VKM Vitenskapskomiteen for mat og miljø Norwegian Scientific Committee for Food and Environment

VKM Report 2024: 4

Risks posed by managed honey bees (*Apis mellifera*) to wild pollinators in Norway

Anders Nielsen, Bjørn Arild Hatteland, Jo S. Hermansen, Lawrence Kirkendall, Claus Rasmussen, Kristin O. Seljetun, Markus Sydenham, Henning Sørum, Paul Ragnar Berg, Anders Bryn, Kjetil Hindar, Kyrre Kausrud, Tor Atle Mo, Erlend B. Nilsen, Brett K. Sandercock, Eva Thorstad, Gaute Velle

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

The Norwegian Environment Agency asked VKM to review the effects of bee keeping on wild pollinators and assess risks and mitigation measures in a Norwegian context. VKM concludes that managed honey bees can potentially (i) compete with wild pollinators, (ii) spread pathogens and parasites to wild pollinators, and (ii) alter plant communities and predator populations in ways that are detrimental to wild pollinators. VKM concludes medium risk for competition negatively affecting wild pollinators that depend on a limited set of floral resources and for bumble bees in homogeneous landscapes with limited amounts of floral resources. For all other wild pollinators, VKM concludes that the risk from competition is low. VKM concludes low risk for negative impacts of pathogen and parasite spillover as well as for detrimental plant community and predator population changes. Identified mitigation measures include managing and mapping floral resources, maintaining bee colony health, and limiting hive numbers near sensitive areas. Further research is needed on floral preferences, competition effects, and pathogen and parasite transmission to better protect wild pollinators.

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Cover photo: Honey bee (*Apis mellifera*) and mining bee (*Andrena* sp.) foraging on the same inflorescence (cow parsley, *Anthriscus sylvestris*). © Bjørn Arild Hatteland.

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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 two VKM members, two VKM staff and four external experts. Two referees commented on and reviewed the draft opinion. The Committee, by the Panel on Biodiversity with supplementation, 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 with supplementation from the VKM Panel on Animal Health and Welfare.

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Competence of VKM experts

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

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Summary

Background
Pollinators are under threat from a variety of environmental drivers, including habitat loss and fragmentation, pesticides, climate change, and invasive species. Despite being domesticated animals, honey bees (*Apis mellifera*) share many traits with invasive species and several studies have suggested that beekeeping might pose a threat to wild bees and other pollinators.

In Norway, the history of beekeeping dates to at least the 18th century, yet little is known about the consequences of this agricultural practice on biodiversity, especially on wild pollinators. The Norwegian Environment Agency therefore asked VKM to provide a brief summary of the available literature on the impact of honey bee keeping on wild pollinating insects and assess whether keeping of honey bees might pose a risk to wild pollinators in Norway. VKM was also asked to specifically assess the impact of stocking rates and placement of honey bee hives in relation to important wild pollinator habitats and vulnerable populations of wild pollinators (e.g. threatened species). Finally, VKM was asked to identify and assess possible risk-reducing measures related to any risk identified.

Methods
To provide a brief review of the literature on how keeping of honey bees affect wild pollinators, VKM conducted a rapid review, using the "updates of systematic reviews" approach. This approach aimed to update and supplement the two existing systematic reviews on the topic. Following established search protocols, the literature review thus focused on the effects of managed honey bees (*Apis mellifera*) on wild pollinators, specifically addressing three key areas: (i) competition for floral and nesting resources, (ii) transmission of pathogens and parasites, and (iii) indirect effects via changes in plant communities.

Based on the hazards identified in the literature review and one additional hazard identified by experts in the project group, VKM conducted a risk assessment that included hazard identification, hazard characterization, likelihood of impact, and risk characterization for each of the hazards identified, focusing on the Norwegian context. Additionally, for each identified hazard, VKM estimated the confidence levels for each step in the risk assessment.

