mostly climate-driven range expansion is bringing *Dirofilaria* and its mosquito vectors into greater contact with European and Russian pets and humans (Fuerher et al. 2021, Kondrashin et al. 2022), making it an issue in the foreseeable future. However, dogs are a much larger part of the epidemiology than cats, should the parasites establish.

Toxocara cati is of the most common roundworms in cats and Fennoscandian lynx (Virta et al. 2022). It seems to be an easily treated and undramatic intestinal parasite in felids together with *T. leonine,* which occur in cats and dogs. On the other hand, toxocariasis in humans is usually contracted by ingestion of eggs and can either be asymptomatic or cause conditions, such as fever, cough, pneumonia and vision loss. Pigs can also be infected from rodents or cat faeces (Davidson et al. 2012).

3.6.4.3 Ticks and mites

Norway has 13 known tick species. Ticks inhabit a range of habitats and have complex life cycles involving multiple hosts, some of which may involve cats.

Sheep ticks: The sheep tick (*Ixodes ricinus*) is by far the most common Norwegian tick[21]. It is adapted to a temperate climate and used to be most abundant along the coast from Oslo to Helgeland. Sheep ticks are expanding their range in Scandinavia, likely in large part due to climate change (Kjær 2019, Hvidsten 2020). Their contact rate with cats and humans increases accordingly.

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[20] https://www.vetinst.no/sykdom-og-agens/tr%C3%A5dorm-strongyloides-stercoralis

[21] https://flattsenteret.no/in-english/#:~:text=In%20Norway%20ticks%20are%20most,tall%20grass%2C%20shrubs%20and%20woodland

Tick densities vary considerably among areas, and the sheep tick thrives in shady places with tall grass, shrubs and woodland in deciduous forests. Ticks can also be found in gardens and urban parks. Cats, functioning as ambush predators in dense foliage, might imply that they frequently encounter ticks. However, their adept grooming behavior allows them to efficiently remove ticks (Samish et al. 1999; Hart et al. 2018). As a result, accurately estimating their overall tick exposure becomes challenging.

The sheep tick feeds on several species, including cats, rodents, birds, deer and sheep, as well as other grazing production animals. It may vector several diseases, especially Lyme disease (borreliosis), tick-borne encephalitis (TBE, Soleng 2018), and anaplasma, which is a particular problem in Norwegian sheep farming. In addition, neoehrlichia, babesia, rickettsia and tularemia have occasionally also been found in ticks in Norway.

House ticks: The house tick or dog tick (*Rhipicephalus sanguineus)* is a parasite that can form persistent infections in houses and vector multiple tick-borne diseases (Gray et al. 2013). Not currently endemic to Norway, a recent finding suggests an ongoing range expansion by house ticks with climate change. In countries where it is endemic, the house tick is mostly found on dogs, but it also occurs on cats. With their greater propensity for frequenting multiple houses, cats may be an effective vector of spreading ticks between households as it expands northwards, especially households containing both dogs and cats.

Scabies / mange: The mite *Sarcoptes scabiei* var. *canis* cause sarcoptic mange in foxes and dogs, but can also infect cats, requiring treatment. Humans can be infected by the mites from cats, but, as opposed to human scabies, the canid variant is self-limiting in humans and humans usually have only mild symptoms. The feline scabies caused by the *Notoedres cati* mites, on the other hand, are highly transmissible between cats and other felids. It can for example form serious infections in lynx, as well as lagomorphs and certain rodents. It may also infect humans, but with mild symptoms (Kraabøl et al. 2015). Both forms are rare in Norwegian cats, and the form of scabies that has been sharply rising in Norway 2012 –2022 (Amato et al. 2019) *S. Scabiei* var. *Hominis,* does not involve cats or other animals[22].

3.6.4.4 Protozoans

Giardia duodenalis is a globally distributed intestinal parasite that affects many species, including cats and dogs (Piekara-Stępińska et al. 2021). It is the most seen intestinal flagellate in Norway, yet likely underdiagnosed[23]. The most common infection route is fecal-oral, and while infection from cats is possible, most domestically acquired cases in Norway are likely to be from other sources in the environment. Cats do not

[22] https://www.fhi.no/sm/smittevernveilederen/sykdommer-a-a/skabb/?term=

[23] https://www.fhi.no/nettpub/smittevernveilederen/sykdommer-a-a/giardiasis---veileder-for-helsepers/

seem to play a notable role in the epidemiology, except for potentially being a source of feces close to humans and domestic animals.

***Leishmaniasia* spp.**: These protozoan trypanosome parasites cause the major global zoonosis leishmaniasis, which in the old world is vectored by sandflies in the *Phlebotomus* genus. The disease is currently not found endemically in Norway, being mostly just found in dogs who have been infected in other countries. Dogs are more likely to become sick and infectious to sandflies than cats, but cats can also be competent hosts in close contact with humans (Fernandez-Gallego et al. 2020). Therefore, although not currently a concern, feline leishmaniasis could become significant if the trypanosomes establish in Norway. This is particularly concerning due to the potential establishment of vector competent species in south-eastern Norway under near-future climate scenarios (Koch et al. 2017), coupled with ongoing surveillance that indicates a northward spread of the disease and vectors[24] (Semenza and Paz 2021).

3.6.5 Toxoplasma gondii

The coccidian protozoan *Toxoplasma gondii* infects more than one hundred species of vertebrates from bats to beluga whales (Johnson and Johnson 2020) and is the zoonosis most associated with cats. Cats and other *felidae* serve as the definite host producing oocysts, which is an environmentally resistant life cycle stage found in cat faeces. Oocysts can transmit the infection when ingested orally. A wide variety of warm-blooded animals, including humans, serve as intermediate hosts in which tissue cysts (containing bradyzoites) develop. Transmission can also occur from ingestion of these tissue cysts. The asexual *T. gondii* life cycle (Figure 16) can be indeterminately sustained in intermediate hosts through a combination of carnivory and vertical transmission. However, *T. gondii* produces gametes only in felids after the predation of infected intermediate hosts, so they play a key role in the parasite life cycle. *Toxoplasma* in the environment is likely closely connected to cat density. Cats become hosts by eating infected rodents, birds, or other small animals, and pass the parasite on in their faeces for up to 3 weeks after infection. Mature cats are less likely to shed *Toxoplasma* if they have been previously infected, but all age groups can shed oocysts.

Host species, including humans, are infected by *Toxoplasma* when they ingest oocytes in soil particles, cat litter, contaminated vegetables, shellfish or drinking water, or by ingesting contaminated or infected meat. Congenital transmission and tissue cyst also play roles in maintaining the parasites in as intermediate hosts including small mammals and birds. In humans, congenital transmission from mother to child occurs and is very serious (Dubey et al. 2021), but this is currently extremely rare in Norway. Transmission through transfusion or other medical procedures is also rare. Most

[24] https://www.ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data/phlebotomine-maps

animals that have toxoplasmosis show no signs of illness. Severe disease is most often seen in young animals, whereas sign is abortion is most noted in adult animals, particularly sheep. Affected dogs may show signs of encephalitis, whereas adult cats may show signs of pneumonia or damage to the nervous system or eyes.

There are three predominant *T. gondii* lineages, termed Types I, II and III. The Type I strain is associated with a higher pathogenicity in humans (Halonen and Wales 2013).

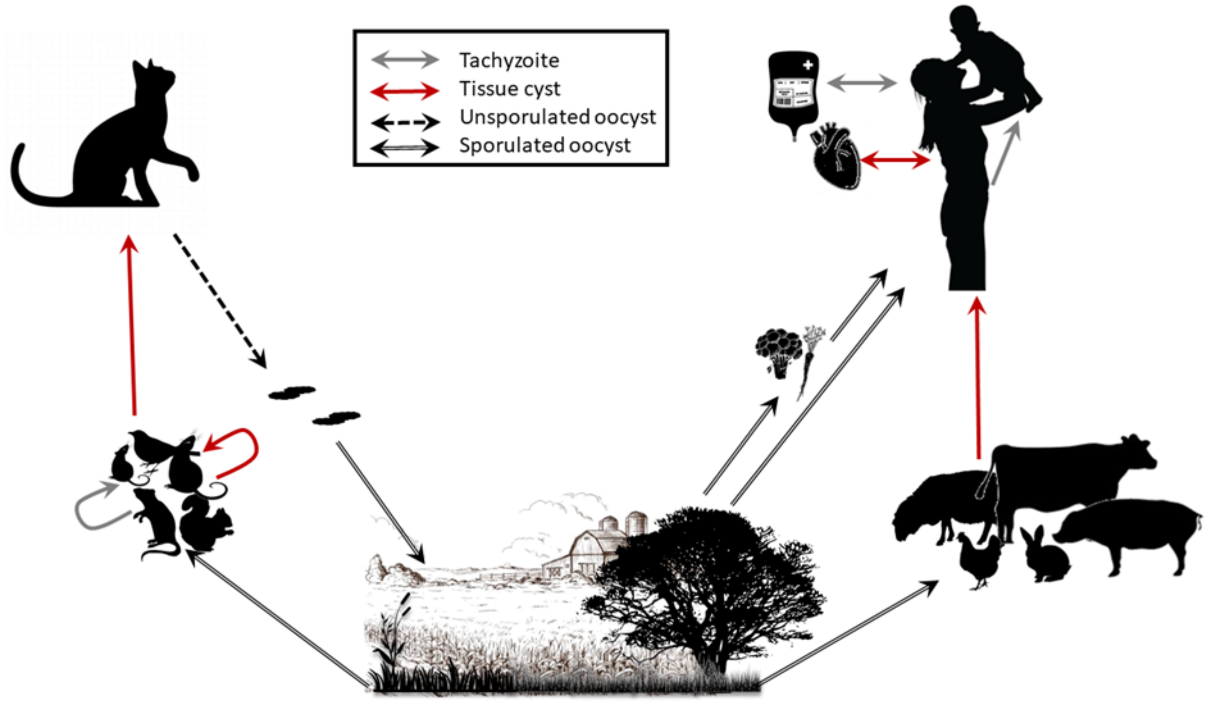

Figure 16: The life cycle of *T. gondii* in main transmission pathways relevant for humans, marked with the corresponding stages of the parasite life cycle. Cats are necessary for parasite reproduction and deliver oocysts to the environment through faeces. Humans and other animals are infected either directly through ingestion of oocysts from faeces, contaminated soil or vegetables, or indirectly through eating undercooked meat with tissue cysts. *T. gondii* can cross the placental barrier and be present in donated blood or organs. Congenital toxoplasmosis and tissue cyst transmission also may play roles in maintaining infection in the intermediate hosts (small mammals and birds).

3.6.5.1 *Toxoplasma* in the food chain

Toxoplasmosis is worldwide common in sheep, goats, pigs, and chickens, while cattle and horses are notably resistant to the disease. In sheep, congenital infection is a major cause of stillbirth / preterm lamb loss. If they survive, congenitally infected lambs are an infection risk. Pigs rarely show clinical signs, but the uncooked meat of infected pigs serves as a source of human infection (Aguirre et al. 2019).

3.6.5.2 *Toxoplasma* and birds

There are several reports of clinical toxoplasmosis in doves, sometimes in the epizootic form. Affected birds were anorexic, dull, emaciated, and had inflamed eyes affected by conjunctivitis with excessive fluid or ocular exudate and convulsions towards the time of death. Some species or breeds of pigeons appear to be more susceptible to clinical toxoplasmosis than others (Dubey 2002).

Anthropogenic disturbance is facilitating the spread of *T. gondii,* and wild birds are important intermediate hosts. A recent study utilized serological, bioassay and molecular prevalence data from 81 studies conducted globally. This comprehensive analysis covered 24,344 individuals representing 393 avian species from 84 families. The findings revealed that the prevalence of *T. gondii* increased with the trophic level within terrestrial environments, reaching its highest levels in terrestrial omnivores (Wilson et al. 2020).In aquatic species, prevalence is more consistent across trophic levels, but high prevalence in aquatic herbivores and insectivores reflects significant waterborne exposure to oocysts.

The presence of *Toxoplasma* seropositive animals in felid-free areas, such as the Arctic and oceanic islands, has been attributed to migratory birds infected elsewhere that arrive and enter the local food chain (Deem et al. 2010, Prestrud 2008). Toxoplasmosis in avian populations can be a considerable concern from the wildlife conservation perspective, as several species are acutely sensitive and have died of disseminated toxoplasmosis. The large population declines in birds worldwide means that human disturbance-mediated pathogens, such as *T. gondii*'s role in bird health, should be better understood (Dubey 2002; Rosenberg et al. 2019; Wilson et al. 2020, Prestrud 2008).

3.6.5.3 *Toxoplasma* and rodents

A key aspect of *T. gondii* success is its ability to facilitate their own transmission by changing the behaviour of infected intermediate hosts. Healthy lab rats avoid the source of cat urine odour and secrete stress hormones along with increased vigilance. *T. gondii* infected rats do not avoid the odour, and some are even attracted to it. However, the behavioral consequences of *T. gondii* infection exhibit a range of variations. These variations encompass effects, such as the avoidance of cat odors, a syndromic loss of various host defensive behaviors that enhance general trappability and catchability, and even the induction of a behavioral syndrome characterized by a wide array of maladaptive behavioral changes that heighten predation risk. A significant portion of this diversity appears to be systematically influenced by the specific lineage (I, II, or III) of T. gondii and the particular rodent species under study. For instance, rats infected with the less virulent type II lineages typically show milder changes during the acute phase of infection and more specific behavioral effects during the chronic period. Conversely, infection of inbred mice with virulent type I parasite strains leads to pronounced acute sickness and a wide range of behavioral alterations (Galeh 2020; Dubey 2021; Tong 2021).

Considering the strong behavioural effects of the parasite, it seems likely that the spill over will influence the disease burden and survival rate of local rodent populations. but few if any studies have been done on the population/conservation effects of parasite load on wild rodent populations.

3.6.5.4 *Toxoplasma* and other wildlife

The number of documented infected species is extensive, and pathways for wildlife infection include consumption of infected felids, predation or scavenging of infected intermediate hosts, direct ingestion of oocysts in contaminated soil, water and plants, and congenital transmission by transplacental transmission of tachyzoites from the infected parent. Depending on their geographic range, serologic studies in herbivores correlate with density of domestic cats linked to oocyst density, indicative of a greater prevalence of oocysts in the soil as domestic cat densities increase with human populations.

The same pattern is apparent in marine mammals, driven by land-to-sea coastal oocyst pollution linked to oocysts from storm water runoff from dense populations of domestic cats. Land-to-sea coastal exposure has resulted in fatal toxoplasmosis in phocids, otariids, mustelids and cetaceans, negatively impacting some threatened and endangered populations. Yet data on mortality in marine mammals are limited to those obtained through necropsies of stranded animals, implying that the number of affected marine mammals is likely underrepresented.

The effect on wildlife is not well quantified. *T. gondii* oocysts from domestic cats in runoff from terrestrial to marine environments has for instance been identified as a major cause of death in southern sea otters *Enhydra lutris nereis.* Otters are affected through direct mortality from the disease and increased vulnerability of infected otters to shark attacks, and as hampering the otter population's recovery (Shapiro et al. 2019a; 2019b). Toxoplasma also infect foxes (Milne et al. 2020a).

3.6.5.5 *Toxoplasma* effects on humans

T. gondii infects approximately one-third of the world human population, making it one of the most successful parasitic organisms in humans. Most human cases are seemingly asymptomatic or mild flu-like, but toxoplasmosis can cause serious problems for pregnant women (and their fetuses). Individuals who have compromised immune systems are at an increased risk for acute or re-activated infection, which may take a more severe form that causes damage to the eyes, brain or other organs. Risk groups includes infants born with congenital toxoplasmosis from newly infected mothers. Toxoplasmosis is the second leading cause of death among foodborne illnesses in the USA.

Exposure rates are significantly influenced by dietary habits and behaviour and can range from 10 to 80% in specific populations (Milne et al. 2020b). A study in Norway (Findal 2017) found toxoplasma antibodies in 9.3% of pregnant women, with marked regional differences. These rates are fairly consistent over time, despite a general decrease in infectious diseases over the last decades. Human incidences of toxoplasmosis in most high-income countries seem to have been declining over the last decades (Milne et al. 2022).

Although preventable and treatable, congenital, ocular and postnatal *T. gondii* infection is not curable and persists in all infected persons. Even amongst asymptomatic patients, toxoplasmosis has been linked to a range of behavioural alterations and conditions, such as changes in risk tolerance, neuroticism, mental illness, suicide and accident proneness (Johnson and Johnson 2021; Postolache et al. 2021) Whether such links are causal or simply correlational has been the subject of intense study and debate. However, the evidence and proposed causality linking *T. gondii* to various human neuropsychiatric disorders suggests that the public health burden of latent infection may far outweigh that caused by acute and congenital toxoplasmosis (Milne et al. 2020b). More research is needed to establish the magnitude of the effects, the relationship with cat density and interaction with parasite strain type and other eco-epidemiological factors. Even establishing a non-infected baseline is challenging due to the ubiquitous nature of cats and *T. gondii* (Damek 2023).

3.6.6 Other health conditions and diseases related to keeping cats

3.6.6.1 Asthma and allergy

Exposure to cats can trigger allergic reactions, whereas growing up with a dog or cat in the house during the first year of life has also been suggested by some studies to confer some degree of protection against childhood asthma and allergy in humans, possibly through exposure to parasites. However, these results are contested and other studies have reached different conclusions (Jõgi et al. 2018, Ojwang et al. 2020, Ji et al. 2022, Gao et al. 2020).

3.6.6.2 Feline Spongiform Encephalopathy

The transmissible spongiform encephalopathies (TSEs) include Creutzfeldt-Jakob disease (CJD) in humans, scrapie in sheep and goats, chronic wasting disease (CWD) in cervids, bovine spongiform encephalopathy (BSE) in cattle and Feline Spongiform Encephalopathy (FSE) in felids. FSE is a transmissible spongiform encephalopathy in domestic cats and other Felidae. CWD, BSE, FSE and other TSEs are likely occur after the consumption of prion-infected material. Strain typing studies suggest similarity between the FSE and BSE prion strains, which supports the hypothesis that FSE is caused by an infection with BSE prions (Kathiriya et al. 2020; Onodera and Sakudo 2020). Most cases of human prion disease occur from unknown reasons, but the remaining uncertainties about the origins and relationships between animal prion diseases emphasize the importance of limiting human exposure, and of continued surveillance for both animal and human prion diseases (Houston and Andréoletti 2019; Onodera and Sakudo 2020; Etchecopaz et al. 2021).

3.6.7 Note on cats and rodent-born disease control

The use of domesticated animals as predators, such as the combined application of dogs and cats, has effectively culled and scared away rodent pests since the early days of agriculture (Ottoni et al. 2017; Abdullahi et al. 2020; Badenes-Perez 2023). As mesopredators that receive food from humans and thus can maintain high population densities when rodents are scarce, they can theoretically be successful in locally suppressing prey populations. However, surprisingly little is known about the cost-effectiveness of cats in controlling the population densities of peridomestic rodents and their associated diseases and damages under different circumstances. It is possibly a trade-off between agricultural losses and disease risks from rodents versus disease risks from cats. Cats can be cost effective at rodent control but still pose health risks through spread of diseases and parasites. The use of cats as a part of rodent control in traditional rural communities apparently reduces plague incidence (Banda et al. 2023). However, it is unclear to what degree this positive effect translates into the current Norwegian modern infrastructure and if there are circumstances under which the benefits of rodent control outweighs the potential risk of disease transmission through the cats. This knowledge gap might be important as ecological and sustainable modes of agriculture and pest control become more popular and climate and socioeconomic changes affect zoonotic pathogen distributions.

4 Risk assessments

Cats, as other alien species, can represent a hazard to biodiversity and animal welfare through various mechanisms. The IUCN[25] has defined 12 mechanisms through which an alien taxon might have an impact (IUCN 2020, based on Nentwig et al. 2010, Kumschick et al. 2012 and Blackburn et al. 2014). Of these, the VKM project group concluded that cats potentially have negative impacts through four mechanisms: predation, competition, transmission of diseases (or pathogenic organisms) and indirect impact through interactions with other species. These impacts were assessed individually for groups of species, or individual species, depending on available data. Impact of predation on fishes and invertebrates were not assessed due to lack of data.

4.1 Risks related to cat predation

4.1.1 Direct effects of cat predation on rural and urban bird populations

Risk: Potentially High
Confidence: Medium to High

4.1.1.1 Hazard identification

As described in sections 3.1 - 3.4, cats are efficient predators of a wide variety of prey, and we estimated that 3.9–13.8 million birds are killed annually by domestic cats in Norway (Table 21). Assuming the predation is at least partially additive, losses to cats might impact prey populations negatively.

4.1.1.2 Hazard characterization

Cat predation risk for birds is high in urban and rural habitats, but low in continuous forest and in mountains. In urban and rural areas, cats were estimated to kill between 2.7 – 11% of the total bird populations each year, for species exposed to cat predation. For the most vulnerable species, predation rates can be higher. The most vulnerable bird species are those with a small body size, nesting low or on the ground, foraging on the ground, and occurring frequently close to human habitation (Table 23). These bird species are likely to experience higher predation rates than other species. The potential population impacts of cat predation are likely to be highest for species with high vulnerability, having most of their populations in urban and rural habitats, and which are also red-listed (Table 24). For species and populations that are highly vulnerable, cat predation could potentially have a substantial negative impact on population trajectories. Across all bird species in Norway, the impact of cat predation might vary from **Minimal** (especially for species with low vulnerability and not regularly occurring in neither urban or rural habitats) to **Major** (in particular species

[25] http://www.iucngisd.org/gisd/

listed in Table 24). The hazard characterizations are assessed with **High** and **Medium** confidence, respectively.

4.1.1.3 Likelihood

For species with low vulnerability, not regularly occurring in urban and rural habitats, and not red-listed, cats are **Very unlikely** to have negative population consequences. For the most vulnerable species having a large proportion of their populations in urban and rural habitats, and being red-listed, negative impacts are **Likely**. The likelihoods are assessed with **High** and **Medium** confidence, respectively.

4.1.1.4 Risk characterization

Depending on the vulnerability, distribution and population status of individual bird species, the risk from cat predation is assessed to vary from **Low** to **High**. Species with low risk are birds of low vulnerability, not regularly occurring in urban and rural habitats, and not red-listed. Species at high risk include species of high vulnerability, having most of their populations in urban and rural habitats, and which are also red-listed. The risk is assessed with **High** to **Medium** confidence, with the highest confidence for the lower risks.

4.1.2 Direct effects of cat predation on specific bird "hotspots"

Risk: Potentially High
Confidence: Medium to High

4.1.2.1 Hazard identification

Apart from the general effects of cat predation on birds in urban and rural areas, some cats occur close to bird hotspots, and may pose a greater hazard at a local scale.

Norwegian RAMSAR areas vary significantly in the exposure to potential cat predation from owned cats in surrounding settlements (Table 30). Ilene and Presterødkilen Wetland System in Tønsberg, Åkersvika in Hamar, Nordre Øyeren, Fiskumvannet, Reisautløpet, and parts of the Trondheimfjord, Giske, Lista and Jæren wetlands systems are all narrow wetlands where cats from surrounding farms, suburban and urban areas seem to have physical access. The degree to which cats move into the areas important for bird nesting, resting and feeding to hunt likely vary between locations, but these locations seem particularly exposed. Importantly, the RAMSAR areas are predominantly established to preserve specific wetland habitats that are utilized as both stop-over sites for migrating birds and breeding sites. The wetland-birds utilize open water and mud-banks in these areas, and the potential predation in these areas is therefore likely to affect other species than the threatened migrating wetland-birds.

Cat densities are likely to be highest around the Oslo fjord area, the Trondheims fjord area, and in a belt along the south-western coast of Norway (Figure 14). Thus, species attracted to mild winters and coastal climates are on average more likely to live in habitats exposed to high cat densities (Figure 15).

4.1.2.2 Hazard characterization

Bird hotspots, such as seabird colonies, wetland nature reserves, or important stopover sites for migratory birds may occasionally experience high rates of cat predation (see e.g., Heggøy and Shimmings 2018), although most such sites are safe from cat predation. In such sites, cat predation may affect a wide range of species, including some birds that are red-listed in Norway. At seabird colonies, cats may pose a threat to Common Eider (*Somateria molissima*, ærfugl), several species of shorebirds (Charadrii, vadefugler) and gulls and terns (Laridae, måker og terner). At bird-rich wetlands, many types of birds may be at risk, including ducklings, and migrating shorebirds may be taken by cats at stopover sites (Michaelsen 1998). Across all bird hotspots in Norway, the impact of cat predation is likely to vary significantly. In most sites, the effects will be "Minimal" or "Minor", but it can be "Major" on a local scale in a few hotspot sites. However, each of these hotspot areas only constitute a relatively small part of the total Norwegian population of the species of concern, and thus, the overall impacts at a regional or national scale are assessed to be **Minimal** to **Moderate** with **Medium** confidence.

4.1.2.3 Likelihood

At bird hotspots where large number of cats occur, such as colonies of feral cats, negative impacts on several bird species are **Very likely**. On the other hand, because cats generally avoid wet and open areas, most seabird colonies and wetlands important for breeding or stopover are not likely to be affected by cat predation and population impacts are **Very unlikely**. The likelihood is assessed with **Medium** confidence.

4.1.2.4 Risk characterization

The risk of effects of cat predation on birds is assessed to vary from **Low** in most areas to **High** in a few areas where large number of cats occur close to bird hotspots. The risk of negative effects on vulnerable species and assemblages in the species-rich areas corresponding to high cat exposure is thus **High**. This is assessed with **Medium** to **High** confidence, with the highest confidence for the highest risks.

4.1.3 Indirect effects of cats on prey populations

Risk: Potentially Medium
Confidence: Low to Medium

4.1.3.1 Hazard identification

Predators may have non-lethal effects on their prey by creating a 'landscape of fear' where exposure to predation risk may modify space use or depress reproduction and survival, with potential implications for population size and viability. For instance, birds and bats may abandon roosts due to cat presence or disturbance. Exposure may be less relevant for reptiles that either give birth to live young or lay eggs without brood care. Amphibians lay eggs in water where cats do not live, although they are susceptible to predation during terrestrial life stages. Few studies have assessed the non-lethal effects of cats, but the limited evidence available suggests that cats may also have such effects on their prey.

4.1.3.2 Hazard characterization

In Norway, several million pairs of birds and mammals may be exposed to non-lethal effects through cat presence. The reduction in reproduction may amount to several million young produced per year. The impact of the non-lethal effects is likely to depend on cat density and is therefore likely to be most widespread in urban and rural areas where the density of cats is highest. The same species that are normally vulnerable to cat predation may be most affected among birds (Tables 23 and 24 and mammals (Table 26).

The population impact of non-lethal effects is likely to be highest for species with high vulnerability, having most of their populations in urban and rural habitats, and which are also red-listed (Tables 24 and 26). In addition, it is possible that species with low predation vulnerability may also respond to cat presence to some degree, with potential consequences for reproduction. Overall, the impacts of cat presence may vary from **Minimal** to **Moderate**. The hazard characterization is assessed with **Low** confidence.

4.1.3.3 Likelihood

The likelihood of non-lethal effects is expected to depend closely on cat density, varying from **Very unlikely** to **Likely**. Vulnerable bird species occurring in urban and rural habitats are most likely to be affected. The likelihood is assessed with **High** confidence.

4.1.3.4 Risk characterization

Depending on cat density, the risk related to non-lethal effects of cat presence for individual bird species is assessed to vary from **Low** to **Medium**. Species with low risk are those with low vulnerability, not regularly occurring in urban and rural habitats, and not red-listed. Species with high risk are those with high vulnerability, having most of their populations in urban and rural habitats, and which are also red-listed. The risks are assessed with **Medium** to **Low** confidence, with the highest confidence for the lower risks.

4.1.4 Impacts of direct cat predation on population dynamics of non-red-listed small mammals

Risk: Potentially Medium
Confidence: Low

4.1.4.1 Hazard identification

A total of 35 mammalian species are potential prey for domestic cats in Norway and predation by cats is documented for 30 of these species (Table 26). The species currently listed on the Norwegian Red List are threated separately in section 4.1.5. Cat predation might also affect the population dynamics and perturb the local and regional dynamics of the species that are not threatened. In particular, several non-threatened rodent species are potentially affected. Species populations that are located close to human settlements in urban and rural areas are most vulnerable. Note that cats are sometimes kept to limit populations of rodents that can damage food and property and spread zoonoses. However, it is unclear if this effect on the prey population is only local or affects population dynamics on a larger spatial scale.

4.1.4.2 Hazard characterization

We estimated that ca. 20.3 million mammals are taken per year in Norway by cats (range 12.6 to 42.8 million). If comparable to the findings in studies of cat predation from other European countries, approximately 80% of the mammalian prey items in Norway include rodents (Table 25). Population sizes of small rodents fluctuates widely in time and space, and no estimates of total abundance exist. Moreover, also cat density vary in space and time, and predation pressure on small mammals is likely to be heterogenous in space. It is expected that species at risk (see Table 26) that are distributed close to urban and rural areas are more susceptible compared to species that are mainly distributed in habitats further away from human settlements.

The impact of cat predation is assessed to vary from **Minimal** (especially for species in the larger end of the body sizes that are potential prey for domestic cats, and species not regularly occurring in urban and rural habitats) to **Moderate** (small species in rural and urban habitats, Table 27). The assessment is made with **Medium** confidence’.

4.1.4.3 Likelihood

For species of mammals with low vulnerability (e.g. due to large body mass) and not regularly occurring in urban and rural habitats, and with high reproduction rates, cats are **Very unlikely** to have negative population consequences. For the most vulnerable species, having a large proportion of their populations in urban and rural habitats, negative population impacts locally are **Likely**. The likelihood is assessed with **Low** confidence.

4.1.4.4 Risk characterization

Depending on the vulnerability, distribution and population status and reproductive output of individual mammal species, cat predation is assessed be a **Low** to **Medium** risk. The assessment is made with **Low** confidence.

4.1.5 Impact of cat predation on red-listed mammalian prey species

Risk: Potentially Medium
Confidence: Low to High

We assessed the impact of cat predation on eight of the nine red-listed mammals potentially preyed upon by cats in Norway (Table 27). Two of the species, the northern bat and the even-toothed shrew, are not associated with rural and urban habitats where most cats reside (Table 26). Evidence for cat predation on northern bat populations exists from several locations in Norway and the species was therefore fully assessed. For the even-toothed shrew, there are no documentation of cat predation from Norway or elsewhere, and the species was therefore disregarded for further analysis.

4.1.5.1 Hazard identification

Table 26 presents the habitat types in Norway and the Norwegian Red List statuses for each of the mammals assessed. IUCN lists the western barbastelle as Vulnerable in Europe (Hutson et al., 2007a) and Near Threatened globally (Piraccini, 2016), while the northern bat, common noctule bat, Nathusius' pipistrelle and parti-coloured bat are listed as species of Least Concern both in Europe (Hutson et al, 2007b; Hutson et al., 2007c; Hutson et al., 2007d) and globally (Coroiu, 2016a; Coroiu, 2016b; Csorba and Hutson, 2016; Paunović and Juste, 2016). On the Norwegian Red List, the conservation status of the northern bat was changed from Least Concern in 2015 to Vulnerable in 2021 due to decreasing population size (Eldegard et al., 2021b), while the status of Nathusius' pipistrelle bat was changed from Vulnerable in 2015 to Near Threatened in 2021 due to increasing populations in neighboring countries (Eldegard et al., 2021e). Natterer´s bat is listed as a species of Least Concern by IUCN (Gazaryan et al., 2020), but the population trend is uncertain. Also, the mountain hare and the northern birch mouse are listed as species of Least Concern both in Europe (Henttonen et al., 2007; Meinig et al., 2007) and globally (Smith and Johnston 2019; Meinig et al., 2016). However, the mountain hare population size in Fennoscandia is decreasing (Eldegard et al. 2021g).

The range of the western barbastelle bat is largely restricted to central and southern Europe. The main habitat is deciduous forest, but the western barbastelle may also inhabit buildings for roosting and breeding. The western barbastelle is cold tolerant, mainly stationary, and can overwinter in basements, or other underground building structures. Few observations have been recorded in Norway, but the finding of one individual in a tunnel (near Larvik) was taken as evidence of occurrence of a local breeding population (Zeale, 2012). Documentation of cat predation exists from Germany (Meschede and Rudolph, 2004).

The northern bat has a northern Palearctic distribution and is the only bat distributed throughout Norway with breeding populations in Nordland and Indre Troms. The northern bat is found in a variety of habitats, but its habitat in Norway does not include semi-natural and artificial sites (Table 26). It can nevertheless be observed hunting under streetlights and summer roosts are almost always found on buildings, often in heated buildings attached to chimneys (Eldegard et al., 2021b). The colony size is usually 10-30 animals but can reach 100. The species is mainly stationary, but movements over larger distances (100km) occur. Small winter roosts of 2 to 4 individuals can be found in basements. Disturbance of colonies in houses is a major threat in Europe (Hutson et al., 2007b). Predation by cats on northern bats has been documented in several locations in Norway, as well as in other European countries (Table 26 and Figure 12).

The Natterer´s bat has a western Palearctic distribution and is widespread in Europe. The population size in Norway is estimated to less than 50 individuals (Eldegard et al. 2021c). The species has not been observed since 2010 despite efforts to find it. Nursing colonies of up to 200 individuals can be found in buildings. Predation by cats has been documented in several European countries (Table 26).

The common noctule bat has a wide Palaearctic distribution and undertakes seasonal migrations between breeding area and hibernation ranges, which are situated in central and southwest Europe (Hutson et al., 2007b). The common noctule usually breeds in old trees, such as in woodpecker holes, but may also roost in buildings where it can be vulnerable to cat predation (Vlaschenko et al., 2019). There are no documented breeding locations in Norway. Predation by cats has been documented in Europe (Table 26).

The Nathusius' pipistrelle bat has a western Palearctic distribution. The species is migratory with maternity colonies of 10 to 200 animals and summer roosts in tree holes and buildings, and winter roosts in rock crevices, caves and buildings. It is unclear if the species overwinters in Norway. Cat predation has been documented in Europe (Table 26).

The parti-coloured bat has a wide distribution in the northern Palaearctic. Summer roosts are usually situated in houses or other buildings. Winter roost sites include rock crevices in tall buildings, especially in cities. Documentation of cat predation exists from Norway and other European countries (Table 26).

The mountain hare is distributed from Fennoscandia to the Pacific coast of Russia and is found throughout Norway. In a report on the population status of hares in Norway from 2012, Pedersen and Pedersen (2012) suggested that domestic cats may be a considerable cause of mortality to juvenile hares (leverets). In a study from Sweden (Dahl, 2005), cats were accountable for 47% of the mortality of leverets in urban areas. Kauhala et al. (2015) reported that young lagomorphs particularly were favored by feral cats in Finland.

The northern birch mouse has a wide northeastern Palearctic distribution, while the Scandinavian populations are isolated from the rest of the range. The species is found within three separated areas of Norway of which one is connected to the Swedish population. It is mainly nocturnal. Predation by cats has been documented in Sweden (Table 26).

4.1.5.2 Hazard characterization

There are no documented cases of cat predation on the western barbastelle in Norway, but the species is rare and recorded from only two locations (see Figure 12). Its habitat overlaps with that of cats, and it may occur inside buildings where it may be vulnerable to cat predation. Given the small population size and its high extinction risk, VKM assesses that cat predation could have **Massive** impact on the western barbastelle in Norway. This assessment is made with **Medium** confidence.

The northern bat forms relatively large maternity colonies that could be vulnerable to cat predation, but its main habitat in Norway is not within rural or urban areas where the density of cats is highest. The northern bat is, however, widely distributed throughout the country (Figure 12) with decreasing population size and cat predation has been documented in several locations. VKM assesses that cat predation could have **Minor** impact on the northern bat in Norway. This assessment is made with **Medium** confidence.

There are no documented cases of cat predation on the Natterer’s bat in Norway, but the species is rare and very few observations exist (see Figure 12). Its habitat overlaps with that of cats, and it may occur inside buildings where it may be found by cats. Given the small population size and its high extinction risk, VKM assesses that cat predation could have **Massive** impact on the Natterer’s bat in Norway. This assessment is made with **Medium** confidence.

The habitat of the common noctule overlaps with that of cats and it may occur inside buildings where it may be found by cats. Its population was estimated to around 500 individuals and is decreasing in Norway. VKM assesses that cat predation could have **Moderate** impact on the common noctule in Norway. This assessment is made with **Medium** confidence.

The habitat of the Nathusius' pipistrelle overlaps with that of cats, but the species is mainly associated with forest. The population in Norway has been estimated to less than 1000 individuals, but with a supply from neighboring countries. VKM assesses that cat predation could have **Minor** impact on the Nathusius' pipistrelle in Norway. This assessment is made with **Medium** confidence.

The parti-coloured bat is found in rural and urban habitats where the density of cats is high. It forms colonies in buildings where it could be vulnerable to cat predation. The population size has been estimated to be less than 2000 individuals (Table 27). VKM assesses that cat predation could have **Moderate** impact on the population of parti-coloured bat in Norway. This assessment is made with **Medium** confidence.

The mountain hare is associated with semi-natural and artificial sites with expected high density of cats. Cat predation on leverets is well documented in Norway. VKM assesses that cat predation could have **Minor** impact on populations of mountain hare in Norway. This assessment is made with **Medium** confidence.

The northern birch mouse is associated with semi-natural and artificial sites with expected high density of cats. VKM assesses that cat predation could have **Minor** impact on populations in Norway. This assessment is made with **Low** confidence.

4.1.5.3 Likelihood

Given the rarity of the western barbastelle in Norway, VKM assesses that negative effects of cat predation are **Unlikely** to occur. This assessment is made with **High** confidence.

VKM assesses that cat predation is **Moderately** likely to have negative impact on the northern bat in Norway. This assessment is made with **Medium** confidence.

Given the rarity of the Natterer’s bat in Norway VKM assesses that cat predation is **Unlikely** to occur and thereby negatively impact populations. This assessment is made with **High** confidence.

The nursing colonies of the common noctule will be less accessible to cats when they are in trees than in buildings. VKM assesses that the likelihood of cat predation to negatively impact populations of common noctule in Norway to be **Moderately likely**. This assessment is made with **Medium** confidence.

The Nathusius' pipistrelle is mainly associated with forest and only parts of the life cycle take place in Norway. VKM assesses the likelihood of cat predation to negatively impact populations of Nathusius' pipistrelle in Norway to be **Unlikely**. This assessment is made with **Medium** confidence.

The parti-coloured bat forms colonies in buildings where it could be vulnerable to cat predation. The sound made by males could attract cats. The estimated probability for the parti-coloured bat of experiencing high cat predation is relatively high (Figure 15). VKM assesses that the likelihood of cat predation having a negative impact on populations of parti-coloured bat in Norway to be **Moderately likely**. This assessment is made with **Medium** confidence.

The likelihood of cats preying on juvenile mountain hares is high. However, hares have a high reproductive output, low rates of juvenile survival (see Table 27) and are widely distributed throughout the country, including natural habitats with low cat density. Hence, the likelihood of cats having negative impact on Norwegian hare population is assessed to be **Very unlikely**. This assessment is made with **Medium** confidence.

Documentation of cat predation on northern birch mouse in Norway was not found and the likelihood of cats having negative impact on the Norwegian populations is assessed to be **Unlikely**. This assessment is made with **Low** confidence.

4.1.5.4 Risk characterization

VKM assess that the potential direct effects of predation by cats represent a **Moderate** risk to the populations of western barbastelle, northern bat, Natterer's bat, common noctule bat, Nathusius' bat and parti-coloured bat in Norway. Potential non-lethal effects of cats on breeding success and pup survival would also be a negative impact. The assessment is made with **Medium** confidence.

For the mountain hare and northern birch mouse populations in Norway, VKM assess that the potential direct effects of predation by cats represent a **Low** risk. Potential non-lethal effects of cats on breeding success and pup survival would also be a negative impact. The assessment is made with **Medium** confidence.

4.1.6 Direct effects of cat predation on reptile and amphibian populations

Risk: Potentially Medium
Confidence: Low to Medium

4.1.6.1 Hazard identification

Table 28 provides an overview of the habitat requirements for the Norwegian reptiles and amphibians, and Figure 13 illustrates their distribution in Norway. The species-specific knowledge of the ecological requirements is good for all the Norwegian species. The knowledge about distribution is also good, but the knowledge about the size and status of the populations is poor (Dervo et al. 2021). The size of the populations of all the Norwegian species is in slight decline, mainly due to loss of habitat (Artsdatabanken 2021). Four species are listed on the Norwegian Red List as species that are near endangered or higher categories (Table 29). However, all the other Norwegian reptiles and amphibians are listed as least concern (LC) in the Norwegian Red List. Basic information on species distribution, ecological requirements and climate tolerance is only of sufficient quality for pool frogs and great crested newt (Table 31). For the other species, such information is partially missing.

All reptiles and amphibians that occur naturally in Norway are potential prey for cats. Except for pool frogs, there is currently no monitoring of the Norwegian reptiles and amphibians. For pool frog, no cat predation has been reported. However, the pool frog population is very small, which makes it potentially vulnerable to any cat predation. For the other Norwegian species, there are observations of individuals taken by cats. However, there are no concrete numbers on the proportion of populations taken by cats. With few observations of cat predation, it is difficult to estimate the proportion of natural populations that cat predation represents.

4.1.6.2 Hazard characterization

Smooth snake (*Coronella austriaca*) (Red List status: NT) and pool frog (*Pelophylax lessonae*) (Red List status: CR) will be the two most vulnerable species to cat predation based on their population size and lifestyle (Table 31).

Smooth snake is listed as near threatened (NT) in the Norwegian Red List, mainly due to habitat loss. The population of smooth snake is declining in Norway and cat predation can be an important contributing factor to a reduced population in the most urban areas. Many residential areas are close to the preferred habitats for smooth snake in Norway. There are only three areas in Norway where annual counts of the number of smooth snakes take place (Beate Strøm Johansen, pers. comm.) There are not enough observations to allow an estimate of the proportion taken by cats. However, it is well known that predation occurs and is the project group assess that predation can have a **Moderate** effect on the smooth snake population. The assessment has **Medium** confidence.

The pool frog lives in a habitat that is not favorable for cats. However, less than 170 individuals of this species occur in Norway (Engmyr and Reinkind, 2019, Lars Mørch Korslund pers. comm.). A very small population size combined with the fact that they are distributed close (3-500 m) from settlements where there are cats, still make the pool frog very vulnerable. The size of the pool frog population is estimated annually. It has not been documented that cats have taken pool frogs, but the species could easily be exterminated if cats catch even a few individuals of the species. The potential effect is therefore assessed to be **Major**, with **Medium** confidence.

For the last two red-listed amphibians, cat predation probably has little effect on the population size. Great crested newts (*Triturus cristatus*) (NT) are poisonous and not a popular prey for cats. The national monitoring program that lasted from 2012 to 2017 did not document cat predation as a problem for this species (Dervo et al. 2013). The habitat of the moor frog (*Rana arvalis*) (VU) is often humid and unattractive to cats (Dervo et al. 2021). VKM assesses that the potential effect of cats on the great crested newt is **Minor** (with **Medium** confidence) and **Moderate (**with **Low** confidence), respectively for moor frog.

The common lizard (*Zootoca vivipara*) and slow worm (*Anguis fragilis*) are the two species that have the most observations of being taken by cats. However, these are also quite common species, and a large proportion of the population lives outside areas with high cat density. Therefore, the impact of cat predation is estimated to be **Minor**. This assessment has **Low** confidence.

All other Norwegian species of reptiles and amphibians are estimated to be less vulnerable to cat predation and the effects are assessed to be **Minimal**. This is assessed with **Low** to **Medium** confidence.

4.1.6.3 Likelihood

The population of pool frog is very limited, both in numbers and distribution, and it has close proximity to human settlement and potential cat predation. Thus, the project group assesses that negative effects on this species are **Moderately** likely to occur with **Medium** confidence.

The likelihood of negative consequences is assessed to be **Unlikely** for smooth snake, great crested newt, moor frog, common lizard, slow worm, grass snake (*Natrix natrix*) and smooth newt (*Lissotriton vulgaris*). The assessment is made with **Low** confidence.

For the European viper (*Vipera berus*), common frog (*Rana temporaria*) and common toad (*Bufo bufo*), the negative consequences are expected to be **Very unlikely**. The assessment is made with **Medium** confidence.

4.1.6.4 Risk characterization

The risk from cat predation on the species of reptiles and amphibians is listed in Table 31.

Table 31: Risk characterization for the impact of predation of cats on reptiles and amphibians.