Finally, VKM identified potential risk mitigating measures and assessed their effectiveness. This was done by conducting a literature search to identify potential risk reducing measures and assessing the identified mitigating measures their effectiveness, certainty of effectiveness, and potential harms using the approach developed by Conservation Evidence (see www.conservationevidence.com).

Results/Conclusions
Status of knowledge
The literature review performed by VKM identified 45 recent studies that were not included in the two previous systematic reviews on the topic. The new studies did not provide results that altered the conclusions of the previous reviews. A brief summary of the review is presented below.

Competition for floral resources. Managed honey bees can compete with wild pollinators for shared floral resources and this competition can have clear, measurable, negative effects on wild pollinators.

Spillover of pathogens and parasites. Managed honey bees can potentially spread bacterial, viral, and fungal pathogens to wild pollinators. The extent to which these pathogens cause disease in wild pollinators is, however, unknown for most wild pollinators. Several parasitic mites can infest hives of managed honey bees, but none of these have been shown to infest wild pollinators found in Norway. One common honey bee pest, the small hive beetle (*Aethina tumida*), has been found to also infect nests of wild bees. This species is not currently found in Norway.

Indirect effects through alterations of plant communities. Managed honey bees can facilitate the spread of invasive plant species, potentially altering plant communities and thereby negatively affecting the preferred floral resources for wild pollinators. VKM did, however, not identify any study directly investigating the effect on wild pollinators due to altered plant communities caused by managed honey bees.

Risk assessment

Based on the hazards identified in the literature review and one additional hazard identified by the project group (altered predation pressures), VKM assessed the risk posed by managed honey bees to wild pollinators in Norway. A brief summary of the main conclusions of the risk assessment is presented below.

Competition for floral resources. The risk of exploitative competition from managed honey bees having negative impact on oligolectic bees (species that only forage on a limited number of plant species) with high dietary overlap with honey bees and bumble bees in homogeneous landscapes and/or landscapes with low amounts of floral resources is assessed to be medium. For all other wild pollinators, the risk from exploitative competition is assessed to be low. For interference competition, the risk is assessed to be low for all wild pollinators in Norway.

Spillover of pathogens and parasites. The risk of managed honey bees negatively affecting wild pollinators through spillover of pathogens and parasites is assessed to be low. The low risk is partly due to the high hygienic standards of beekeeping in Norway, with continuous monitoring and strict measures for eradication that are implemented when disease outbreaks are detected.

Indirect effects through alterations of plant communities and predator populations. The risk of managed honey bees, through selective pollination of certain plants, affecting plant community composition in a way that negatively affect floral resource availability for wild pollinators is assessed to be low. The risk of managed honey bee predators negatively affecting wild pollinators is also assesses as low, as the only potential predator in Norway is the European hornet (*Vespa crabro*) and it currently occurs in relatively low numbers and only in certain parts of the country.

Risk reducing measures
Based on the results from the risk assessment, VKM identified the following mitigation measures that might reduce the risk of negative effects of managed honey bees on wild pollinators:

Management of food resources. The potential for competition for floral resources may be reduced by either reducing the number of managed honey bees or increasing the amount of floral resources in an area. There is, however, limited scientific evidence quantifying the effects of these measures. To increase the amount of floral resources, both establishing flower strips and promoting native flora in existing habitats have been suggested. Mapping of floral resources can be used to estimate the carrying capacity of an area, for both managed honey bees and wild pollinators, and can thus be used to guide the placement of honey bee hives in the landscape. Mapping of floral resources on larger scales is difficult, and for most wild pollinators their floral preferences and resource needs are unknown. Hence, for such an approach to be valuable, further research is needed. Putting a limit on the number of hives allowed within an area or establishing buffer zones without managed honey bees in a radius around vulnerable pollinator populations can protect wild pollinators and may be a useful strategy to guard populations of sensitive species.