Species	Hazard characterization	Likelihood	Risk characterization	Overall confidence
Listed as "Near threatened" or higher				
Smooth snake	Moderate	Unlikely	Medium (bordering to Low)	Medium
Great crested newt	Minor	Unlikely	Low	Medium
Moor frog	Moderate	Unlikely	Medium (bordering to Low)	Low
Pool frog	Major	Moderately likely	Medium (bordering to High)	Medium
Listed as "Least Concern"				
Common lizard	Minor	Unlikely	Low	Low
Slow worm	Minor	Unlikely	Low	Low
European viper	Minimal	Very unlikely	Low	Medium
Grass snake	Minimal	Unlikely	Low	Low
Smooth newt	Minimal	Unlikely	Low	Medium

Common frog	Minimal	Very unlikely	Low	Low
Common toad	Minimal	Very unlikely	Low	Low

4.1.7 Effects of cats through competition with wild populations of native avian and mammalian predators

Risk: Potentially medium
Confidence: Low

4.1.7.1 Hazard identification

By preying on a variety of species, cats may potentially be competitors for native predators, including birds of prey, foxes and snakes. Examples of resource competition are well known in nature, but rates of competition are difficult to assess under field conditions.

4.1.7.2 Hazard characterization

Competition with wild carnivorous species in Norway over scarce resources is not documented in the literature. Importantly, European wild cats (that might experience competition with domestic cats) are not distributed in Norway. Three key conditions for interspecific competition to take place include: 1) the availability of prey is limiting the population growth or other state variables in the wildlife population, 2) cats have substantial dietary overlap with the wildlife species at stake, and 3) cats have substantial effects on the abundance of their shared prey resource. Point 3) is discussed in section 4.1.1 and 4.1.4.

To the extent that cats compete with other carnivorous wildlife, it is likely that the competition is strongest in urban and rural areas where cat density is high, and that it mainly affects predators of small birds and small rodents. George (1974) suggested that cats could compete with birds of prey for rodent prey, but did not present evidence that such competition occurred. This issue has not yet been investigated in more detail later. Among mammalian predators, the red fox is most likely to be affected by competition from cats as the two species have overlapping prey. Similarly, stoat typically include a large proportion of small rodents in their diet and might thus potentially be affected. Evidence for competition affecting the habitat use of foxes and feral cats exists from Australia, where both species are introduced (Roshier and Carter, 2021). Both common European vipers and smooth snakes have small rodents as an important food source. Slow worms and common lizards are also important food for smooth snakes and that cats can depredate.

Although some prey species may be impacted negatively by cat predation, cat predation might not lead to competition with wild species with shared prey species if cat predation does limit prey population sizes. This is probably the case for many common and abundant prey species.

Species that interact with prey species of cats or are influenced by non-lethal effects of cats may experience release from competition or predation. While there are limited examples specifically pertinent to Norway, it is conceivable that such instances could involve diminished competition for food among bird species that nest in elevated locations or cavities, like tits (Paridae, meiser). This could occur if cats lower the population of bird species that nest on the ground or in low shrubs, such as warblers (Sylviidae and Phylloscopidae, sangere), which share a similar diet. Similarly, rats could be released from competition for food from smaller rodents that are the preferred prey by cats. In Norway, examples of release from predation appear unlikely, but a theoretical example could be if cats reduce populations of squirrels (*Sciurus vulgaris*, ekorn) with the consequence that predation on eggs and nestlings of birds is reduced.

Overall, the impact of competitive interactions is assessed to be **Minimal** to **Moderate**. The hazard characterization is assessed with **Low** confidence with a clear need for studies in relevant habitats.

4.1.7.3 Likelihood

Negative consequences of competitive interaction between cats and native wildlife are assessed to vary from **Very unlikely** in areas where cats are rare to **Moderately likely** in urban and rural areas where cats are common. The likelihood is assessed with **Low** confidence.

4.1.7.4 Risk characterization

Depending on cat density, the risk to native wildlife from competitive interactions with cats is assessed as **Low** to **Medium**. The risk is assessed with **Low** confidence.

4.2 Risks related to cats and disease transmittance

Risk: Potentially Medium
Confidence: Low to High

4.2.1.1 Hazard identification

Cats have a unique position in being closely embedded in the human private sphere while at the same time being in close contact with other pets, domestic animals and wildlife (see Figure 9). Cats can play a role in transmitting diseases by harboring disease-causing organisms and pathogens, and often parasites that affect the intestines, respiratory system, or skin. These organisms can then directly infect humans, wildlife, or other domestic animals either through direct contact or indirectly via the environment. The cat may also carry materials that are infected by ticks or other parasites or bring dead or injured infected prey like small birds or rodents into the house. As a result, disease-causing agents can come into contact with humans or food, even if the cat itself remains unaffected by the illness.

There are other potential effects on disease prevalence, distribution and or severity. These effects encompass the cat's role in controlling or displacing rodents and other carriers/reservoirs of diseases, the repercussions of deceased cats, and the influence of cats on human immune responses that could impact autoimmune diseases. However, substantial knowledge gaps lower our confidence in the assessments of the severity and likelihood of the known diseases and makes it likely that there are unidentified hazards.

The severity of impact from cat-mediated diseases can be measured with regards to the number of individuals affected, the proportion of the population affected, the severity of the disease in those affected and the vulnerability or ecological or economic importance of the species. Probability of impact can be measured as an individual rate, which would make sense for the rate of cat transmission of relatively common diseases, or as the likelihood of an spill over event of an emerging disease happening at least once. VKM did not perform a formal risk evaluation of disease hazards associated with cats but has identified and described the pathogens where cats is known to play a role in disease transmission.

Wildlife hazards: As a free-roaming mesopredator, cats may connect vulnerable wildlife with disease reservoirs in human, peridomestic or domestic animals (sections 1.5 and 3.6). Where cats connect vulnerable wildlife to diseases from the human, peridomestic or domestic domain that they otherwise would rarely if ever be in contact with, the impact may be considerable. The impact is likely to be largest where the wildlife population in question is small and/or naïve to the disease, for instance feline-specific diseases that spill over from domestic cats to the endangered population of Eurasian lynx (*Lynx lynx*, gaupe). However, as cats have been present in Norway for a long time, most currently endemic diseases are likely to have small to moderate impact on wildlife from cat-mediated disease today. A few long-established diseases mediated by cats, in particular toxoplasmosis, are nevertheless still likely have a moderate to serious impact on wildlife health. Toxoplasmosis is prevalent, affects many species, is known to affect rodent health and behaviour, and may have negative neurocognitive effects of other species too.

Domestic: Cats may be in contact with other pets and domestic and peridomestic animals that may otherwise not be in touch with each other or with humans and wildlife (sections 1.5 and 3.6). The most notable impact may be from *Toxoplasma gondii*, a highly prevalent parasite cabable of infecting a wide range of species (section 3.6.4). The disease burden of *T. gondii* is likely to have a major impact, particularly evident in domestic sheep during lambing. However, given that cats have been consistently present in modern Norway, the disease burden added by toxoplasma is part of our "normal" situation. We lack a cat-free "baseline" for comparison, which makes it challenging to assess variations in rates of conditions, like neurocognitive issues.

Human: As described in 1.5 and 3.6, cats may transmit a series of zoonoses and affect the prevalence of disease. The by far most likely to have an ongoing impact on human as well as non-human communities is toxoplasmosis, given its wide distribution, high abundance, vertical transmission and range of serious effects.

The potential impact of cats on new emerging diseases is hard to predict. Cats are, as described earlier, well placed to bridge different reservoirs and may thus theoretically be expected to facilitate spillover events. The most plausible type of scenario would involve cats facilitating emergence of a highly pandemic respiratory virus variants, like an avian flu from birds or c coronavirus variant from rodents or mustelids.

Table 32 lists the main infectious pathogens known to the authors to be transmitted or vectored by cats (see 1.5 and 3.6). We note that the list is unlikely to be exhaustive, especially in relation to pathogens leading to diseases affecting wildlife.

Table 32: Overview of known pathogens where cats may play a role. The list is not exhaustive, but includes diseases known to be potentially relevant in Norway now or the near future. For details on the specific diseases, see sections 1.5 and 3.6. The Agent column list the species name or group of disease agent. The Concern column indicate the main concern for the agent in Norway: Zoonotic disease in humans (HUM), Wildlife disease (WIL), or disease in other (non-cat) domestic animals (DOM). The Cat role column indicate whether the cat role is to mainly host, transmit or mechanically carry the agent or its vector. Incidence N. is a rough qualitative indicator of whether the agent is currently absent (not yet observed except maybe in imported cases), rare (domestic transmission occurs, but the number of cases is probably insignificant for the host population on an national scale), or common (domestic transmission is widespread and part of the normal environment over much of the host habitat) in Norway, and whether this status is likely to change with climate change (CC). Cat relevance N indicate whether cats are of very low, low, moderate or high relevance to the epidemiology of concern in Norway given the presence of the disease. The relevance score is meant to indicate roughly whether cats are accidentally and occasionally involved for instance in transmission to humans but is not a part of the overall epidemiology (i.e. cats could be removed from the system and nothing would really change from the disease agents' point of view) to cats being a key component such as the main host (i.e. removing cats from the system would practically eradicate the agent, such as *toxoplasma*). More complex effects are described in the main text and referenced literature.

Agent	Concern	Cat role	Incidence N.	Cat relevance N.
Bacteria				
Bacillus anthracis	HUM, WIL, DOM	Transmit	Absent	Very low
***Bartonella* spp.**	ZN, WIL	Host, Transmit	Rare, but likely rising with CC	Low, but rising

***Borrelia* spp.**	ZN, DOM, WIL	Transport vector	Common, spreading with CC	Low
Brachyspira hyodysenteriae	DOM	Host? Transmit?	Rare	Low to non-existent
***Brucella* spp.**	ZN	Transmit	Absent	Very low if any
***Campylobacter* spp.**	ZN	Transport vector, Host	Rare, possibly rising with CC	Low, rising with incidence
Capnocytophaga canimorsus	ZN, (DOM?)	Host, Transmit	Common agent, rare disease	Moderate
***Chlamydia/Chlamydophila* spp.**	ZN, WIL	Transmit	Common	Low
Clostridium tetani	ZN, DOM	Transmit	Common agent, rare disease	Low
Coxiella burnetii	HUM, DOM	Transmit	Absent, but likely to establish	Moderate if established
Francisella tularensis	HUM, WIL	Transmit	Fairly common	Low to Moderate
***Leptospira* spp.**	HUM, WIL	Host, Transmit	Absent, but may establish with CC	Low to Moderate if established
***Mycobacterium* spp.**	HUM, DOM	Transmit	Rare	Low
Pasteurella multicoda	HUM	Transmit	Very rare	Moderate
***Salmonella* spp.**	HUM, DOM, WIL	Transmit, Host	Common	Moderate
Staphylococcus aureus	HUM, DOM	Transmit	Rare	Very low, rising with incidence
Yersinia pestis	HUM, DOM, WIL	Transmit	Absent	Low to Moderate if established
Viruses				

Feline morbillivirus	WIL	Host, transmit	Absent	High if established
Hantavirus	HUM, WIL, DOM	Transmit?	Rare	Very low if at all
Influenza viruses	HUM, DOM, WIL	Transmit, Host	Absent to common or emerging	Low to High depending on virus
Cowpox	DOM, HUM	Transmit	Rare	Low
Mpox	HUM	Transmit	Rare	Non-existent to moderate
Orf virus	DOM, HUM	Transmit	Rare to moderately common	Low
Pseudorabies virus	WIL, HUM	Host, Transmit	Absent	Moderate to High if established
Rabies virus	HUM, DOM, WIL	Host, Transmit	Absent	Moderate to High if established
SARS-CoV-2	HUM, DOM, WIL	Transmit	Common	Non-existent to low or moderate
West Nile virus	HUM, DOM, WIL	Host	Absent	Low even if established
Eukaryotes				
Echinococcus multilocularis	HUM, WIL, DOM	Transmit	Absent	Non-existent to low
Strongyloides stercoralis	HUM, DOM, WIL	Transmit, Host	Absent or very rare	Low to moderate

Giardia duodenalis	HUM, DOM, WIL	Transmit, Host	Rare	Low
***Leishmaniasia* spp.**	HUM, DOM	Host	Absent, but may establish with CC	Low to Moderate
Dirofilaria spp.	DOM, HUM	Host, Transmit	Absent or very rare, but may increase with CC	Low
Toxocara cati	DOM, HUM, WIL	Host, Transmit	Moderately common	Low to Moderate
Sheep ticks	DOM, WIL	Transport	Common	Low
House ticks	DOM, WIL	Transport	Absent, may establish with CC	Low to Moderate if established
Scabies / mange	DOM, WIL, HUM	Transmit, Host	Rare to moderately common	Low
Toxoplasma gondii	DOM, WIL, HUM	Main host, Transmit	Common	High
Others				
Feline Spongiform Encephalopathy	DOM, WIL, HUM	Host, Transmit	Absent and likely limited	High
Sporotrichosis	DOM, HUM	Host, Transmit	Absent	Moderate to High
Dermatophytes	HUM, DOM (WIL)	Host, Transmit	Rare to Common	Low to Moderate

4.3 Risk of negative effects of cat predation on the welfare of prey animals

Risk: Potentially High
Confidence: Medium

4.3.1 Hazard identification

Cats are predators with a strong motivation to hunt, even when fed to meet their nutritional needs. For every prey animal killed, many more are chased, and an unknown number are injured. It is recognized under the Norwegian animal welfare act that the vertebrate prey species in question are sentient beings with the capacity to experience positive and negative emotions. The invertebrate species considered in this report, such as butterflies and moths, are not covered by the Norwegian animal welfare act.

4.3.2 Hazard characterization

While mortality is commonly utilized as a welfare indicator in animal husbandry, this report emphasizes that the manner in which an animal dies is more important. When it comes to the impact on animal welfare by mortality, a quick and pain free death is preferable compared to suffering over time. Surviving with a sustained reduced quality of life may also influence the welfare state more than a quick death. For all negative experiences, such as pain and fear, the intensity, duration and frequency are important to consider.

Cats are not the only predator that these prey animals experience. Being alert and careful to avoid predators is part of wild animals' lives, and successful prey species have well-developed antipredator strategies. However, anti-predator strategies may not have been sufficiently adapted to domestic cats for some prey species. Prey animals are at risk of being killed, injured, to suffer from pain and fear, being disturbed when searching for food, and, in the breeding season, a killed parent may leave offspring to die from hunger and dehydration. In this respect, cats are not different from other natural predators. Much like predators in nature, the time required for a cat to kill its prey tends to increase with the size of the prey.

In urban and suburban areas, cats can be one of the most prevalent predators. Thus, cats may contribute significantly to the number of occasions where prey animals are in danger of being killed or injured, or at least feel threatened, and may be disturbed in their efforts to feed or care for young. Further, "playing" with the prey by not killing it immediately upon capture is a common cat behaviour, which will cause the prey animal to suffer and feel fear for a longer time before death. The hazards to prey animal welfare will thus include a painful death, and disturbances leading to less efficient feeding.

4.3.3 Likelihood

In rural habitats, it is **“Unlikely”** that cats add significantly to the welfare-reducing effects of other predator species. In urban and suburban areas where cats are more numerous, it is **“Very likely”** that cats have a negative effect on prey animal welfare. These likelihoods are assessed with **medium confidence**.

4.3.4 Risk characterization

Depending on cat density and prey species, the risk of negative effects by cats on prey animal welfare is assessed to vary from **“Low”** in most rural habitats to **“High”** in urban and sub-urban habitats. The risk is assessed with **medium confidence**.

5 Mitigating measures

Cat owners and authorities may take a range of actions that influence the impact of cats on wildlife in Norway. Possible measures include: i) restricting the cats' access to outdoor areas, ii) measures that reduce hunting success by warning the prey, changing the cat diet, and iii) measures that reduce the number of owned-, feral- and stray cats.

Importantly, VKM has based the assessment on the current regulations regarding pet keeping and has not evaluated the effects of a ban on keeping cats in Norway.

Each of the potential measures may have advantages in terms of efficiency of desired outcomes and disadvantages related to undesired outcomes. Efficiency and disadvantages will be discussed in relation to potential effects on: (i) Predation on various groups of prey species, (ii) Competition between cats and Norwegian fauna, (iii) Animal welfare of prey animals, (iv) Animal welfare of cats, and (v) Spread of pathogens. For each of the positive and negative effects, ratings on their magnitude under Norwegian conditions are ranked in the following categories; Minimal or No", Minor, Moderate, Major or Massive, as described in Table 33. All ratings are given as related to the alternative of no measure taken. Combining several measures may enhance both positive and negative effects. Positive and negative effects for the cat's welfare will vary considerably between individual cats as this relates to the personality and earlier experience of the cat and how the cat owner handles the measure. Measures related to owned cats are given scores without considering the untreated feral or stray cats. The overall effect on wildlife is therefore somewhat reduced in relation to the population size of such unowned cats. Our assessment is based on expert judgement of the literature, and not on quantitative analyses.

Table 33: Rating of the magnitude of effects of measures to counteract negative impact on biodiversity of cat predation in Norway. Effects are rated for (i) Predation on various groups of prey species, (ii) Competition between cats and Norwegian fauna, (iii) Animal welfare of prey animals, (iv) Animal welfare of cats, and (v) Spread of pathogens.

Rating	Magnitude descriptors
Minimal or No	(i) The prey animals are almost equally affected by cats as without the measure. (ii) Competition between cats and Norwegian fauna are almost equal as without the measure. (iii) Animal welfare of prey animals is almost as without the measure. (iv) Animal welfare of cats is almost as without the measure. (v) Pathogens are spread almost as without the measure.
Minor	(i) The prey animals are somewhat less affected by cats than without the measure. (ii) Competition between cats and Norwegian fauna are somewhat less than without the measure. (iii) Animal welfare of prey animals is somewhat improved as compared to the measure not being taken. (iv) Animal welfare of cats is somewhat reduced as compared to the measure not being taken. (v) Pathogens are somewhat less spread as compared to the measure not being taken.

Moderate	(i) (ii) (iii) (iv) (v)	The prey animals are less affected by cats than without the measure. Competition between cats and Norwegian fauna are less than without the measure. Animal welfare of prey animals is improved as compared to the measure not being taken. Animal welfare of cats is reduced as compared to the measure not being taken. Pathogens are less spread as compared to the measure not being taken.
Major	(i) (ii) (iii) (iv) (v)	The prey animals are much less affected by cats than without the measure. Competition between cats and Norwegian fauna are much less than without the measure. Animal welfare of prey animals is markedly improved as compared to the measure not being taken. Animal welfare of cats is markedly reduced as compared to the measure not being taken. Pathogens are markedly less spread as compared to the measure not being taken.
Massive	(i) (ii) (iii) (iv) (v)	The prey animals are only to a small extent affected by cat predation. Competition between cats and Norwegian fauna are only to a small extent occurring, in comparison with the measure not being taken. Animal welfare of prey animals is almost as if the cats were not present. Animal welfare of cats is severely affected by the measure. Pathogens are only to a small extent spread as compared to the measure not being taken.

5.1 Counteracting effects of predation by limiting access to prey

Access by owned cats to potential prey animals might be restricted in several ways. Cats can be kept indoors, either completely or part of the day or in particular seasons. They can also be kept in outdoor enclosures (catios), they can be walked on leash when outdoors, or they can be prohibited from free-roaming outdoors near particularly vulnerable areas (see section 4.1.2).

5.1.1 Keeping the cat indoors

Under this measure, cat owners would be recommended (or mandated) to keep their cats indoors. Controls could be applied either as a permanent measure to keep the cat indoors at any time, or during night when cats may hunt small rodents and birds in their nest. For cats that go freely in and out through a cat flap, the cat flap could be closed during night. To reduce catch of diurnal species, like many birds, it could help keeping cats indoors during dawn and daytime. To mitigate excessive predation on birds and mammals during their breeding season in spring (as demonstrated by Pisanu et al., 2020), keeping cats indoors during the springtime would have the most positive effect. Keeping cats indoors is recommended by the American Veterinary Medical Association[26] in the USA and required in some areas of Australia[27].

Predation on birds by cats may also occur at bird feeders during winter and at nest boxes during the breeding season. Such predation may be reduced to some degree by paying attention to location and design of feeders and type of food supplied (National Bird-feeding Society 2011, Heggøy and Shimmings 2018), and the location and protection of nest boxes (Nestbox Pro 2023). However, predation of birds by cats during winter is much lower than during summer (Churcher and Lawton 1987, Thomas et al. 2012, Krauze-Gryz et al. 2017), suggesting that measures taken at bird feeders during winter will only reduce total predation by a small amount. We are not aware any reports that predation by cats on birds breeding in nest boxes is an important source of bird mortality.

Based on the most recent data (Table 1), only 7% of Norwegian non-pedigree cats, 5% of forest breeds and 15% of other breeds are kept permanently indoors. Among cats allowed to roam freely outdoors, 6.2% were let out less than three hours a day during summer, while 43.9% were less than three hours outdoors during winter (Table 2). The percentage of cats being kept indoors during night is unknown.

5.1.1.1 Efficiency

Keeping cats indoors substantially reduce the potential for negative impacts of cat predation and competition with other wild predator species. Importantly, feral cats and stray cats will still have some impact on the biodiversity. The effectiveness is highest when owned cats are kept indoors permanently. Effects are gradually reduced as the regulations are less overarching such that hunting cats have free access outdoors parts of the day or during some seasons. Cats that are outdoors for a large part of the day are expected spend proportionately more time resting and sleeping outdoors, while many cats being let outdoors for only a few hours a day may spend a larger fraction of this time hunting. Keeping cats indoors will improve aspects of cat health, as they are less prone to contagious diseases, to injuries from cat fights or encounters with dogs or wildlife, or to being hit by a car (Cecchetti 2022a).

5.1.1.2 Disadvantages

Keeping cats indoors may be disadvantageous to cats, especially to those being experienced with free-roaming outdoors. To such cats, animal welfare may be compromised as their habituated behavioural needs are not fulfilled (section 1.2.2). Most cats spend time outdoors when given the choice, even when they have access to food and other needs indoors. Cats kept indoors may suffer from boredom unless

[26] https://www.avma.org/resources-tools/avma-policies/free-roaming-owned-cats

[27] https://www.cityservices.act.gov.au/pets-and-wildlife/domestic-animals/cats/cat-containment

actions are taken to stimulate activity. The extent to which cats suffer from being kept only indoors varies among individuals. Improper handling of resulting behaviour problems may in turn result in further welfare challenges to the cat. However, there are still substantial knowledge gaps concerning how social and environmental factors affects welfare of cats kept indoors only (Foreman-Worsley and Farnworth 2019).

Transitioning cats that are already accustomed to roaming freely outdoors to being indoors only during specific times of the day or year could pose difficulties and potentially lead to frustration for these cats, given their accustomed lifestyle. It might be less stressful for the cat to adapt to a lifestyle where they spend part of the day outdoor, compared to a lifestyle where they have no outdoor access during part of the year.

Measures that restrict outdoor access by cats might be particularly challenging for typical "farm cats" that are accustomed to roaming freely outdoors on and around the farm. Another disadvantage with keeping cats only indoors is the lack of pest control function for rodents that some cats have, and especially in rural areas. See section 1.9.2 and 3.6.6.

5.1.1.3 Assessment

Table 34 presents the overall efficiency and challenges related to keeping the cats only indoors. Partial access outdoors, either part of the day or outside the breeding seasons of prey species, will reduce the positive effects of the measure.

Table 34: Summarised assessment of efficiency and disadvantages related to keeping the cats only indoors.

Effects on	Efficiency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Massive	Minimal or no	
Predation on birds	Massive	Minimal or no	
Competition with Norwegian fauna	Massive	Minimal or no	
Animal welfare of prey animals	Massive	Minimal or no	
Animal welfare of cats	Minor	Minimal to Massive	Pronounced individual variation. May be massive challenges for some cats, but minor for cats not experienced with outdoor conditions. Indoor environment and stimulation will also have a pronounced effect.
Spread of pathogens	Major	Minor	

5.1.2 Restrictions on outdoor access near vulnerable areas

In, or close, to habitats with particularly vulnerable populations of birds or other wild-living prey animals for cats (section 4.2.1), restrictions on outdoor access for domestic cats would be an effective mitigation measure, either during the whole year or in particular seasons.

This measure includes a buffer zone around the area where cats have restricted possibilities to roam freely. The zone can be related to the reported home range sizes and roaming distances (section 1.2.4.2). Importantly, this measure will not affect predation and other negative impacts caused by feral cats.

5.1.2.1 Efficiency

Restricting cats ability to roam freely in- or near specific vulnerable or protected areas (e.g., RAMSAR areas and areas with vulnerable species), will reduce predation by owned cats in these areas, reduce potential competition with other predators and increase overall welfare among prey animals.

5.1.2.2 Disadvantages

Apart from moderate challenges to the welfare of at least some of the cats kept indoors, reducing free-roaming of owned cats may give more territories for feral and stray cats, resulting in some immigration of such cats into the protected areas. When it comes to particularly vulnerable prey species, it will be important to enhance the control of unowned cats in such areas by measures discussed in section 5.4.

5.1.2.3 Assessment

Restrictions on free-roaming owned cats in protected areas where there are vulnerable prey species may have massive effects on prey, as long as compensatory immigration by feral and stray cats is low (see Table 35).

Table 35 Summarised assessment of efficiency and disadvantages related to prohibiting free-roaming of owned cats in vulnerable or protected areas with relevant prey species.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Massive	Minimal or no	
Predation on birds	Massive	Minimal or no	
Competition with Norwegian fauna	Massive	Minimal or no	

Effects on	Efficency	Disadvantages	Comments
Animal welfare of prey animals	Major	Minimal or no	
Animal welfare of cats	Minimal to Moderate	Minimal to Major	
Spread of pathogens	Major	Minor	

5.1.3 Keeping cats in outdoor enclosures (catios)

Allowing cats to spend time in an outdoor enclosure in a so called catio, will provide the cat with safe and regular experiences with outdoor setting. To be efficient, a catio must be escape-proof. Moreover, a catio should include all the cat's needs, like food, water, shelter, resting places and cat toys. Figure 17 shows a catio at Follo

Figure 17: A large sized catio for many cats at Follo kattepensjonat (Follo Cat Boarding House). Photo: Audun Braastad.

kattepensjonat (Follo Cat Boarding House). A good catio gives the cat free access by a cat flap from the house and includes a lawn and some vegetation. Larger catios may also include areas and resources for owners as an extension of the indoor living room.

5.1.3.1 Efficiency

A catio offers cats the chance to experience the outdoors, enjoy fresh air, and be exposed to natural weather conditions, while ensuring that prey species are protected from being hunted by the cats. The catio may improve the cat's welfare by providing environmental enrichment. The catio prevents cat predation on almost all prey species, except for some insects and small animals that may accidentally access the catio. The catio will hence avoid virtually all competition with other predator species. The welfare of both cats and their prey species may be improved.

5.1.3.2 Disadvantages

Properly sized catios has almost no disadvantages or negative side effects. Catios should not be placed near areas with bird nests or nesting boxes, as this might induce risk mediated effects in the bird population.

5.1.3.3 Assessment

Using a catio has massive effects with respect to reducing predation by cats and the welfare of prey and cats (Table 36).

Table 36: Summarised assessment of efficiency and disadvantages related to keeping cats in catios, outdoor enclosures for cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Massive	Minimal or no	
Predation on birds	Massive	Minimal or no	
Competition with Norwegian fauna	Massive	Minimal or no	
Animal welfare of prey animals	Massive	Minimal or no	
Animal welfare of cats	Minimal to Moderate	Minimal to Moderate	
Spread of pathogens	Major	Minor	

5.1.4 Use of cat leash outdoors

The cat can be kept on a leash when taken outdoors. Training to wear a leash should start indoor when the cat is young and gradually move outdoors as the adolescent cat ages. To reduce the risk of harm for the cat, the leash could be connected to a harness rather than a necklace.

5.1.4.1 Efficiency

Walking a cat on a leash minimizes the possibility that the cat can catch prey, as long as the cat cannot escape, or the leash is not too long. Hence, the animal welfare of the prey animals is not compromised. The use of cat leash outdoors during birds' breeding season(s) would have a marked effect of reducing the predation on ground-breeding birds and fledglings of all potential prey species of birds.

5.1.4.2 Disadvantages

Rather than walking on a leash with its owner, most cats prefer to move independently of people. The cat's welfare is therefore somewhat impaired.

As potential prey might not differentiate between cats that are on a leash and those that are free roaming, leashed cats might initiate fear responses to their prey. Cats may potentially be infected or spread pathogens during a walk on leash, but less than for free-roaming cats since they are less in contact with other animals,

5.1.4.3 Assessment

Table 37 summarizes the effectiveness and disadvantages related to the use of a leash.

Table 37 Summarised assessment of efficiency and disadvantages related to keeping cats on leash with a human.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Massive	Minimal or no	
Predation on birds	Massive	Minimal or no	
Competition with Norwegian fauna	Massive	Minimal or no	
Animal welfare of prey animals	Major	Minimal or no	
Animal welfare of cats	Minimal to Moderate	Minimal to Major	
Spread of pathogens	Moderate	Minor	

5.2 Measures to reduce predation

A measure intended to reduce predation success must either warn potential prey, such that the likelihood of escaping attack is increased, or reduce the tendency of a cat to hunt. To decrease the success and effectiveness of cat predation on wildlife, many tools have been developed to alert prey to the presence of cats by emitting sounds or by presenting visual signals. The tools include colourful collars (or collar covers), collars with bells and collar-mounted sonic devices. The tools are all attached around the neck of the cat and are designed to be as non-intrusive as possible.

5.2.1 Making cats more audible to potential prey

The knowledge that bells on cats might warn potential prey about cat presence goes back at least 1500 years (Baum 1919). Belled collars are easily obtained and non-intrusive, and most research has shown that cats wearing bells have reduced hunting success. Ruxton et al. (2002) and Gordon et al. (2010) showed a reduction in hunting success by about half. Nelson et al. (2005) showed that cats brought back 34% fewer mammals and 41% fewer birds when wearing bells, compared to not wearing bells. Cecchetti et al. (2022a) found, however, that bells had no discernible effect on numbers of prey brought home, neither for mammals nor birds. Many types of belled collars are commercially available, which may vary in effectiveness. Size, colour, shape and the material can affect a bell's ability to alert prey of potential danger. To our knowledge, no systematic overview of the effectiveness of the different types of bells exists.

There are also several commercially available collar-worn electronic alarms. The alarm CatAlertTM sounds a chime every seven seconds as a warning of the cat's presence; Nelson et al. (2005) found that it nearly halved the number of preys brought home by hunting cats in the UK. With the LiberatorTM, both an alarm and a light flash are triggered by sudden motion, such as (but not exclusively) when a cat chases or pounces on prey. Gillies and Cutler (2001) in an unpublished report did not find a significant reduction in captures of birds, mammals or reptiles by 54 New Zealand cats that wore this collar alarm compared with when the same cats did not wear the collar. On the other hand, a similar study of this collar alarm carried out with 15 cats in Australia found that the cats caught significantly fewer birds, mammals and reptiles when wearing the LiberatorTM (Calver and Thomas 2011). The authors could not determine if the effect was due to prey being alerted or to cats becoming reluctant to make sudden movements that would trigger the alarm. Further, the study period was not long enough to determine if cats become habituated to the alarm noise (and flash). However, some owners were dissatisfied with the collar alarm because cat movements inside the house frequently triggered the alarm, and a surprising high number of the alarms were defective (Calver and Thomas 2011).

Ultrasonic devices in suburban settings can potentially reduce predation by deterring cats from specific areas. Cats can hear sound frequencies up to 32 kHz (Heffner et al. 1985), which is much higher than humans. Several devices have been developed that detect the motion of small animals and trigger loud bursts of high-frequency sound.

The responses of cats are highly variable, but most cats probably find the sounds uncomfortable and react negatively to them. These devices are placed in small areas that owners wish to protect from cat incursions, such as gardens or lawns.

5.2.1.1 Efficiency

Most research shows that bells worn on detachable collars can reduce predation on birds and small mammals. Belled collars are inexpensive and easily acquired, and do not seem to bother cats wearing them. Available research suggests that there is a potential for reducing predation on birds and mammals by half.

Research on selected devices has been carried out in the UK (Nelson et al. 2006) and Australia (Crawford et al. 2018). Nelson et al. (2006) found that the Catwatch© device reduced cat incursions in gardens by about one third, as well as reducing the duration of incursions by nearly 40%. Crawford et al. tested two devices, CatStop© and On-Guard Mega-Sonic Cat Repeller©. Ultrasonic devices reduced the frequency of incursions by nearly half, and the duration of incursions by almost 80%.

Ultrasonic devices placed on stakes seem to protect small areas from cats, which would incidentally reduce cat predation in these areas.

5.2.1.2 Disadvantages

There are few disadvantages with using bell collars with cats, other than a lack of research to optimize the design of bells for this purpose. Some cats might also shed their collars, leading to costs to the owners. Motion-activated ultrasonic devices can only protect small and limited areas, and it is not clear that only protecting gardens or lawns has an overall effect on cat predation. Ultrasonic devices might be harmful to cats as cats have an acute hearing of ultrasound. Other bells emitting strong sounds may also affect the cat negatively, although experience indicates that cats may quickly habituate to moderately strong sounds from bells. This topic needs further investigation. Sound pitch and volume should be optimized for bells and ultrasonic devices to achieve positive effects while minimizing the negative effects.

5.2.1.3 Assessment

Tables 38 and 39 present the overall evaluation for belling cats or equipping cats with sonic devices. Research on the effectiveness of the devices is encouraging and suggests that widespread adoption of this simple measure could significantly reduce cat hunting success. However, there is a limited amount of research on the topic. Electronic alarms are also promising. The limited available data suggests that predation on birds, mammals and even reptiles can be reduced if cats wear alarms. A major drawback is that the sounds are often reported as irritating to cat owners when cats are indoors. In addition, there have been quality control issues. Bells and electronic devices with strong sound may affect cat welfare adversely.

Table 38: Summarised assessment of efficiency and disadvantages related to belling cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minor to Moderate	Minimal or no	Variable effect due to type of bell
Predation on birds	Minor to moderate	Minimal or no	Variable effect due to type of bell
Competition with Norwegian fauna	Moderate	Minimal or no	
Animal welfare of prey animals	Minor	Minimal or no	
Animal welfare of cats	Minimal or no	Minor	
Spread of pathogens	Minimal or no	Minimal or no	

Table 39: Summarised assessment of efficiency and disadvantages related to putting electronic alarms (sonic collars) on cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minor to Moderate	Minimal or no	Variable effect due to type of sonic device
Predation on birds	Minor to Major	Minimal or no	Variable effect due to type of sonic device
Competition with Norwegian fauna	Major	Minimal or no	
Animal welfare of prey animals	Minor	Minimal or no	
Animal welfare of cats	Minimal or no	Minor	
Spread of pathogens	Minimal or no	Minimal or no	

5.2.2 Making cats more visible to potential prey

Many bird species that are preyed upon by cats have good colour vision. By collaring cats with a colourful collar or bib, a striking visual signal could alert potential prey. Visual signalling prevents the natural camouflage of cats. CatBib™ is a mitigation measure that reduce the effectiveness of cats' predation (Calver et al. 2007). The CatBib™ is also named a "pounce protector", as it serves as a barrier to pouncing, and thus preventing predation, as well as a colourful, visual warning to prey animals. The primary mechanism behind the reduction in predation is related to the interference with paw coordination of the bib during prey capture (Calver et al., 2007).

The anti-predation collar cover Birdsbesafe® (BBS) was developed in 2008 to make cats more visible against natural backgrounds. The BBS is a 5 cm diameter cotton fabric tube made of colourful figured fabric that can be fitted over a standard breakaway collar. The bright colours and patterns of the BBS are intended to increase the visibility of stalking cats and hence reduce their hunting success.

5.2.2.1 Efficiency

Cats wearing the CatBib™ caught 81% fewer birds and 45% fewer mammals compared to cats that did not wear the bib. Adding a bell to the CatBib™ did not decrease predation effectiveness of the cat (Calver et al. 2007). While the bib reduced the number of vertebrate prey caught, wearing the bib does not reduce roaming by cats (Hall et al. 2016).

Willson et al. (2015) tested the BBS cover in two season trials of 12 weeks each in New York (USA). Wearing a BBS cat collar strongly reduced predation on birds: BBS-collars reduced the number of birds brought home by cats by 19 timesin comparison with uncollared cats in the spring trial, and by 3.4 times in the fall. The effect on small mammals was less clear. A study in the UK found that cats brought home four times fewer birds when wearing the BBS collar cover than when not wearing a collar (Pemberton and Ruxton 2020). In England, Cecchetti et al. (2021c) found that Birdsbesafe® reduced numbers of birds captured and brought home by 42%, but there was no discernible effect on mammals. In Australia, predation of prey with good colour vision, like birds and herptiles, was reduced by 54% when the cats wore a BBS of any colour (Hall et al. 2015). Rainbow and red patterns protected birds better than yellow BBS colour. The predation rate of prey with limited colour vision, like mammals, were not significantly reduced when cats wore the BBS. Among the cat owners who took part in the study, 79% reported that their cat had no problems with BBS and 17% that the cat adjusted within two days. Finally, Jensen et al. (2022) combined data from studies conducted during bird breeding seasons in New York (the data published in Willson et al. 2015) and in Florida, with a total of 94 cats. Across the two studies, BBS cats brought home 2.7 times fewer birds than did uncollared cats. In all these studies, predation was measured as prey that were brought home to cat owners. As with the CatBib, wearing a BBS collar cover did not affect the area roamed by hunting cats (Hall et al. 2016). In addition, the reduction in prey brought home was even greater than for bells or electronic alarms. Cats adjust quickly to wearing them, and these devices are technologically simpler than electronic measures. There are some concerns that wet collars might become uncomfortable for cats.

Both cat bibs and colourful collar covers can lead to substantial reductions in predation on birds, but the effects of colourful collars on predation on small mammals are uncertain. Both measures are inexpensive and easily acquired.

5.2.2.2 Disadvantages

There are few disadvantages with these collar-worn solutions. However, Cecchetti et al. (2022b) speculated that extroverted or neurotic cats might be uncomfortable wearing collar covers. More research should be carried out to study the effects of cat bibs on their normal locomotion.

5.2.2.3 Assessment

Though research is lacking, available information indicates that bibs and collars effectively reduce the number of birds and small mammals brought home by cats. Table 40 and 41 presents a summary of bibs and colorful collars, respectively.

Table 40: Summarised assessment of efficiency and disadvantages related to using bibs on cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Major	Minimal or no	
Predation on birds	Major	Minimal or no	
Competition with Norwegian fauna	Major	Minimal or no	
Animal welfare of prey animals	Moderate	Minimal or no	
Animal welfare of cats	Minimal or no	Minimal to Moderate	Variable effect depending on bib size and shape
Spread of pathogens	Minimal or no	Minimal or no	

Table 41: Summarised assessment of efficiency and disadvantages related to using colorful collar covers on cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minor to Moderate	Minimal or no	Effects documented on hertiles, but no or minimal effects on mammals
Predation on birds	Major	Minimal or no	
Competition with Norwegian fauna	Major	Minimal or no	
Animal welfare of prey animals	Moderate	Minimal or no	
Animal welfare of cats	Minimal or no	Minimal or no	Not all cats accept collars, and the covers can become uncomfortable when wet.

Effects on	Efficency	Disadvantages	Comments
Spread of pathogens	Minimal or no	Minimal or no	

5.3 Measures to reduce hunting behaviour

5.3.1 Choice of cat breed

Breeds of domestic cats differ in hunting motivation and hunting skills (section 1.2.2.4), implying that promoting certain breeds could potentially reduce overall predation on native wildlife. Many pedigree cats are only kept indoors, or on leash or in enclosures, indicating that a reduction in predation by some breeds could be a combined effect of reduced hunting ability and fewer cats roaming freely outdoors. Breeds with the least hunting motivation include Oriental, Siamese, Persian and Birman cats (Eriksen, 2014). Still, many individuals in these breeds may hunt effectively, and owners of pedigree cats sometimes claim that their cat hunt prey. However, the breeds mentioned above are also among the breeds that more seldom roam outdoors. Forest breeds like Maine coon, Norwegian forest cat and Siberian are considered to be as effective hunters as non-pedigree cats.

5.3.1.1 Efficiency

The number of registered pedigree cats in Norway increased by 60% from 2016 to 2021 (www.nrr.no/opprett_test/statistikk). Non-pedigree cats also appear to be increasing in number, although data are lacking (section 1.3.2). We do not know to what extent the most recent increase has been due to increased cat acquisition during the COVID-19 pandemic, and whether numbers will be reduced again after 2022. If a larger fraction of domestic cats were pedigree cats, the overall predation pressure on wildlife would be somewhat lower, partly because of less hunting motivation or ability and partly as they are more often kept indoors. If most of the new cats were of forest breeds such as Maine coon, Norwegian forest cat and Siberian, the effect would be negligible.

5.3.1.2 Disadvantages

Pedigree breeds are often genetically susceptible to diseases or physical ailments as a result of intense breeding within a limited pool of breeding animals (Golovko et al. 2013, Farnworth et al. 2016, Balmer et al. 2020, Matsumoto et al. 2021). Higher frequencies of inbred pedigree cat breeds would thus add challenges to the overall health and welfare of domestic cats.

Forest breeds have become the most popular breeds in Norway, comprising 50% of the registered pedigree cats in 2021. As the breeds thought to have less hunting behaviour (e.g., Oriental, Siamese, Persian and Birman cats) constitute only a total of about 12% of the pedigree cats in 2021, promoting an increase in such pedigree cats would have only minor effects on levels of wildlife predation by cats during the next few decades. Many of the other less frequent breeds would also hunt less than non-pedigree cats.

5.3.1.3 Assessment

Encouraging a shift towards breeds with less hunting motivation and/or reduced hunting skills and that roam less outdoors would be a slow process when it comes to positive effects on populations of wildlife (Table 42). Such a promotion would challenge the health and welfare of the cat populations by leading to more cats from inbred lineages.

Table 42: Summarised assessment of efficiency and disadvantages related to promoting the keeping of cat breeds with less efficient predation ability.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minimal or no	Minimal or no	
Predation on birds	Minimal or no	Minimal or no	
Competition with Norwegian fauna	Minimal or no	Minimal or no	
Animal welfare of prey animals	Minimal or no	Minimal or no	
Animal welfare of cats	Minimal or no	Minor	
Spread of pathogens	Minimal or no	Minimal or no	

5.3.2 Adjusted feeding

Cecchetti et al.(2021c) found that feeding cats a high-meat grain-free diet can reduce prey brought home with as much as 44% for birds and 33% for mammals. Unfortunately, the study is not yet replicated. In particular, this measure could be considered in combination with other measures. A disadvantage to cat owners is that such a high-meat cat food might be more expensive. VKMs assessment of this measure is summarized in Table 43.

Table 43: Summarised assessment of efficiency and disadvantages related to adjusted feeding.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Major	Minimal or no	High uncertainty regarding the positive effects
Predation on birds	Massive	Minimal or no	High uncertainty regarding the positive effects
Competition with Norwegian fauna	Minor	Minimal or no	
Animal welfare of prey animals	Minor	Minimal or no	
Animal welfare of cats	Minimal or no	Minimal or no	
Spread of pathogens	Minimal or no	Minimal or no	

5.3.3 Increased playing activity

Cecchetti et al. (2021b) studied the effect of playing with the cat, and how playing affected predation behaviour. When owners spent 5-10 minutes daily object-playing with the cat, the number of mammals brought home was reduced by 35% and with a 25% decrease in the overall number of prey brought home. No effect on avian prey was detected. Interestingly, although not a play device as such, the puzzle-feeder (a hollow plastic ball filled with feed pellets that fall out through small holes as the cat pushes/manipulates it around), increased number of mammals brought home by 49% but with no effect on avian prey. Thus, choice of play items, or other elements of enrichment, may influence the effectiveness of the measure (Table 44).