Management of colony health. Maintaining good health of managed honey bees will reduce the potential for pathogen and parasite spillover to wild pollinators. VKM assessed the risk from spillover of pathogens and parasites from managed honey bees to wild pollinators to be low in Norway, for the time being. Currently, the health status of Norwegian managed honey bees is good, due to high competence among the beekeepers and effective surveillance coordinated by the Norwegian Food Safety Authority. Local disease outbreaks or a general reduction in the health of managed honey bees could potentially increase the risk of spillover to wild pollinators and all means of keeping managed honey bees healthy will mitigate this potential risk.

Needs of wild pollinators. Increased knowledge on floral resource availability and floral needs and preferences of wild pollinators can be used to guide the number and geographic placing of honey bee hives within a landscape, to minimize the potential for floral resource competition. Better knowledge on dietary overlap between managed honey bees and wild pollinators is also needed for effective mitigation of potential negative effects.

Uncertainties and data gaps
There is a lack of knowledge on the floral preferences of many pollinators in Norway. Little is also known regarding competition between managed honey bees and other pollinators than wild bees, such as hover flies, moths, and beetles. Only a few studies have investigated the impact from managed honey bees on the fitness of wild pollinators, such as potential negative effects on growth, reproductive output, and survival due to competition over shared food resources or due to pathogens. Furthermore, there is also a lack of experimental studies manipulating the number and strength of beehives. There are also few studies investigating spillover and consequently negative effects of pathogens and parasites from managed honey bees to wild pollinators. Furthermore, uncertainties exist regarding the effectiveness of risk-reducing measures that involve maintaining a minimum distance from beehives to

minimize risk. Studies are needed to further explore which distances could be recommended for different stocking densities and in different types of landscapes.

Key words: *Apis mellifera*, biodiversity, competition, disease, honey bees, Norwegian Environment Agency, Norwegian Scientific Committee for Food and Environment, parasites, pathogens, pollination, pollinators, risk assessment, spillover, VKM

Sammendrag på norsk

Bakgrunn
Pollinatorer er truet av en rekke miljøfaktorer, inkludert tap og fragmentering av habitater, plantevernmidler, klimaendringer og invaderende arter. Til tross for at honningbier (*Apis mellifera*) er husdyr, deler de mange trekk med invaderende arter, og flere studier har antydet at birøkt kan utgjøre en trussel for ville bier og andre pollinatorer.

I Norge har birøkt eksistert i alle fall siden 1700-tallet, men lite er kjent om konsekvensene av denne landbrukspraksisen for biologisk mangfold, spesielt for ville pollinatorer. Miljødirektoratet ba derfor VKM om å oppsummere tilgjengelig litteratur om virkningen av birøkt på ville pollinerende insekter og vurdere om birøkt kan utgjøre en risiko for ville pollinatorer i Norge. VKM ble også spesifikt bedt om å vurdere virkningen av antall bikuber og plassering av bikuber i forhold til viktige habitater for ville pollinatorer og sårbare populasjoner av disse (f.eks. truede arter). Til slutt ble VKM bedt om å identifisere og vurdere mulige risikoreduserende tiltak knyttet til eventuelle identifiserte risikoer.

Metoder
VKM oppsummerte den tilgjengelige litteraturen om hvordan birøkt påvirker ville pollinatorer ved å oppdatere og supplere de to eksisterende systematiske gjennomgangene av temaet. I henhold til etablerte søkeprotokoller, fokuserte litteraturgjennomgangen derfor på effektene av birøkt på ville pollinatorer, med særlig vekt på tre nøkkelområder: (i) konkurranse om blomster- og bolressurser, (ii) overføring av patogener og parasitter, og (iii) indirekte effekter via endringer i plantesamfunn.

Basert på farene identifisert i litteraturgjennomgangen og en ekstra fare identifisert av ekspertene i prosjektgruppen (endret predasjonstrykk), gjennomførte VKM en risikovurdering i en norsk kontekst.

Til slutt identifiserte VKM mulige risikoreduserende tiltak og vurderte effekten av disse. Dette ble gjort ved å gjennomføre et litteratursøk for å identifisere mulige risikoreduserende tiltak og vurdere effekten av de identifiserte tiltakene ved bruk av tilnærmingen utviklet av Conservation Evidence (se www.conservationevidence.com).