Table 44: Summarised assessment of efficiency and disadvantages related to playing.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Major	Minimal or no	High uncertainty regarding the positive effects
Predation on birds	Minimal to Minor	Minimal or no	
Competition with Norwegian fauna	Minor	Minimal or no	
Animal welfare of prey animals	Minor	Minimal or no	
Animal welfare of cats	Moderate	Minimal or no	
Spread of pathogens	Minimal or no	Minimal or no	

5.4 Measures to reduce the numbers of cats

5.4.1 Neutering of owned cats

Castration (neutering) involves removing the gonads (testicles or ovaries and usually also the uterus). Neutering renders cats infertile and reduces sexual behaviours due to ceased production of sex hormones from the gonads. For female cats, an alternative is contraceptive pills with progesterone effect that must be administered weekly at the same day every week. A disadvantage to hormonal contraception is increased risk of diseases, such as diabetes and mammary tumors (Felleskatalogen; Munson, 2006). In addition, not all cats are easy to medicate, and some may spit out the pill. Contraceptive pills are considered less reliable method for birth control compared to neutering. Relative frequencies of neutered cats in Norway are presented in section 1.3.4.3

5.4.1.1 Efficiency

Neutering mitigates predation by cats in two ways. Firstly, a reduction in unplanned or unwanted litters might reduce the number of kittens that could end up as homeless or feral cats. A reduction in the population of feral cats will result in reduced predation on wildlife. Secondly, castration alters behaviour (see section 1.2.2 and 1.2.4). Neutered cats, especially male cats, have smaller home ranges (section 1.2.4). Further, neutered male cats tend to defend their territory more against unfamiliar or neighbouring cats compared to intact males (section 1.2.2).

Mandatory neutering of cats will in the long run reduce overall predation by cats and reduce competition between cats and wildlife. Likewise, the predation pressure is reduced, implying that the prey has a reduced risk of compromised welfare. Also, the spread of pathogens will be reduced. However, achieving such effects require time and effort. The magnitude of the effect will depend on how neutering impacts the overall population size of cats. For the neutered cats, there will be less sexual aggression and therefore a reduced risk for injuries.

5.4.1.2 Disadvantages

The primary obstacle lies in ensuring that all cat owners have their cats neutered and in verifying the completion of this procedure. Neutered cats have increased risk for some health issues, such as obesity and urinary disorders. A system may be developed where approved cat breeders may be allowed to breed on their cats.

Note that four of five pet cats in Norway are already neutered, including cats allowed outdoors (section 1.3.4.3.). To the extent that these surveys are accurate, implementing measures including mandatory neutering would affect few additional cats.

5.4.1.3 Assessment

See Table 45 for a summary of effects as assessed by the project group.

Table 45: Summarised assessment of efficiency and disadvantages related to mandatory castration of owned cats. Grading is made for the approximate lifetime of a cat (10-15 years) after effective measures have been undertaken, as effects take a long time to appear.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minimal or no	Minimal or no	
Predation on birds	Minimal or no	Minimal or no	
Competition with Norwegian fauna	Minimal or no	Minimal or no	
Animal welfare of prey animals	Minimal or no	Minimal or no	
Animal welfare of cats	Moderate	Minor	
Spread of pathogens	Minimal or no	Minimal or no	

5.4.2 Mandatory ID tagging/chipping

Mandatory ID marking will make it easier to reunite lost cats with owners and increase ownership responsibility to reduce the number of homeless and feral cats. There are systems in place for ID tagging cats with microchips in Norway, and there is a database that links tags to cat owners (DyreID, www.dyreid.no). According to DyreID, about 81% of owned Norwegian cats are ID tagged in 2020, as compared to 96% of dogs (DyreID, 2021). In 2006, about 31% of cats were ID tagged, indicating that ID tagging with a microchip increased markedly between 2006 and 2020. Several animal welfare and cat organisations, as well as the Veterinary Association, have repeatedly requested that authorities make ID marking of cats mandatory. The Norwegian parliament has debated over topic several times. In 2002, when debating the Norwegian White Paper to the Parliament No. 12, 2002–2003 on Animal Keeping and Animal Welfare, the parliament asked the Ministry of Agriculture, Food and Fisheries to consider implementing mandatory ID marking of cats. The Norwegian Food Safety Authority (NFSA) prepared work to achieve this, but it was decided to not implement it for various legal reasons. Currently, NFSA recommends mandatory ID tagging and registration of dogs in Norway (https://www.mattilsynet.no/dyr_og_dyrehold/kjaledyr_og_konkurransedyr/hund/forskrift_om_identifikasjonsmerking_og_registrering_av_hunder.45820).

5.4.2.1 Efficiency

Mandatory ID tagging of cats makes it easier to reunite lost cats with owners, which in turn is likely to reduce the number of homeless and feral cats by reducing recruitment to populations of homeless cats. Most veterinarians, the police and some animal welfare organisations have a scanner and can therefore scan stray cats for a microchip and thus reunite marked cats with their owners. Fewer stray cats would result in less predation on wildlife, less competition with other predatory species, increased welfare of prey animals and markedly increased welfare of the stray cats themselves. Such cats would also contribute to less spread of pathogens, as stray and feral cats frequently suffer from various contagious diseases.

5.4.2.2 Disadvantages

There are few disadvantages of mandatory ID tagging. In rare cases, the tag may cause problems in the cat by moving around in its body. ID tagging with a microchip has a cost to cat owners, and some may hesitate to follow up a new rule about mandatory ID tagging.

5.4.2.3 Assessment

Given that about 80% of owned cats in Norway are already equipped with ID tags, the positive effect on wildlife of mandatory tagging will probably be rather limited. Most pedigree cats are ID tagged because identification is required to participate in cat shows, implying that most unmarked cats are non-pedigree cats. However, it can also be assumed that a large fraction of the untagged cats are kept only indoors. Yet, mandatory ID tagging is recommended as one of several measures to reduce recruitment to stray cats, which in the long run or in the next generation may become feral. Effects of ID-tagging are summarized in Table 46.

Table 46: Summarised assessment of efficiency and disadvantages related to mandatory ID tagging by a microchip. Grading is made for the approximate life time of a cat (10-15 years) after effective measures have been undertaken, as it takes a considerable amount of time for the effects to become evident.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minimal or no	Minimal or no	
Predation on birds	Minimal or no	Minimal or no	
Competition with Norwegian fauna	Minimal or no	Minimal or no	
Animal welfare of prey animals	Minimal or no	Minimal or no	
Animal welfare of cats	Moderate	Minimal or no	

Effects on	Efficency	Disadvantages	Comments
Spread of pathogens	Minimal or no	Minimal or no	

5.4.3 Restrictions on the number of cats per household

To limit the number of cats that predate on wildlife, it has been suggested to restrict the number of cats per household. In a study on 1204 Norwegian cats, 61% of cat households had one to two cats and 77% had one to three cats (Eriksen, 2014). Average number of cats was 2.15 (*SD* = 1.4). Other reports have given an average of 2.4 cats (Sandem, 1998) and 1.4 cats (Mejdell, 2003). Further details about the population of owned cats in Norway are found in section 1.

Earlier, some Norwegian communities attempted to restrict the number of cats in a household to four or five, mainly aiming at reducing nuisance to neighbours. Such rules attracted heavy protests from cat owners, although few cat owners do have more than four to five cats. Pedigree cat breeders may often have higher number of cats, and most manage to keep the cats with a high standard of animal welfare. Such cats are typically kept only indoors or in catios (section 5.1.2).

5.4.3.1 Efficiency

If restricting cat numbers in a household lead to overall fewer owned cats in Norway, it can be assumed that overall predation on wildlife is reduced accordingly, with corresponding positive effects on prey welfare and less competition by cats with other fauna. It is speculated that cats from multi-cat households have a higher likelihood of escaping from their home and become stray cats (eventually feral) but this is not documented.

5.4.3.2 Disadvantages

If limiting the number of cats in a household is achieved by allowing owners to continue with current cats, but not allow to replace them, it will take several years to realise positive effects from this measure.

5.4.3.3 Assessment

Restrictions on the number of cats in a household may have some beneficial effects on wildlife, and the effect will be stringer if fewer cats are allowed outdoors per household. However, most cat owners only have one to three cats, and this limit the effectiveness of this measure (Table 4). Most households that have a large number of cats are pedigree cat breeders, and most of these cats do not roam freely outdoors. Nevertheless, there can be a high effect locally in certain areas where several households have many cats. VKM find that other measures will be more effective, but also that this measure could be considered on a regional scale, for instance close to protected areas.

Table 47: Summarised assessment of efficiency and disadvantages related to statutory restriction on the number of cats in a household to one cat. A higher limit gives correspondingly weaker effects. Grading is made for the approximate lifetime of a cat (10-15 years) after effective measures have been undertaken, as effects take a long time to appear.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minor to Modereate	Minimal or no	Regional variation in efficiency
Predation on birds	Minor to Moderate	Minimal or no	Regional variation in efficiency
Competition with Norwegian fauna	Minimal to Moderate	Minimal or no	Regional variation in efficiency
Animal welfare of prey animals	Moderate	Minimal or no	
Animal welfare of cats	Minor to Moderate	Minor	
Spread of pathogens	Minor	Minimal or no	

5.4.4 Culling of feral and stray cats

Traditionally, populations of feral and stray cats were often reduced by killing, sometimes even by shooting feral cats (Støvring et al., 2001). Later, cats were trapped before being euthanized by a veterinarian. The reasons for the culling were either related to public health (municipal actions) or animal welfare (Statens dyrehelsetilsyn, later part of Norwegian Food Safety Authority). Culling actions are controversial for several reasons. Public concern objecting against this practice were mainly due to owned cats being killed during such actions in several places, as it is not easy to judge whether a caught, untagged cat is owned or not if ID-marking of owned cats is not mandatory. Also, owned cats may panic when trapped, creating concerns for animal welfare. Animal welfare organizations objected to such culling because they considered that homeless cats should be taken care of or rehomed rather than being killed, as killing healthy cats was considered unethical. Practical experience, and later scientific evidence, indicated that culling only had a short-term effect on the size of the feral cat population, and thus necessitated prolonged or new actions to keep the feral cat population at a low level (evidence from Norway: Støvring et al., 2001; international review: Slater 2007).

5.4.4.1 Efficiency

If killing feral and stray cats were effective in reducing their populations, predation on a wide variety of prey species would be reduced, and the competition by such cats with other fauna would be markedly reduced in areas where these cats are numerous.

Eradication of feral cats has been successfully implemented on small islands < 50 km2 with cat densities up to 80 cats/km2 (Nogales et al. 2004) but is more challenging for mainland sites (Doherty et al. 2017). Successful control or eradication of feral cats often has benefits for native wildlife (Ratcliffe et al. 2010; Oppel et al. 2014). Hence, the welfare of prey would be improved. Another side-effect would be a reduced load of pathogens affecting the health of owned cats, particularly feline panleukopenia virus (feline parvovirus), feline immunodeficiency virus and feline leukaemia virus, as these pathogens are frequently found in feral and stray cats. The welfare of owned cats may be somewhat improved, also as they risk less competition and conflict with feral and stray cats. As feral and stray cats often suffer from starvation and poor health, reducing their numbers will increase the overall welfare of such cats.

5.4.4.2 Disadvantages

There are several challenges with culling campaigns on feral and stray cats, and there is a risk that culling might result in compensatory immigration and an increase in population number in some areas (Lazenby et al. 2015).

It might also be problematic to discern between owned free-roaming cats and feral cats in the same area, resulting in unintentional deaths of owned cats.

In some countries, particularly on islands where cats have markedly reduced bird populations, massive effort has been done to try to eradicate feral cat populations – including hunting, trapping, poisoning, and even biological control with feline panleukopenia virus. On Marion Island, such methods were implemented for 15 years, following four years of study and planning. This show that intense effort is required to eradicate cats (Bester et al., 2000, 2002, referred by Slater (2007)). Eradication of feral cats can however have unintended consequences for biodiversity if cats are effective at controlling rodents and other non-native species (Courchamp et al. 1999, Hughes et al. 2008). In Norway, the Animal Welfare Act regulates killing of animals, and there is even a directive on the killing of cats. Even feral cats are not considered wildlife, and hunting cats is not legal.

Culling campaigns directed towards stray cats may have no long-term effect on populations of free-roaming cats (Støvring et al., 2001; Slater, 2007. When the number of cats is reduced, after some time peripheral cats enter the available territories or locations (Apps, 1983; Tabor, 1983). Such actions therefore must be repeated regularly.

5.4.4.3 Assessment

Although not directly disadvantageous to animal welfare (see Table 48), culling campaigns are highly controversial, and the implementation can be limited due to a range of practical issues. In addition, the effectiveness of the method has been questioned, unless the effort is high and repeated regularly.

Table 48: Summarised assessment of efficiency and disadvantages related to culling campaigns on feral and stray cats. Grading is made for effects related to feral and stray cats only, without considering their frequencies in the total populations of cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minimal to Moderate	Minimal or no	
Predation on birds	Minimal to Moderate	Minimal or no	
Competition with Norwegian fauna	Minimal to Moderate	Minimal or no	
Animal welfare of prey animals	Moderate	Minimal or no	
Animal welfare of cats	Moderate	Minor	
Spread of pathogens	Minor	Minor	

5.4.5 Alternative methods to culling feral and stray cats

As culling campaigns are controversial and need sustained effort through time to have an effect (see section 5.4.4), other methods to reduce the feral cat population size have been developed and examined. A common method is termed the Trap, Neuter, Return (TNR) method. Free-roaming cats are trapped in live traps, neutered, and returned to the location where they were trapped. Where rabies is present, the method includes rabies vaccination and is then termed Trap, Neuter, Vaccinate, Return (TNVR). An extension of the TNR method is often termed Trap, Test, Vaccinate, Alter, Rehome or Release (TTVARR). Note that the TNR term is also used by many authors as an acronym to describe what we term TTVARR.

The TTVARR approach implies that apparently stray or feral cats are trapped alive and tested for an ID marking to find owners and to check for the health condition of captured cats. The non-marked cats are treated according to the following scheme:

A. Seriously ill unowned cats are euthanized. Moderately ill or wounded cats can be given simple veterinary treatment and then entering option B.

B. Healthy cats are vaccinated and neutered. They are also ID tagged with a microchip. The cats are checked for their tameness and ease of handling, as well as sociability. For this task, a validated personality test can be used, like the Feline Temperament Profile Test (FTP test; Lee et al., 1983; Siegford et al., 2003) or the Cat Stress Score (CSS test; Kessler and Turner, 1997).

(i) If the cats are poorly socialized and are unable to be housed, including most of the true feral cats, they are *released* again at the place where they were originally trapped.

(ii) Cats that are sufficiently friendly towards people are rehomed (adopted) by new owners. Cats who have had owners and later have become homeless (stray cat) can get used to a life with people again.

(iii) Cats that are not completely wild by nature, but that require more socialization before they can be adopted by new owners – typically stray cats and some feral cats with a sociable personality – can be temporarily placed in a cat shelter run by an animal welfare organization until they are fit for adoption according to a positive FTP test.

In contrast to culling campaigns, the TTVARR and TNR methods aim to return owned and marked cats to their owners and to rehome cats that are sufficiently friendly to people. Healthy unowned cats are released after they are vaccinated and neutered. Only sick and ill cats are euthanized. The goal is then to sterilize enough cats so that reproduction is reduced to the extent that the feral cat population decreases over time (See Coe et al. 2021 and references therein). If many cats are rehomed or euthanized, the removals might result in an additional decrease in the feral cat population. In some Norwegian cities and in many countries, these methods are now being widely applied. Several organizations, such as International Cat Care (iCatCare.org) provide information on cat friendly methods of controlling stray and feral cats, and how such cats can be housed at cat shelters (see The Feral Cat Manual, edited by Claire Bessant).

5.4.5.1 Efficiency

The TNR and TTVARR programs could the reduce risk of negative effects on biodiversity if the methods are efficient at reducing the population size of feral cats. There are, however, mixed results in terms of the ability of the TNR and TTVARR methods when it comes to controlling or reducing the feral cat population (Longcore et al. 2009; Coe et al. 2021). In a study from Florida, USA, application of the TNR method did not resulted in a decrease in the feral cat population over time (Castillo and Clarke 2003). This was partly driven by people that left their unwanted cats into the managed cat colony, and due to immigration of cats from outside the area. A recent unique 12-year study confirmed that a pure TNR project with trapping, neutering and release needs massive, continuous effort to reduce cat populations (Gunther et al., 2022). For context, in the study phase when the cat population declined (by ca. 7% annually), >70% of the cat population was neutered across the entire study area. The authors suggested that more sophisticated methods involving methods similar to TTVARR would increase the effectiveness of the program compared to a TNR program. Demographic modelling supports the finding that a high proportion of cats must be sterilized to reduce the feral cat population (ca. 71-95% sterilization in Foley et al. 2005), whereas another study from Florida concluded that to be efficient at least 50% of the feral cats in the area should be trapped and neutered for the method to influence the cat population (Levy et al., 2014). In addition, they recommended that the program should involve an animal welfare organization that can monitor the released cats, potentially establish feeding stations, and include adoptions of socialized cats (Levy et al., 2014).

Animal welfare can be improved if the program is efficient at detecting and removing sick and ill cats that will be euthanized, and to rehome cats that are sufficiently friendly to people. There are, however, few scientific evaluations of the approach (but see Crawford et al. 2019 for discussion). In general, it will be beneficial to combine the TTVARR or TNR methods with campaigns or regulations encouraging cat owners to ID-mark and neuter their cats to prevent the population of homeless cats from rising if the TTVARR has been implemented.

5.4.5.2 Disadvantages

Cat colonies managed with TNR, TTVARR and similar programs negatively impact biodiversity in the short term because feral cats kill native species of reptiles, birds and mammals (Winter 2004, Longcore et al. 2009). However, prey species can potentially recover once cat populations are reduced or removed (Castillo and Clarke 2003). It has also been regularly reported that feral cat colonies may be used as a dumping place for unwanted cats by some people (Levy et al. 2003, Winter 2004). It is, however, unclear if this applies to Norway. It has also been reported that TNR programs might result in an increased influx of new feral cats to the area if the sites are supplemented with feeding (see Longcore et al. 2009 and discussions therein). Other authors have claimed that such cat colonies are resistant to influx from surrounding areas (Berkeley 2004). A practical challenge is related to the fact that most studies suggest that a large proportion of the feral cat population must be sterilized before there are clear effects on the size and population growth in the feral cat population (Gunther et al. 2022). A high threshold for sterilization means that the program must be extensive both in time and space to achieve a clear reduction in feral cat populations.

5.4.5.3 Assessment

Colonies of feral cats negatively impact native biodiversity and there are mixed results in terms of the ability of the TNR and TTVARR methods when it comes to controlling or reducing feral cat populations. Recent studies suggest that the effort need to be extensive and sustained over time to have clear effects in terms of reducing the risk of negative effects on biodiversity from domestic cats. See Table 49 for summary of effects.

Table 49: Summarised assessment of efficiency and disadvantages related to reducing populations of feral and stray cats by the TTVARR method (Trap, Test, Vaccinate, Alter, Rehome or Release). Grading is made for effects related to feral and stray cats only, without considering their frequencies in the total populations of cats.

Effects on	Efficency	Disadvantages	Comments
Predation on mammals, reptiles and amphibians	Minimal to Minor	Minimal or no	
Predation on birds	Minimal to Minor	Minimal or no	
Competition with Norwegian fauna	Minor	Minimal or no	
Animal welfare of prey animals	Minor	Minimal or no	
Animal welfare of cats	Major	Minor	
Spread of pathogens	Minor	Minimal or no	

6 Uncertainties

- A key uncertainty when assessing the impact of cat predation is related to a lack of studies on additive vs compensatory mortality. Ecological literature states that a range of factors combined can determine the degree of compensation to predation mortality.
- Inference about the cumulative effects of cat predation and other natural and anthropogenic perturbations to ecosystems is uncertain. The effects of cat predation might be context dependent and might change from not important to important under changing environmental conditions.
- Lack of information regarding the number of feral cats in Norway, both in terms of total number, number of colonies and size of colonies impose uncertainty regarding the contribution of feral cats to the total predation pressure of wild species.
- There is uncertainty about which bird hot-spots that are particularly vulnerable to cat predation, in part due to lack of systematic data on location of feral cat colonies close to protected areas and other hot-spots for biodiversity.
- There is uncertainty about which wild species are particularly at risk for negative effects of cat predation. Our assessments are based on generalizations from a range of field studies from a wide range of ecological conditions. However, explicit research on this topic in Norway is lacking. This uncertainty is due to lack of data on prey selection by cats, as well as population stabilization mechanisms within different prey populations.
- There is substantial uncertainty regarding the indirect effects of cat predation on prey populations. While there is ample evidence from the literature that risk mediated behavioural responses to predation might be common, the effects on prey population growth is much more limited and uncertain.
- There is uncertainty about the factors that contribute to variation in hunting success of owned and feral cats. Ecological literature states that hunting success of mammalian predators can vary dramatically under different ecological conditions.
- There is considerable uncertainty about the cat's role in pathogen spread, particularly to wildlife species. Wildlife diseases that are not zoonoses, and not affecting wildlife of great economic or conservation interest, are particularly understudied. The exception is cat-specific diseases, like cat scratch disease and toxoplasmosis where human cases have been well documented.
- There is substantial "implementation uncertainty" related to most of the mitigation measures. The uncertainty concerns how the measures will be perceived and implemented by cat owners and the general public. This uncertainty is particularly high for the most invasive or controversial measures, e.g., keeping the cats indoor only. Implementation uncertainty adds to the total uncertainty for the measures to counteract negative effects of cats.
- There is uncertainty about how the negative impact of cat predation on Norwegian biodiversity will be affected by climate change. The uncertainty includes effects on feral cat population viability, changes in prey distribution and vulnerability, and effects of pathogen spread and virulence.

7 Conclusions (with answers to the Terms of reference)

7.1 Risk of negative effects on biodiversity from cat predation

VKM has assessed the risks associated with cat predation on Norwegian biodiversity by identifying and characterizing potential negative impacts (hazards) and assessing the likelihood of these impacts. Several hazards were identified, including both direct effects from predation, non-lethal effects, and negative effects through competition with native wildlife were assessed. The risks related to predation were assessed separately for birds and mammals and jointly for reptiles and amphibians. For birds, we also assessed the risk in relation to negative effects on specific local areas that might be particularly sensitive to cat predation. Such areas, hereafter termed hotspots, include RAMSAR sites (wetland areas that are breeding or stop-over sites for migratory birds) and breeding colonies for seabirds and shorebirds. The risk associated with cat predation on red-listed mammal species was assessed independently from general effects on small mammal communities.