Resultater/Konklusjoner
Kunnskapsstatus
Litteraturgjennomgangen til VKM identifiserte 45 nyere studier som ikke var inkludert i de to tidligere systematiske gjennomgangene av temaet. De nye studiene ga ikke resultater som endret konklusjonene fra de tidligere litteraturgjennomgangene. En kort oppsummering av litteraturgjennomgangen er presentert nedenfor.

Konkurranse om blomsterressurser. Honningbier kan konkurrere med ville pollinatorer om delte blomsterressurser, og denne konkurransen kan ha målbare, negative effekter på ville pollinatorer.

Spredning av patogener og parasitter. Honningbier kan spre bakterier, virus og sopp til ville pollinatorer. I hvilken grad disse patogenene forårsaker sykdom hos ville pollinatorer er imidlertid ukjent for de fleste ville pollinatorer. Flere parasittiske midd kan infisere bikuber av honningbier, men ingen av disse har blitt vist å infisere ville pollinatorer funnet i Norge. Et vanlig skadedyr på honningbier, liten kubebille (*Aethina tumida*), kan infisere bol av ville bier. Denne arten er ikke funnet i Norge.

Indirekte effekter gjennom endringer av plantesamfunn. Honningbier kan påvirke spredningen av invaderende plantearter, noe som potensielt kan endre plantesamfunn og dermed negativt påvirke de foretrukne blomsterressursene for ville pollinatorer. VKM identifiserte imidlertid ingen studier som direkte undersøkte effekten på ville pollinatorer av endrede plantesamfunn forårsaket av honningbier.

Risikovurdering

Basert på farene identifisert i litteraturgjennomgangen og en ekstra fare identifisert av prosjektgruppen (endret predasjonstrykk), vurderte VKM risikoen honningbier utgjør for ville pollinatorer i Norge. En kort oppsummering av hovedkonklusjonene fra risikovurderingen er presentert nedenfor.

Konkurranse om blomsterressurser. VKM vurderer at hold av honningbier medfører medium risiko for enkelte biearter som er avhengige av én eller få plantearter for å overleve, som rødknappsandbie og humler i ensartede landskaper med begrensede blomsterressurser. Dette skyldes mulig konkurranse om disse ressursene. For alle andre ville pollinerende insekter i Norge, vurderes risikoen fra konkurranse om blomsterressurser som lav.

Spredning av patogener og parasitter. Risikoen for at honningbier påvirker ville pollinatorer negativt gjennom spredning av patogener og parasitter vurderes som lav. Den lave risikoen skyldes delvis de høye hygienestandardene i norsk birøkt, med kontinuerlig overvåking og strenge tiltak for utryddelse som iverksettes dersom sykdomsutbrudd oppdages.

Indirekte effekter gjennom endringer i plantesamfunn og rovdyrpopulasjoner. VKM vurderer at risikoen for at honningbier påvirker sammensetningen av plantesamfunn på en slik måte at tilgjengeligheten av blomsterressurser for ville pollinatorer reduseres, er lav. VKM vurderer også at risikoen for at predatorer av honningbier påvirker ville pollinatorer negativt er lav, da geithams (*Vespa crabro*) er den eneste relevante predatoren, og den forekommer i lave antall og innenfor begrensede områder.

Risikoreduserende tiltak

Basert på resultatene fra risikovurderingen identifiserte VKM følgende risikoreduserende tiltak for negative effekter av honningbier på ville pollinatorer.

Forvaltning av blomsterressurser. Å redusere antallet honningbier eller øke mengden blomsterressurser i et område, kan minske konkurransen om blomsterressurser. Etablering av blomsterstriper og skjøtsel av stedegen flora er mulige tiltak. Kartlegging av blomsterressurser kan brukes til å anslå bæreevnen i et område og veilede plasseringen av bikuber. For de fleste ville pollinerende insekter i Norge, er blomsterpreferanser og ressursbehov ukjente, og videre forskning er derfor nødvendig for at slike tiltak skal bli effektive. Etablering av buffersoner rundt sårbare populasjoner av ville pollinator vil kunne beskytte disse.

Fremme god helse hos honningbier. God helse blant honningbier reduserer risikoen for spredning av sykdommer og parasitter til ville pollinatorer. Risikoen for spredning av sykdommer fra honningbier til ville pollinatorer vurderes som lav i Norge, som følge av godt hygienearbeid blant norske birøktere, og effektiv overvåking fra Mattilsynet. Lokale sykdomsutbrudd eller generell reduksjon i helsen til honningbier kan øke risikoen for negative konsekvenser for ville pollinatorer, mens tiltak for å opprettholde god helse blant honningbier vil redusere denne risikoen.

Økt kunnskap om blomsterressurser og behovene til ville pollinatorer. Økt kunnskap om tilgjengeligheten av blomsterressurser og fødebehovene til ville pollinatorer vil kunne veilede plassering av bikuber og slik redusere potensialet for konkurranse mellom honningbier og ville pollinerende insekter. Bedre forståelse av graden av fødeoverlapp mellom honningbier og ulike grupper av ville pollinatorer er også viktig for å kunne tilpasse forvaltningstiltak på en best mulig måte.

Usikkerheter og kunnskapshull
Det mangler kunnskap om blomsterpreferanser hos mange ville pollinatorer i Norge. Lite er også kjent om konkurransen mellom honningbier og andre pollinatorgrupper villbier, som blomsterfluer, møll og biller. Kun få studier har undersøkt effekten av honningbier på fitnessen til ville pollinatorer, som mulige negative effekter på vekst, reproduksjonsutbytte og overlevelse som følge av konkurranse om delte matressurser eller overføring av patogener. Videre er det også mangel på eksperimentelle studier som manipulerer antall og styrke på bifolk. Det er også få studier som undersøker spredning og følgelig negative effekter av patogener og parasitter fra honningbier til ville pollinatorer. Videre er det usikkerheter knyttet til effektiviteten av risikoreduserende tiltak som involverer opprettelsen av buffersoner med minimumsavstand fra bikuber til sårbare populasjoner av ville pollinatorer. Studier er nødvendig for å utforske hvilke avstander som kan anbefales for ulike bestandsmengder og i forskjellige typer landskap.

Abbreviations and glossary

Frequently used acronyms

AFB	American foulbrood (see Table 1.3-1 and section 4.2.2.1).
EFB	European foulbrood (see Table 1.3-1 and section 4.2.2.1).
BQCV	Black queen cell virus (see Table 1.3-1 and section 4.2.2.1).
DWV	Deformed wing virus (see Table 1.3-1 and section 4.2.2.1).
SBV	Sacbrood virus (see Table 1.3-1 and section 4.2.2.1).
WOAH	World Organisation for Animal Health

Glossary

Agent	A macro parasite or pathogen that might cause harm or disease to its host.
Clinical disease	A disease with recognizable signs and symptoms.
Entomophilous crops	Crops depending on insect pollination for optimal yields.
Exploitative competition	When individuals interact indirectly as they compete for a common resource. Here it refers to situations where honey bees and wild pollinators visit flowers of the same plant species and honey bees are able to monopolize the floral resources at the expense of wild pollinator species.
Honey bee viruses	Viruses discovered in honey bees, but which may not be restricted to or specialized to honey bees. Many are found in native or managed honey bee colonies from around the world. Also phrased "honey bee associated viruses."
Infection	Refers to the state of being invaded by unicellular parasites (pathogens, see below).
Infestation	Refers to the state of being invaded by a parasite (multicellular).