VKM concludes that cats pose a **High** risk to Norwegian biodiversity through predation under certain conditions. We conclude that cat predation can represent a **High** risk for the most vulnerable bird species living in areas with high cat densities, such as urban areas, and in the bird hotspots that are most exposed to cats. The confidence in these assessments range from **Low** to **High.** For common mammalian prey species, the risk of negative impact is considered **Low** to **Medium.** As there is high uncertainty regarding the population structure of many species this is assessed with **Low** confidence. The impact of cat predation on some red-listed bat species could potentially be **Massive**, but a **Low** likelihood results in a **Low** to **Medium** risk of negative impact (confidence ranging from **Low** to **High**). The risk of negative effects on reptiles and amphibians is mainly assessed as **Low**, although for three species cats pose a **Medium** risk. The confidence in these assessments range from **Low** to **Medium**. The risk of negative effects on avian and mammalian predators due to competition for shared food sources is assessed to be **Low**, although it might be **Medium** in areas with high cat densities for animals that have a high dietary overlap with owned, stray, or feral cats. Du to the lack of data on these interactions, the assessment has **Low** confidence. The risk posed by indirect effects of cats on potential prey species is **Medium** under certain conditions, this is also associated with **Low** a confidence.

7.1.1 Negative effects on wild bird populations from cats

Based on available data, VKM estimated that the 660.000 owned cats kill between 3.9 and 13.8 million birds in Norway annually. In rural and urban habitats, it was estimated that cats might kill between 2.7 – 11.6% of the combined population of bird species. Based on the assumption that this mortality is at least partially additive to other mortality sources, VKM concludes that the risk to bird populations from cat predation (i.e., direct, lethal effects from predation) range from **Low** to **High**. Species that are particularly at risk are those that live in areas with high cat density, such as urban habitats, have a small body size (< 100 g) and that nest and/or feed on the ground. For the most vulnerable populations, VKM find it Likely that cat predation might have a Major impact on the populations (Figure 18).

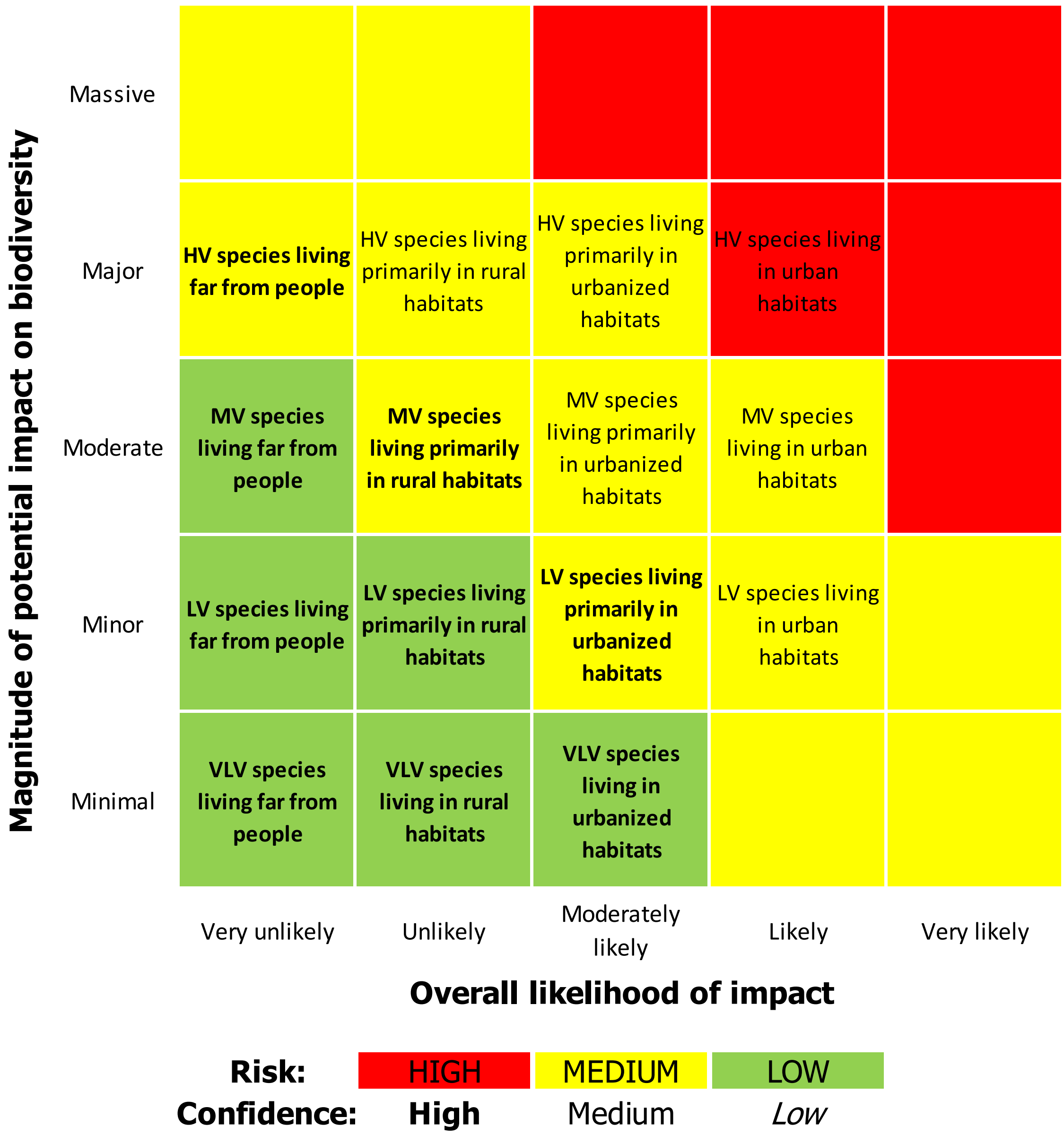

Figure 18: Risk assessment regarding potential negative effects on bird species due to cat predation. The assessment is made with Medium to High confidence. HV = High vulnerability, MV = Medium vulnerability, LV = Low vulnerability and VLV = Very low vulnerability.

Bird populations that inhabit areas with lower cat densities (i.e., more rural areas) have a lower probability of a negative impact, whereas the magnitude of the impact is generally lower for species with larger body mass, that nest high in trees or in cavities or rarely forage on the ground. The species with the highest vulnerability are listed in Table 24. The negative effects due to predation is associated with a Medium to High confidence.

7.1.2 Direct effects on specific bird communities or sensitive habitats

VKM assessed the risk of negative effects from cat predation on specific bird communities that can be considered "bird hotspots".

Such areas include protected areas in the Emerald Network of Norway, international RAMSAR sites (wetland areas that are breeding or stop-over sites for migratory birds) and breeding colonies for seabirds and shorebirds. VKM concludes that the risk associated with cat predation on such hotspots range from **Low** in most areas to **High** in some areas. Areas with the highest risk of negative impact are those that are characterised with a high species richness of vulnerable species, and that are situated close to areas with high cat density. In particular, bird colonies on islands located near feral cat colonies are considered at high risk. The risks posed to bird hotspots from cat predation are presented in Figure 19. This assessment is associated with a Medium to High confidence.

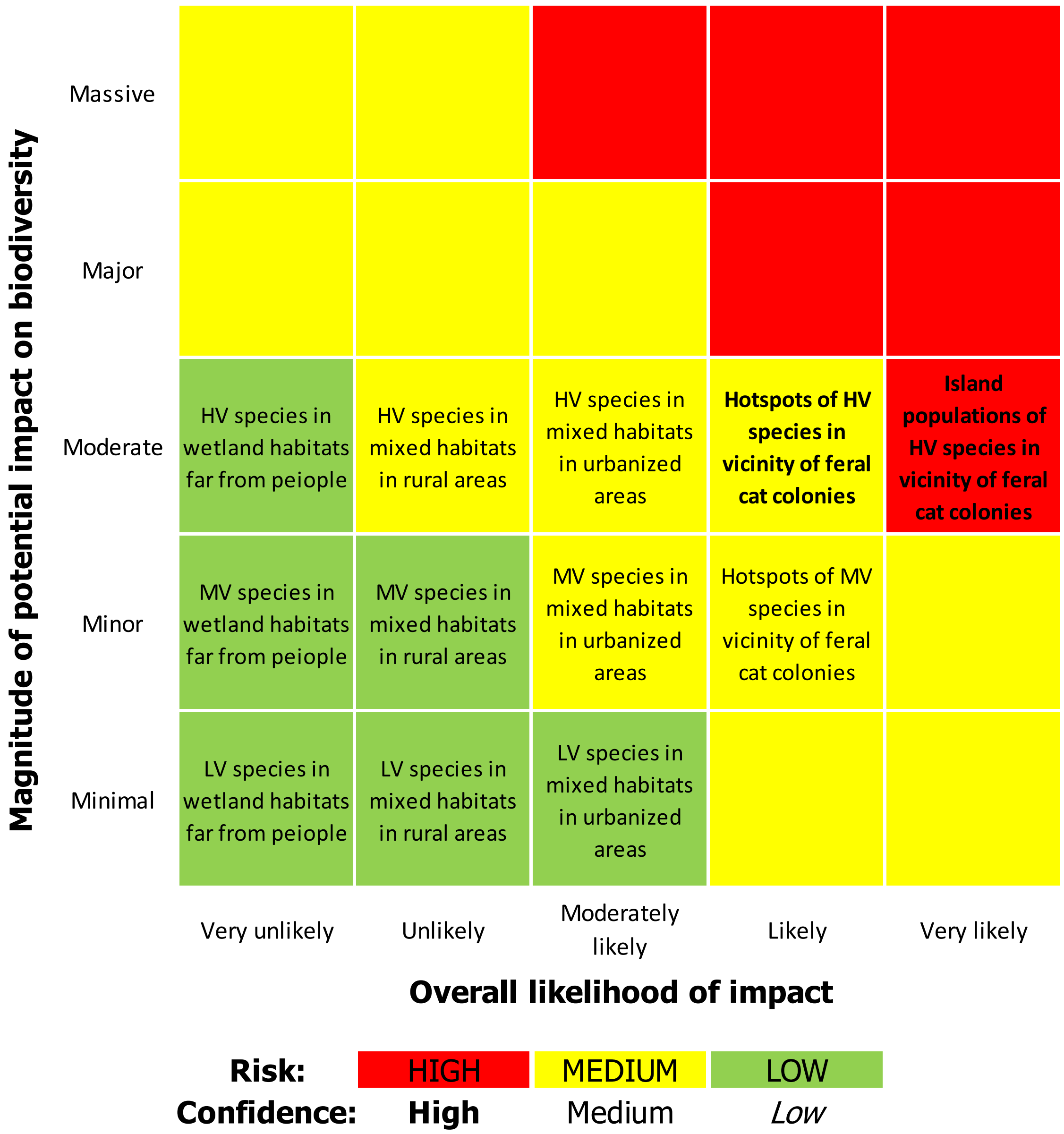

Figure 19: Risk assessment regarding potential negative effects from cat predation in bird hotspots. The assessment is made with High confidence. HV = High vulnerability, MV = Medium vulnerability and LV = Low vulnerability. "Mixed habitats" indicates that the species live in wetland, semi-wetland, and drier habitats.

7.1.3 Indirect effects of cats on prey populations

In addition to direct (lethal) effects of predation, cats might indirectly affect their prey populations by creating a 'landscape of fear' that results in risk-mediated behavioural or life history effects. Avoidance of predation risk by wild animals might include reduced foraging efficiency, altered habitat use, increased vigilance and elevated stress hormone levels. Such effects are well known from the ecological literature, but there is limited evidence for effects of population abundance. VKM assesses the risk related to the negative effects through indirect effects to be **Low** to **Medium**, as presented in (Figure 20). Species that are highly vulnerable to cat predation and live in urban areas have the highest risk, while species with low vulnerability living far from people have a low risk. The assessment is associated with Medium to Low confidence.

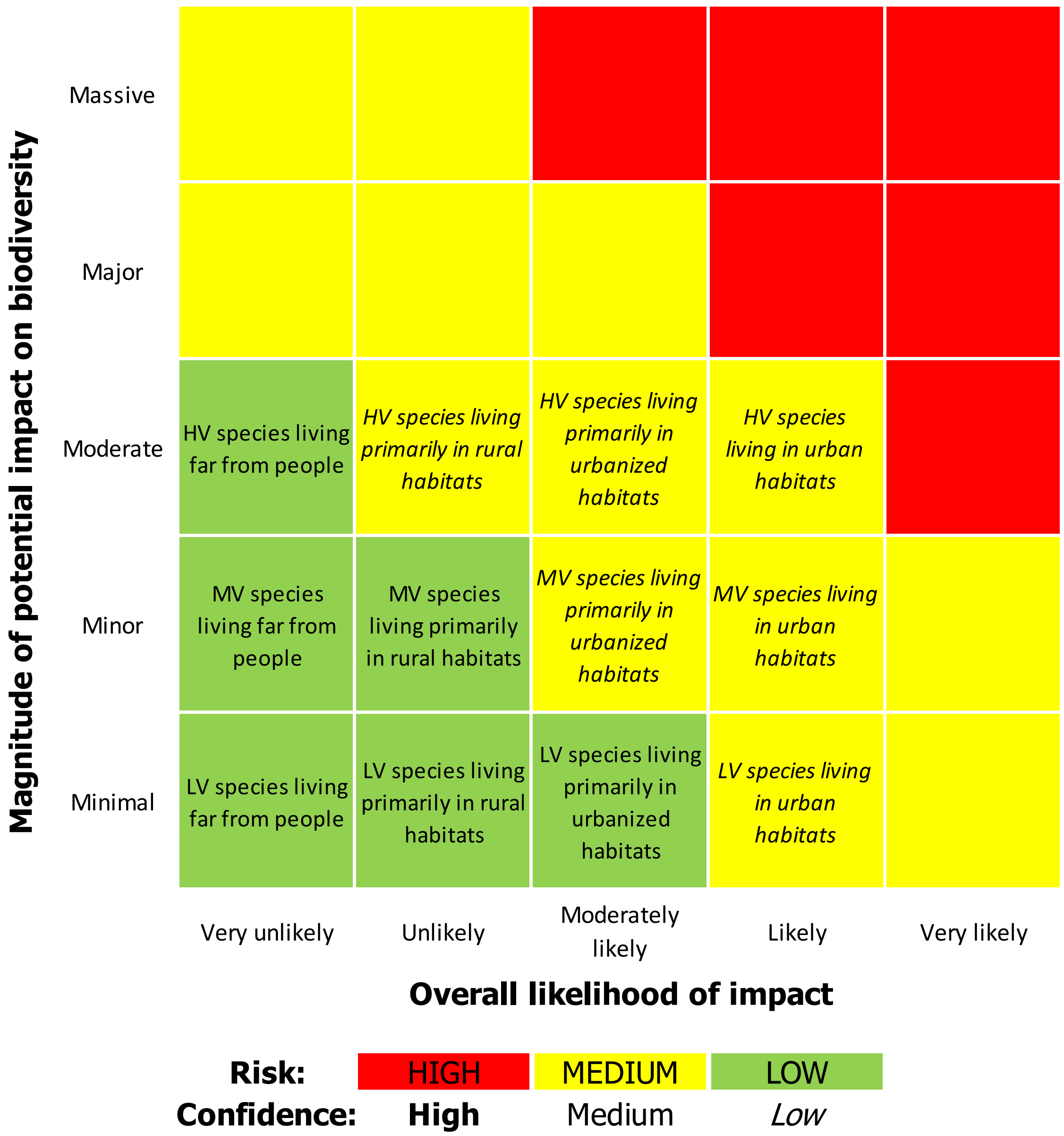

Figure 20: Risk assessment regarding potential negative effects of indirect effects of cats on prey populations. The assessment is done with Medium to Low confidence. HV = High vulnerability, MV = Medium vulnerability, LV = Low vulnerability and VLV = Very low vulnerability.

7.1.4 Direct effects on population dynamics of small mammals

We estimated that 12.6 to 42.8 million mammals are killed by cats in Norway each year. The majority of these mammals include common species, in particular small rodents, like mice. VKM concludes that the risk of negative effects of cat predation on the populations of common mammalian prey species is **Low** to **Moderate** (Figure 21). The assessment is associated with a Low confidence, as there is no explicit research on this topic in Norway.

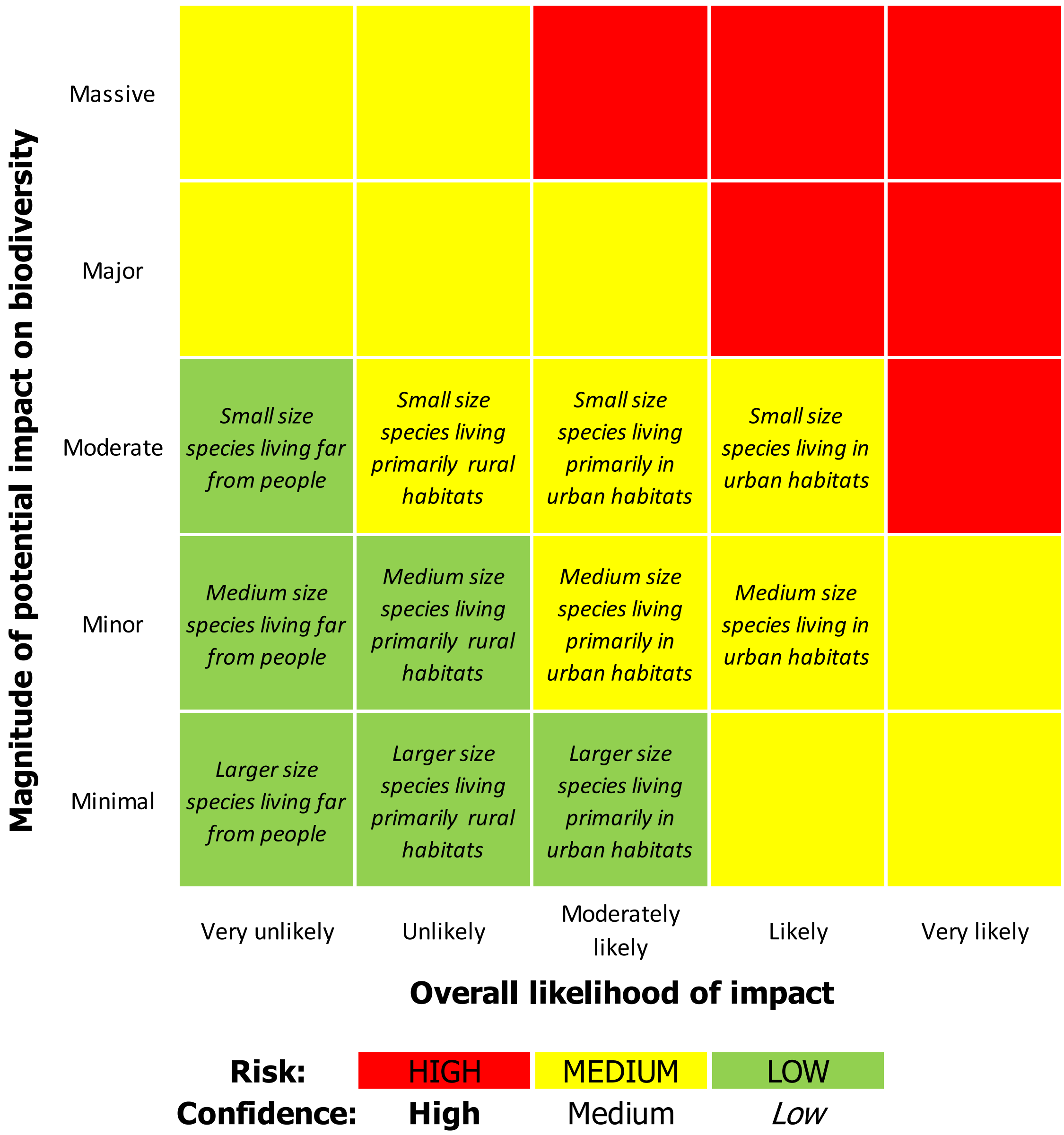

Figure 21: Risk assessment regarding potential negative effects from cat predation on the populations of common small mammals in Norway. The assessment is done with Low confidence.

7.1.5 Risk of negative effects on red-listed species of mammals

VKM assessed the risk of negative effects of cat predation for red-listed mammalian species that are potential prey for cats in Norway. We identified eight species that are potentially vulnerable and conducted individual assessments for each species. Some of these species, in particular some of the bat species, have small populations and range-restricted distributions and are thus vulnerable to stochastic predation events. VKM concludes that the risk of negative impact ranges from **Low** to **Moderate**. The species at highest risk are the four bat species: western barbastelle, Natterer's bat, parti-coloured bat and common noctule (Figure 22). These assessments are associated with a Medium confidence.

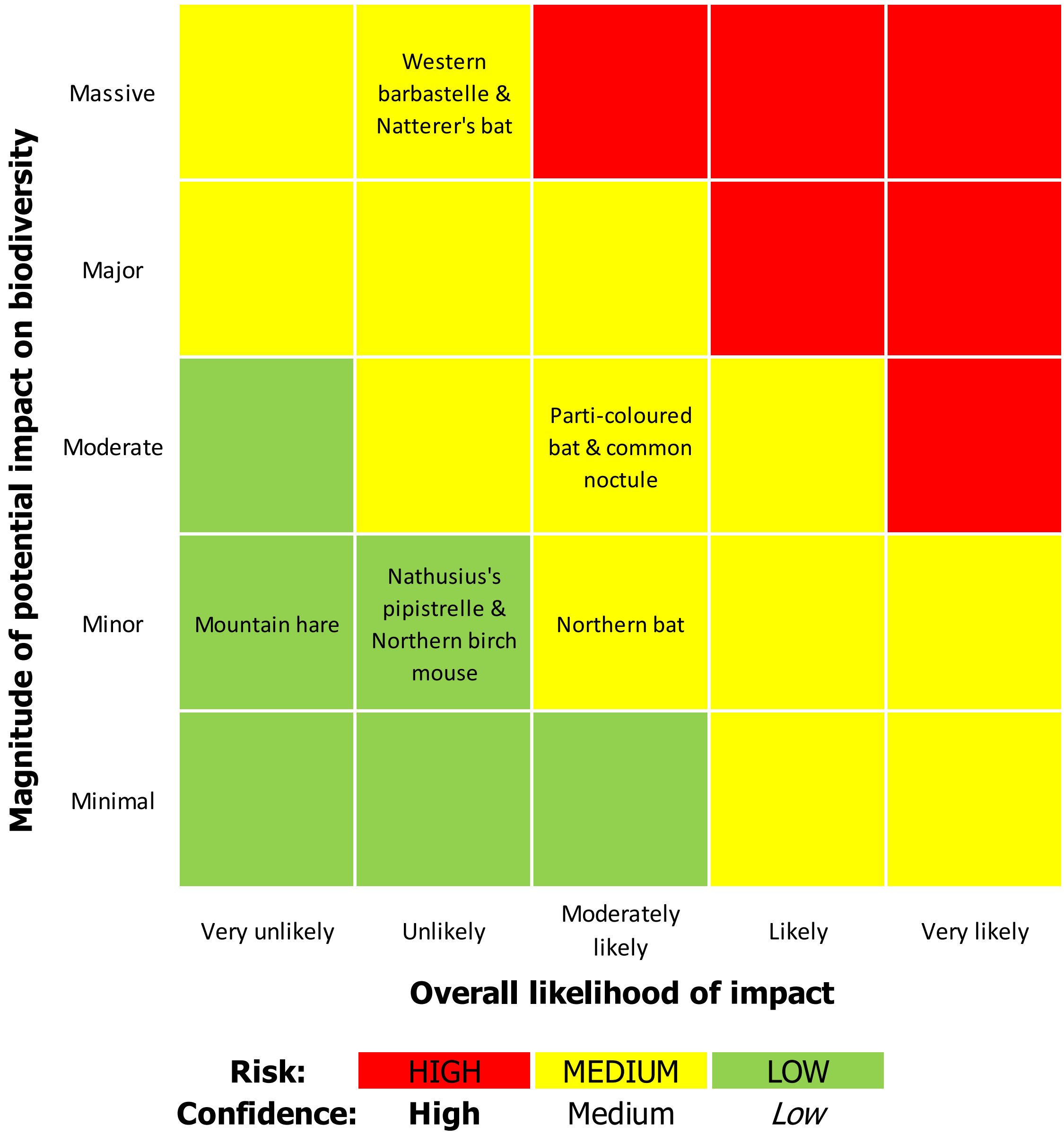

Figure 22: Risk assessment regarding potential negative effects from cat predation on eight species of red-listed mammals vulnerable to cat predation in Norway.

7.1.6 Direct effects on prey population dynamics of reptiles and amphibians

VKM concludes that the risk of negative effects of cat predation on most reptiles and amphibians in Norway is **Low** (Figures 23 and 24). For three species (moor frog, pool frog and smooth snake) the risk is considered **Medium**. The confidence in these assessments range from **Low** to **Medium**.

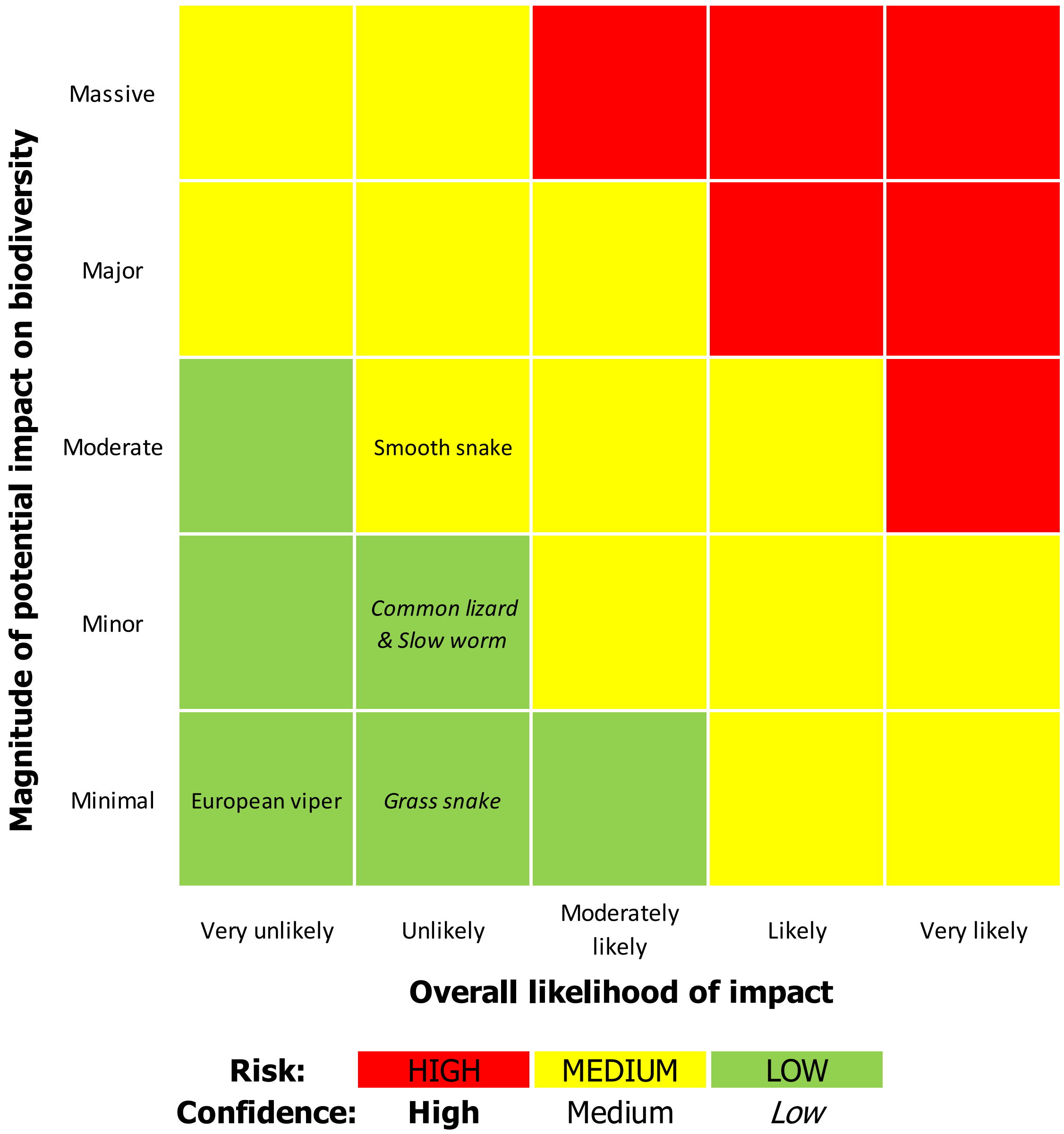

Figure 23: Risk assessment regarding potential negative effects from cat predation on species of reptiles in Norway.

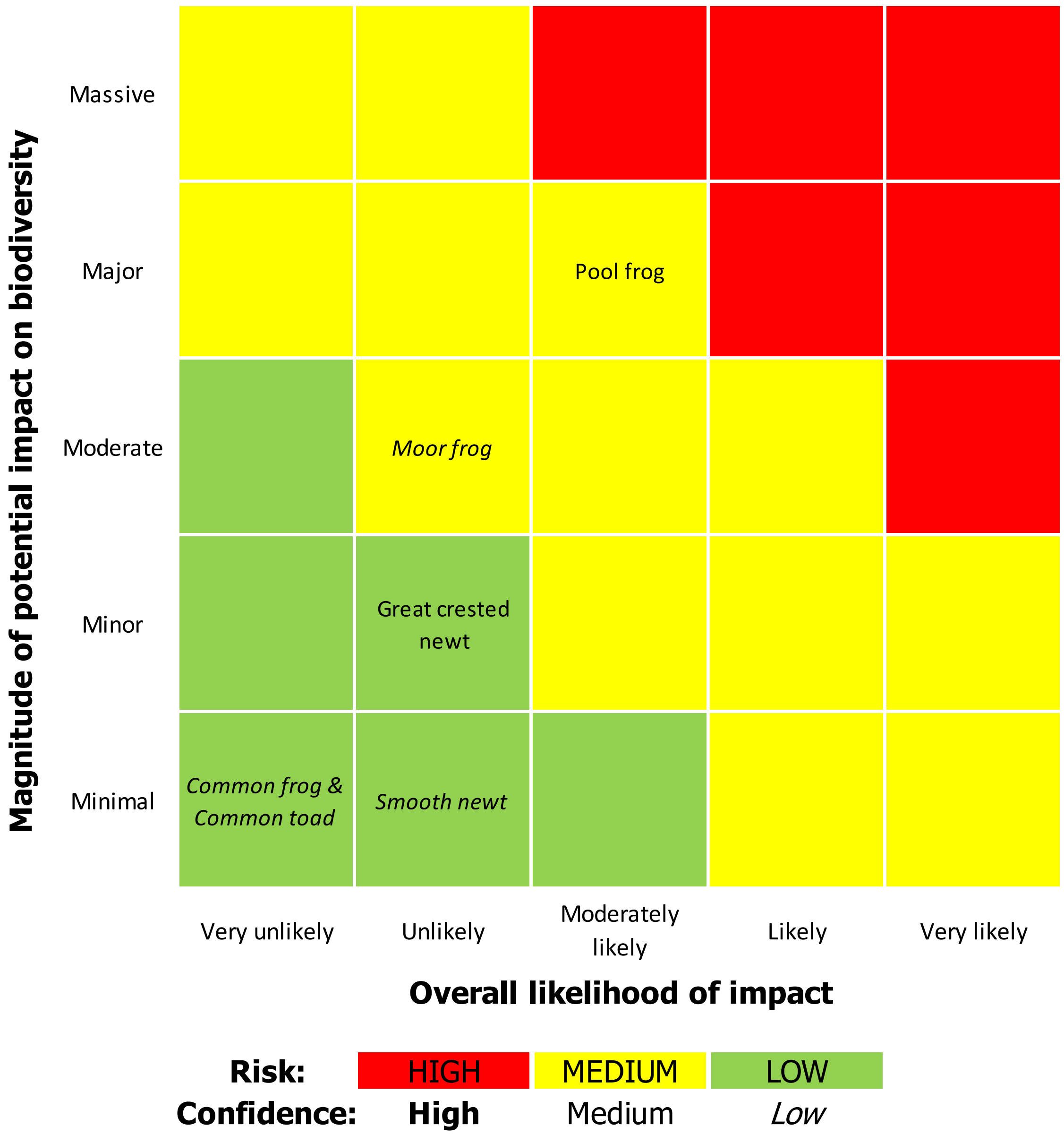

Figure 24: Risk assessment regarding potential negative effects from cat predation on species of amphibians in Norway.

7.1.7 The risk of negative effects due to competition with other wildlife

Domestic cats, whether owned or feral, could compete with predatory wildlife for scarce resources when they have dietary overlap. In Norway, such competition could potentially affect both raptors that prey on mammals and birds, and mammals such as red fox and potentially stoats. VKM concludes that the risk of negative impacts by cats on biodiversity through competition with other wildlife is **Low** to **Medium** (Figure 25). The risk is highest for species living in areas with high cat densities and with a high dietary overlap with cats. The assessment is associated with a **Low** confidence.

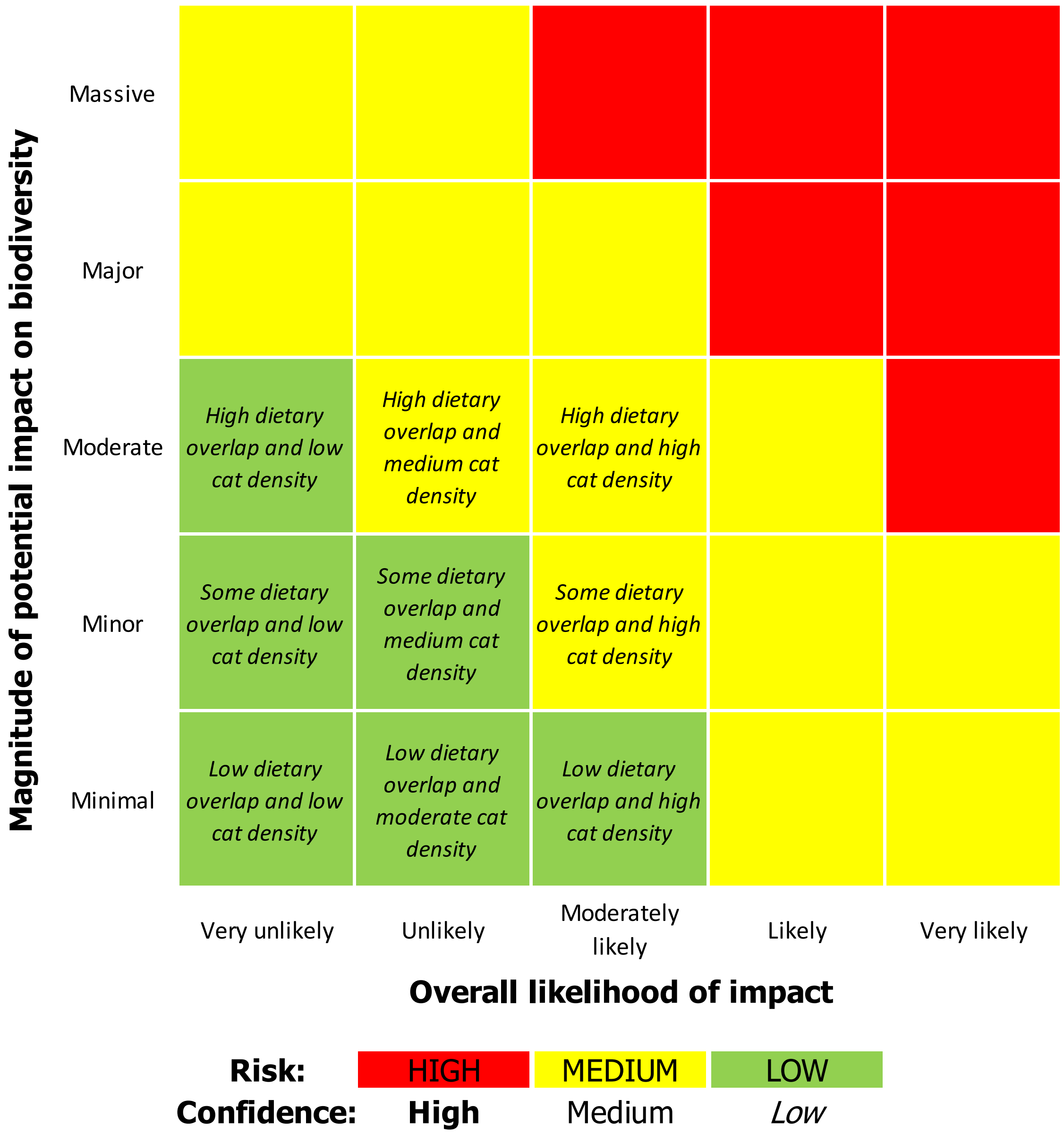

Figure 25: Risk assessment regarding potential negative effects from cats for Norwegian wildlife due to competition for shared prey species.

7.2 Negative consequences of cats for diseases in wild and domestic animals and humans

In Norway and many other countries, cats have an ecological position where they are closely embedded in the human private sphere while at the same time being in close contact with other pets, domestic animals and wild species from several taxa. Because humans sustain artificially elevated domestic cat populations through feeding and care, cats may be effective disease reservoirs compared to other mesopredators. VKM has presented and discussed the role that cats potentially can have in the spread of pathogens and parasites to wildlife, other domestic species and to humans via zoonoses.

VKM concludes that there is virtually certain that cats increase the spread of some diseases that cause harm to both wildlife and other domestic species. Some of these are also known to infect humans. A wide range of diseases and disease-causing agents where cats might play a role in the disease spread and dynamics were identified and assessed. In total, 34 diseases were individually assessed (Table 32).

In a few systems, cats are assessed to be likely relevant contributors to incidence of diseases either causing severe impacts to individuals (in species where individual cases are noted, i.e. humans, domestic animals or threatened species), and/or affect the population dynamics (in other species). The most important seems likely to be toxoplasmosis (caused by the eukcaryotic parasite *Toxoplasma gondii*) in humans and other wild and domestic mammals, tularemia in humans and other mammals (caused by the bacteria *Francisella tularensis*), salmonellosis (common intestinal diseases caused by the *Salmonella* genus of bacteria affecting wildlife, especially birds, domestic animals, and humans), and emerging respiratory viruses (in particular avian influenzas or coronavirus variants).

Several diseases are noted as having a low probability of cat-attributable effects in Norway currently due to the agent being rare or non-existent in here historically. However, they are included as this may change following climate change or introduction in the near to moderately long term (<50-70 years). Examples include rabies, which is currently absent in mainland Norway due to successful control and eradication, but where cats is a disproportionate source of human infections in the US, or leptospirosis which is currently rare in Norway but suspected of becoming more common as the climate warms.

7.2.1 Risk for negative consequences to wildlife from disease spread

Many disease-causing agents can spread from cats to wildlife, but there is limited evidence on rates of transmission from the scientific literature. Norwegian wildlife and cats have a long and shared history, which may moderate the effects under current conditions. There are some notable exceptions, and in particular toxoplasmosis has ongoing detriment to wildlife. Toxoplasmosis might have a range of negative effects on wildlife populations, and seroprevalence and effect studies suggest that cats are instrumental in maintaining the parasite cycle. It is also worth noting that we do not have a "cat -free" baseline with which to compare disease burden in wildlife. Moreover, several cat-related wildlife diseases currently very rare or absent from Norway might become concerns over the next few decades as they are in danger of establishing in Norway due to climate change and/or trade.

7.2.2 Risk for negative consequences to domestic animals from disease spread

Cats may be in contact with other pets, as well as with domestic and peridomestic animals that may otherwise not be in contact with each other or with humans and wildlife. Populations of unvaccinated stray or feral cats can be a reservoir of disease for cats that are house pets. Similar to wild species, the risk associated with disease spread from cats to other domestic animals is mainly considered low to moderate, with the notable exception of toxoplasmosis and diseases spread between pets of different households. It is also worth noting that we do not have a "cat -free" baseline with which to compare disease burden in domestic animals. Several cat-related diseases currently very rare or absent from Norway might become concerns over the next few decades as they are in danger of establishing in Norway due to climate change and/or trade.

7.2.3 Potential negative consequences to humans from spread of pathogen

VKM has not characterized the risks to humans posed by cats through spread of pathogens. However, in this assessment, VKM has identified several zoonotic diseases that might involve owned and feral cats in the disease spread cycle, that has been shown to have negative impact on humans in the literature. Of particular note are toxoplasmosis, tularemia, salmonellosis and influenza. Several cat-related zoonotic diseases currently very rare or absent from Norway could emerge as significant concerns in the coming decades (Table 32). This could be attributed to the potential establishment of these diseases in Norway due to factors like climate change and increased trade activities.

7.3 Negative consequences of cats for prey welfare

The concept of animal welfare originally focused on animals kept by humans. However, most definitions of animal welfare involve a consideration of the state of the individual animal as perceived by the animal itself, not the human care they receive. In legislation, obligations related to animal welfare cover all species, wild or kept, that are directly or indirectly affected by humans. The obligations include effects of predatory animals introduced by humans. Mortality is widely used as a welfare indicator. However, the suffering related to predation by cats, such as pain, impaired function due to injuries, and fear and anxiety in the presence of predators, might be better measures of welfare. Cats are predators with a strong motivation to hunt, even when they are fed to cover their nutritional needs. Nevertheless, domestic cats are not the only predator that potential prey animals will experience. In our assessment of consequences for prey welfare from keeping cats, VKM considers the reduced welfare associated with keeping cats that is additional to the situation for prey populations living sympatric with wild predator species.

In rural habitats, it is Unlikely that cats add significantly to the welfare-reducing effects of other predator species. In urban and suburban areas where cats are more numerous, it is Very likely that cats contribute significantly to the negative effect on prey animal welfare. The likelihood is assessed with medium confidence. Depending on cat density and prey species, VKM concludes that the risk of negative effects by cats on prey animal welfare varies from **Low** to **High**.

7.4 Measures to counteract negative effects of cats

VKM has assessed the potential effects of 15 mitigation measures that can counteract negative effects of cats on Norwegian biodiversity and the spread of pathogens. The effects of mitigation measures on prey and cat welfare were also assessed. The measures were categorized into four groups, depending on the type and scope of the measure. The groups of measures included i) measures that restrict cats' access to prey populations, ii) measures that reduce hunting success of cats, iii) measures that depress or reduce efficacy of hunting behaviour, and iv) measures that reduce impacts by reducing the number of cats. The summary scores for each measure are visualized in Figure 26.

VKM concludes that measures that restrict cats' access to prey populations are likely to have the largest positive effects. The measures are likely to have major to massive effects in terms of reducing the impact on prey populations and spread of pathogens. Keeping cats only indoors (see sections 5.1.1 and 5.1.2) is likely to have the strongest negative effects on cat welfare when imposed on cats that are used to roam outdoors, whereas the negative effects is less for cats that are used to an indoor-only life style. The negative effects on cat welfare can be reduced by using large outdoor enclosures (section 5.1.3), or by giving the cat outdoor access while led by the owner on a leash (section 5.1.4). Keeping the cat indoors only in certain geographic areas or in certain time periods might achieve some of the benefits in terms of reduced impact on biodiversity while at the same time reducing the negative effects on cat welfare. Time periods of specific concern include the period between dusk and dawn, when cat hunting success might be particularly high, as well as during the breeding season for birds in spring and early summer. Likewise, keeping owned cats indoors in areas close to bird hotspots is likely to have a massive risk reduction for these bird communities.

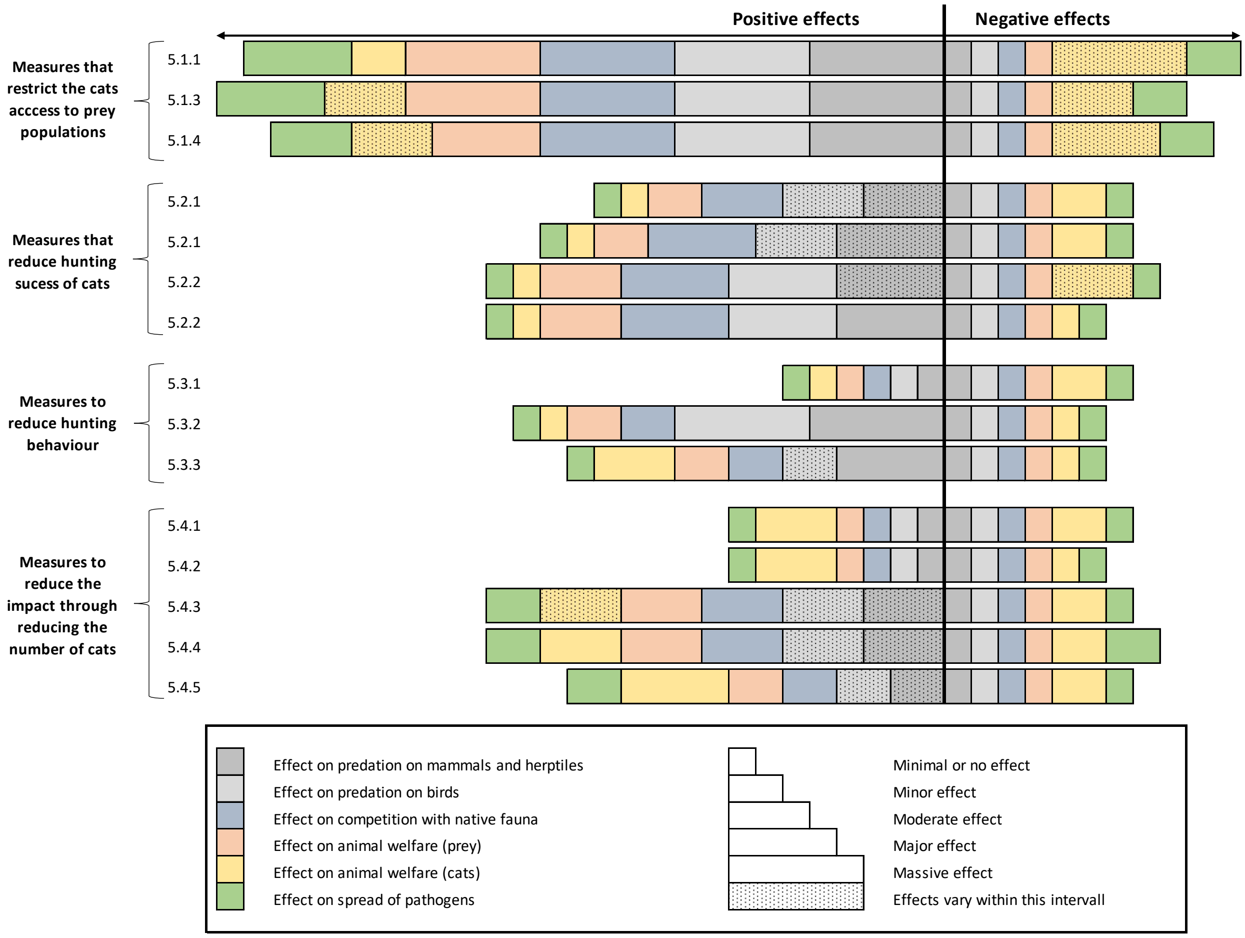

Figure 26: Summarized scores (summary of Tables 35 – 49) for the measures assessed to reduce negative impacts of cats. Both positive and negative effects for each of the measures are presented.

The assessed measures that are proposed to reduce the hunting success of cats are also likely to reduce the negative impact on biodiversity. Importantly, it should be assumed that these measures are less efficient than the measures that restrict the cats access to prey populations (described above), but they also carry fewer negative effects on cat welfare. Based on our assessment (section 5.2.2), bibs and especially colorful collar covers will have a larger positive effect on predation than collars with bells and sonic collars. VKM further concludes that measures suggested to depress the hunting behaviour of cats, such as choice of cat breed, adjusting feeding and increased playing activity, could potentially have massive effects on wildlife predation. However, due to the few studies on this topic, there is high uncertainty regarding these effects.

VKM concludes that measures to reduce the number of cats vary in terms of reducing negative effects. Mandatory castration of cats that are not intended for breeding (section 5.4.1) and mandatory identification (i.e., chipping) of all owned cats (section 5.4.2) will have only minimal effects on the number of feral cats as most owned cats in Norway are chipped already. Chipping is mandatory for pet cats imported to Norway but optional for locally bred animals. This will have a moderate positive effect on cat welfare, as it makes it easy to reunite lost cats with their owners. Mandatory chipping would assist culling- or TTVAAR (Trap, Test, Vaccinate, Alter, Rehome or Release) programs with identifying feral cats without owners. Restricting the number of cats per household (section 5.4.3) might have moderate positive effects in terms of reducing negative effects on biodiversity from predation and competition, but the effect varies regionally. The measure will have only minor effects on cat welfare and spread of pathogens. Repeated culling of feral and stray cats (section 5.4.4) might have moderate positive effects as a mitigation against negative effects on biodiversity from cat predation, also on prey and cat welfare. However, if conducted as a once-off campaign, such culling is less likely to have sustained effects. The effect is limited to feral and stray cats. In addition, if not combined with compulsory ID marking, it cannot be known with certainty if a cat is owned or not. In TTVARR (sometimes referred to as TNR, although TTVARR is an extension to the traditional TNR (section 5.4.5)), apparent stray cats are trapped and tested for an ID marking. ID-marked cats are returned to the owner. Cats that are not ID marked follow a specific protocol where seriously ill and unsocialized cats are euthanized, and healthy cats that are habituated to humans are vaccinated and neutered and then released or rehomed. This method might have only minimal to minor overall effects as risk reducing measure in terms of negative effects from cats on biodiversity. Studies often fail to find any effect on the size of the feral cat population unless the effort is substantial and sustained through time. However, the effects on cat welfare might be major. Disadvantages are graded as minimal to minor.

7.5 Effects of climate change

Climate change is likely to exacerbate the effects of cats on biodiversity for several fundamental reasons, even though the net effect is impossible to quantify at present given the number of species and complexity of the interactions:

1) Non-feral cats are closely linked to humans, with most having access to food and indoor shelter, and are thus more protected from the effects of extreme weather events than their wild prey species. This is likely to increase the likelihood of negative impact on prey species, since cat predation may remain high even when prey is scarce due to climate acerbated population fluctuations. This is as opposed to natural (wild) predators whose populations tend to be limited by the abundance of their prey.

2) As climate zones move northwards and towards higher elevations, the species most likely to persist are often those capable of shifting their range trough dispersal or migration. Human-dominated landscapes often function as barriers to this process, with cultivated fields, roads, gardens, livestock, pesticides, houses, paved areas and other human structures function as barriers to various species. As cat densities are closely correlated with human populations, cat predation is a contribution to this barrier. Thus, in addition to the direct effect on prey species, the barrier effect of cat predation is also likely to hinder prey species' ability to adapt to changing climate.

3) Feral cats may also be more likely to survive in milder winters and thus establish larger and more far-reaching colonies.

4) Several cat-related diseases that currently are very rare or absent from Norway might become concerns over the next few decades as they are in danger of establishing in domestic and/or feral cats in Norway due to climate change and/or trade. When these diseases impact wildlife, it intensifies both the immediate impact on vulnerable wildlife species already affected by climate change (point 1) and the obstructive effect of densely populated cat communities (point 2).

These effects are graphically summarized in Figure 27.

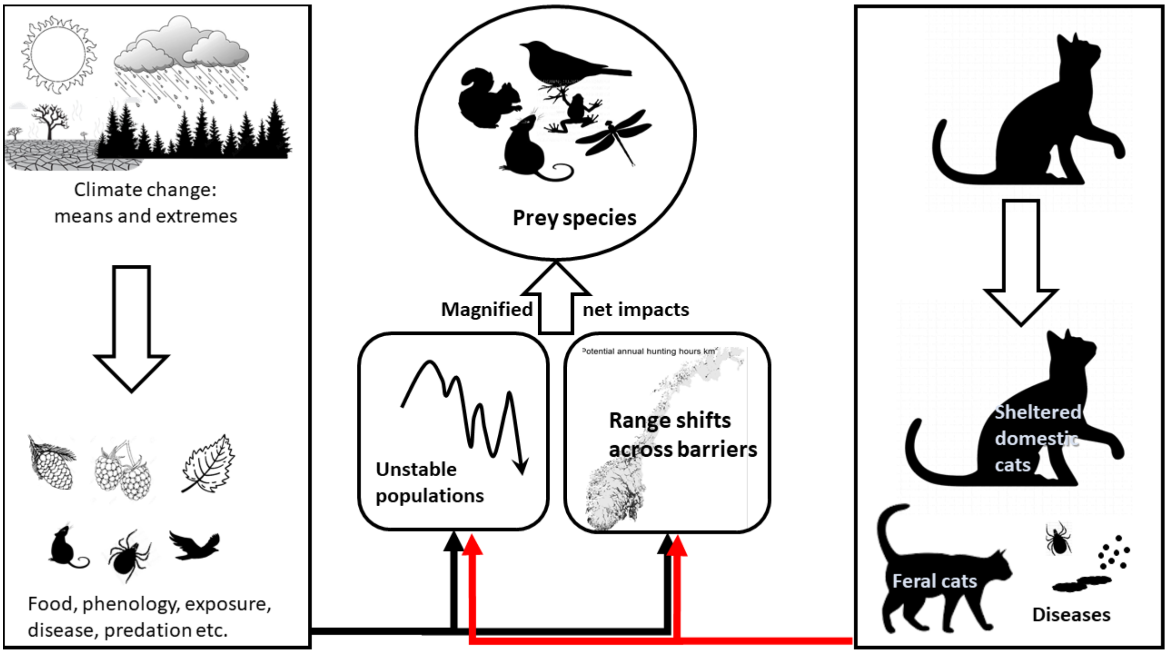

Figure 27: Cascading interactions between climate change and effects of domestic cats on wildlife diversity. Climate change already impacts the ecosystem, in general resulting in more unstable and vulnerable populations suffering from climate debt and having to shift their distributions. Cats, on the other hand, are more sheltered from climate fluctuations and the main foreseen effects are higher winter survival of feral cats and more diseases present in Norway. Thus, when the wildlife species also are impacted by predation and/or disease from cats, they are under constant predation pressure even when their populations are low, and exacerbated barriers to dispersal. The net effect is thus expected to magnify through the process.

8 Data gaps

- There are no or limited empirical data on the number and geographical distribution of feral cats in Norway, as well as the size of the individual colonies. The data gaps have ramifications for the estimated number of prey individuals killed by cats annually, and therefore implications for the assessment of the negative impacts on biodiversity.
- There are limited data about cat prey selection in Norway, and how diet changes with changing availability of different prey species. This data gap relates both to selection at a higher taxonomic level (e.g., proportion of birds vs mammalian prey) and at lower taxonomic level (e.g. the selection of different prey species). Missing information on prey selection reduces our ability to assess relative risk at the species level.
- Good estimates of kill rates of cats are available in Norway, but there is still a gap of data pertaining to exact numbers of prey for longer time periods. Most estimates are based on prey returned home and better data are needed on kill rates of cats under field conditions.
- There are no data on cat predation rates for vulnerable species in Norway based on dedicated primary research.
- There are no data on non-lethal risk mediated effects of cat predation on population development for prey populations.
- There are no data on the role of owned and feral cats on spread of pathogens to wildlife populations in Norway.
- There is a lack of data on the distribution and abundance of bat species in Norway.
- There are no or limited empirical data on the efficacy of most mitigative measures (with some important exceptions). Enhanced insights into the public's and pet owners' acceptance of various mitigation measures are necessary before enacting new regulations.
- There is a lack of data regarding public opinion on whether confining cats indoors is a controversial measure in Norway or not.
- Data are lacking on the impact of cats brought by owners to the increasing number of cabins in Norway. These cabins are primarily situated in regions where the cat density tends to be low (rural and less urbanized areas). Consequently, various species not anticipated in our assessments might be susceptible to cat predation. The cats could also be exposed to different pathogens than in their home environment. Transporting cats between their primary residents and one or more cabins, and releasing them in various environments, could contribute to spread of pathogens.
- There is a lack of data on the occurrence of cats (density and behaviour) within RAMSAR-areas, protected areas and other bird hot-spots.

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10 Appendix I

Species	Latin name	Norwegian name	Body mass	Nest site	Foraging site	Near humans	Vulner-ability index
European honey buzzard	*Pernis apivorus*	Vepsevåk	830	High	Partly ground	Rarely	0.125
Northern goshawk	*Accipiter gentilis*	Hønsehauk	1100	High	Rarely ground	Rarely	0.003
Eurasian sparrowhawk	*Accipiter nisus*	Spurvehauk	204	High	Rarely ground	Rarely	0.062
Common buzzard	*Buteo buteo*	Musvåk	921	High	Rarely ground	Rarely	0.013
Common kestrel	*Falco tinnunculus*	Tårnfalk	203	High	Rarely ground	Rarely	0.062
Eurasian hobby	*Falco subbuteo*	Lerkefalk	232	High	Rarely ground	Rarely	0.062
Common quail	*Coturnix coturnix*	Vaktel	89	Ground	Mostly ground	Rarely	10
Common pheasant	*Phasianus colchicus*	Fasan	1244	Ground	Mostly ground	Sometimes	0.4
Corn crake	*Crex crex*	Åkerrikse	160	Ground	Mostly ground	Rarely	5
Common crane	*Grus grus*	Trane	6078	Ground	Mostly ground	Rarely	0.2
Eurasian oystercatcher	*Haematopus ostralegus*	Tjeld	488	Ground	Mostly ground	Rarely	2
Northern lapwing	*Vanellus vanellus*	Vipe	227	Ground	Mostly ground	Rarely	5
Eurasian woodcock	*Scolopax rusticola*	Rugde	313	Ground	Mostly ground	Rarely	2
Eurasian curlew	*Numenius arquata*	Storspove	709	Ground	Mostly ground	Rarely	1
Black-headed gull	*Chroicocephalus ridibundus*	Hettemåke	256	Ground	Partly ground	Sometimes	2
Mew gull	*Larus canus*	Fiskemåke	387	Ground	Partly ground	Sometimes	2
Lesser black-backed gull	*Larus fuscus*	Sildemåke	753	Ground	Partly ground	Sometimes	1
Herring gull	*Larus argentatus*	Gråmåke	1061	Ground	Partly ground	Sometimes	0.2
Feral pigeon	*Columba livia*	Bydue	270	Cavity	Mostly ground	Often	2
Stock dove	*Columba oenas*	Skogdue	275	Cavity	Mostly ground	Rarely	0.5
Common wood pigeon	*Columba palumbus*	Ringdue	495	High	Mostly ground	Often	2
Eurasian collared dove	*Streptopelia decaocto*	Tyrkerdue	188	High	Mostly ground	Often	5
Common cuckoo	*Cuculus canorus*	Gjøk	111	Ground	Partly ground	Rarely	2.5

Tawny owl	*Strix aluco*	Kattugle	472	Cavity	Rarely ground	Sometimes	0.05
Long-eared owl	*Asio otus*	Hornugle	276	High	Rarely ground	Rarely	0.025
Short-eared owl	*Asio flammeus*	Jordugle	379	Ground	Rarely ground	Rarely	0.1
Common swift	*Apus apus*	Tårnseiler	38	Cavity	Rarely ground	Often	0.5
Eurasian wryneck	*Jynx torquilla*	Vendehals	38	Cavity	Partly ground	Rarely	1.25
Grey-headed woodpecker	*Picus canus*	Gråspett	125	Cavity	Partly ground	Rarely	0.625
European green woodpecker	*Picus viridis*	Grønnspett	199	Cavity	Partly ground	Sometimes	1.25
Black woodpecker	*Dryocopus martius*	Svartspett	339	Cavity	Partly ground	Rarely	0.25
Great spotted woodpecker	*Dendrocopos major*	Flaggspett	87	Cavity	Rarely ground	Sometimes	0.25
Lesser spotted woodpecker	*Dendrocopos minor*	Dvergspett	22	Cavity	Rarely ground	Rarely	0.125
Wood lark	*Lullula arborea*	Trelerke	29	Ground	Mostly ground	Rarely	10
Eurasian skylark	*Alauda arvensis*	Sanglerke	39	Ground	Mostly ground	Rarely	10
Sand martin	*Riparia riparia*	Sandsvale	15	Cavity	Rarely ground	Rarely	0.125
Barn swallow	*Hirundo rustica*	Låvesvale	20	Cavity	Rarely ground	Often	0.5
Common house martin	*Delichon urbica*	Taksvale	16	Cavity	Rarely ground	Often	0.5
Tree pipit	*Anthus trivialis*	Trepiplerke	22	Ground	Mostly ground	Rarely	10
Meadow pipit	*Anthus pratensis*	Heipiplerke	19	Ground	Mostly ground	Rarely	10
Yellow wagtail	*Motacilla flava*	Gulerle	17	Ground	Mostly ground	Rarely	10
White wagtail	*Motacilla alba*	Linerle	22	Cavity	Mostly ground	Often	10
Eurasian wren	*Troglodytes troglodytes*	Gjerdesmett	9	Ground	Mostly ground	Rarely	10
Dunnock	*Prunella modularis*	Jernspurv	20	Low	Partly ground	Rarely	2.5
European robin	*Erithacus rubecula*	Rødstrupe	18	Ground	Mostly ground	Often	40
Common redstart	*Phoenicurus phoenicurus*	Rødstjert	16	Cavity	Rarely ground	Sometimes	0.25
Whinchat	*Saxicola rubetra*	Buskskvett	18	Ground	Mostly ground	Rarely	10
Northern wheatear	*Oenanthe oenanthe*	Steinskvett	24	Cavity	Mostly ground	Rarely	2.5
Common blackbird	*Turdus merula*	Svarttrost	102	Low	Mostly ground	Often	10
Fieldfare	*Turdus pilaris*	Gråtrost	102	High	Mostly ground	Often	5
Song thrush	*Turdus philomelos*	Måltrost	75	Low	Mostly ground	Rarely	5
Redwing	*Turdus iliacus*	Rødvingetrost	68	Low	Mostly ground	Sometimes	10
Mistle thrush	*Turdus viscivorus*	Duetrost	113	High	Mostly ground	Rarely	1.25

Common grasshopper warbler	*Locustella naevia*	Gresshoppesanger	14	Ground	Partly ground	Rarely	5
Marsh warbler	*Acrocephalus palustris*	Myrsanger	12	Low	Partly ground	Rarely	2.5
Icterine warbler	*Hippolais icterina*	Gulsanger	13	Low	Rarely ground	Rarely	0.25
Lesser whitethroat	*Sylvia curruca*	Møller	11	Low	Rarely ground	Sometimes	0.5
Common whitethroat	*Sylvia communis*	Tornsanger	14	Low	Partly ground	Rarely	2.5
Garden warbler	*Sylvia borin*	Hagesanger	21	Low	Rarely ground	Rarely	0.25
Blackcap	*Sylvia atricapilla*	Munk	20	Low	Rarely ground	Sometimes	0.5
Wood warbler	*Phylloscopus sibilatrix*	Bøksanger	10	Ground	Rarely ground	Rarely	0.5
Common chiffchaff	*Phylloscopus collybita*	Gransanger	8	Low	Rarely ground	Rarely	0.25
Willow warbler	*Phylloscopus trochilus*	Løvsanger	9	Ground	Rarely ground	Sometimes	1
Goldcrest	*Regulus regulus*	Fuglekonge	6	High	Rarely ground	Rarely	0.125
Spotted flycatcher	*Muscicapa striata*	Gråfluesnapper	16	Low	Rarely ground	Sometimes	0.5
Pied flycatcher	*Ficedula hypoleuca*	Svarthvit fluesnapper	13	Cavity	Rarely ground	Often	0.5
Long-tailed tit	*Aegithalos caudatus*	Stjertmeis	8	High	Rarely ground	Rarely	0.125
Marsh tit	*Poecile palustris*	Løvmeis	12	Cavity	Rarely ground	Sometimes	0.25
Willow tit	*Poecile montanus*	Granmeis	11	Cavity	Rarely ground	Rarely	0.125
Crested tit	*Lophophanes cristatus*	Toppmeis	11	Cavity	Rarely ground	Rarely	0.125
Coal tit	*Periparus ater*	Svartmeis	9	Cavity	Rarely ground	Rarely	0.125
Blue tit	*Cyanistes caeruleus*	Blåmeis	11	Cavity	Rarely ground	Often	0.5
Great tit	*Parus major*	Kjøttmeis	18	Cavity	Partly ground	Often	5
Eurasian nuthatch	*Sitta europaea*	Spettmeis	23	Cavity	Rarely ground	Often	0.5
Eurasian treecreeper	*Certhia familiaris*	Trekryper	10	Cavity	Rarely ground	Rarely	0.125
Red-backed shrike	*Lanius collurio*	Tornskate	31	Low	Partly ground	Rarely	2.5
Eurasian jay	*Garrulus glandarius*	Nøtteskrike	162	High	Partly ground	Rarely	0.625
Eurasian magpie	*Pica pica*	Skjære	223	High	Mostly ground	Often	5
Western jackdaw	*Corvus monedula*	Kaie	223	Cavity	Mostly ground	Often	5
Rook	*Corvus frugilegus*	Kornkråke	464	High	Mostly ground	Sometimes	1
Hooded crow	*Corvus cornix*	Kråke	543	High	Mostly ground	Often	1
Northern raven	*Corvus corax*	Ravn	1185	High	Partly ground	Rarely	0.025
European starling	*Sturnus vulgaris*	Stær	80	Cavity	Mostly ground	Often	10

House sparrow	*Passer domesticus*	Gråspurv	30	Cavity	Mostly ground	Often	10
Eurasian tree sparrow	*Passer montanus*	Pilfink	24	Cavity	Mostly ground	Often	10
Chaffinch	*Fringilla coelebs*	Bokfink	23	High	Partly ground	Often	5
Brambling	*Fringilla montifringilla*	Bjørkefink	24	High	Rarely ground	Rarely	0.125
European greenfinch	*Chloris chloris*	Grønnfink	30	High	Partly ground	Often	5
European goldfinch	*Carduelis carduelis*	Stillits	16	High	Partly ground	Often	5
Eurasian siskin	*Spinus spinus*	Grønnsisik	13	High	Rarely ground	Sometimes	0.25
Common linnet	*Linaria cannabina*	Tornirisk	18	Low	Partly ground	Sometimes	5
Twite	*Linaria flavirostris*	Bergirisk	16	Ground	Mostly ground	Rarely	10
Common redpoll	*Acanthis flammea*	Gråsisik	14	High	Rarely ground	Rarely	0.125
Common rosefinch	*Carpodacus erythrinus*	Rosenfink	22	Low	Partly ground	Rarely	2.5
Eurasian bullfinch	*Pyrrhula pyrrhula*	Dompap	32	High	Rarely ground	Rarely	0.125
Hawfinch	*Coccothraustes coccothraustes*	Kjernebiter	55	High	Rarely ground	Sometimes	0.25
Yellowhammer	*Emberiza citrinella*	Gulspurv	31	Ground	Mostly ground	Rarely	10
Ortolan bunting	*Emberiza hortulana*	Hortulan	23	Ground	Mostly ground	Rarely	10
Reed bunting	*Emberiza schoeniclus*	Sivspurv	19	Ground	Mostly ground	Rarely	10