Interference competition	When one organism physically restricts another organism's access to resources. Here it refers to situations where honey bees physically exclude wild pollinators from visiting flowers of certain plant species.
Load	In the context of pathogenicity (pathogen load, viral load, microbial load), load refers to the concentration of a microbe within a host. Severity of a disease is correlated with the load: when few microbial copies are present the microbe can be passed on but does not produce a disease, but at higher loads disease symptoms are manifested in the host.
Oligolectic bees	Bees with a specialized diet that forage on a limited diversity of flowering plants.
Parasite	The term parasite is in this report used for macro-organisms (multicellular) living on or in host organisms or causing damage to hives.
Pathogen, pathogenicity	A pathogen is a unicellular parasite that can cause disease, either regularly or opportunistically. Pathogenicity (the state of being a pathogen) is an emergent property, determined by an interaction of pathogen characteristics with those of the host and its environment. See also *virulence*.
PCR	Polymerase Chain Reaction. A commonly used molecular biology technique that makes possible searching for species- or genus-specific sequences of DNA or RNA.
Pollinator network	A pollinator network consists of all plants and all pollinators in an area, and the interactions occurring among them. In pollination ecology, networks of interactions between plants and pollinators can be quantified and then analyzed mathematically, and the structures found in the networks can then be quantified. Several structural properties of pollinator networks relate to ecosystem stability and robustness to perturbations. Also referred to as plant-pollinator network.
Prevalence	In microbiology and parasitology: the estimated proportion of individual hosts that are infected by a particular agent in a population or geographic unit.
Replicative (referring to viruses)	Capable of replicating and hence increasing in a host. If a honey bee virus is not replicative in a host then that host will not become sick; however, live viruses are still present and can be transmitted from one host to another, such as from honey bees to wild pollinators (see spillover) or from wild bees previously

	infected back to uninfected honey bees (see spillback).
Solitary bees, social bees	Solitary bees includes a single egg-laying female while social bees form large colonies.
Spillback	Transmission of parasites (pathogens or macro-parasites) from wild species, here wild pollinators, to domesticated species, here honey bees.
Spillover	Transmission of parasites (pathogens or macro-parasites) from one host species, here honey bees, to other species, here wild pollinators.
Stingless bees	Bee species in the tribe Meliponini, from the same subfamily (Apinae) as honey bees and bumble bees. When threatened, some stingless bees bite as they do not possess a stinger.
Vector (of a disease)	An organism that can transfer a disease-causing agent from one host to another.
Viral haplotype	In the context of honey bee viruses, this refers to the sequence of the single strand of RNA in a given virus strain (the genotype of the virus). Virus strains differ in their RNA sequences and thus have different viral haplotypes.
Virulence	Virulence refers to the degree to which a pathogen harms a host. A highly virulent pathogen is one that is extremely damaging, even deadly, while having low virulence means that a pathogen causes little or no obvious damage to its host. The degree of virulence exhibited by a pathogen can vary among or within pathogen species or strains, in that virulence is an emergent property, determined by an interaction of pathogen characteristics with those of the host and its environment. See also *pathogen*.

Background as provided by the Norwegian Environment Agency

In the National Pollinator Strategy, it is pointed out that beekeeping can pose a risk to wild pollinators. Therefore, the following measure is included in the action plan for wild pollinating insects:

The Norwegian Scientific Committee for Food and Environment (VKM) is commissioned to provide knowledge status and assessment of risk of negative impacts on species of wild bees and other pollinators as a result of various influences from honey production with domestic bees.

The knowledge about pollinators has increased significantly in recent years, and at the same time, the interest in beekeeping has grown. International studies have also been conducted on the relationship between honey bees and wild bees (see, e.g., Valido et al., 2019; Nanetti et al., 2021; Wojcik, 2018). The identified risk associated with keeping honey bees primarily concerns increased competition for resources, and the transmission of pathogens and parasites.

The management authorities need as good documentation as possible on how serious the risk associated with honey bees is in Norway, and more knowledge as a basis for assessments on whether special geographical or local considerations should and can be taken into account in beekeeping. This knowledge will be important in various stakeholders' assessments of where and how many beehives can be placed, balancing this against the consideration of areas important for pollinating insects.

Terms of reference as provided by the Norwegian Environment Agency

The western honey bee has been naturally occurring in Europe north to Southern Sweden and south to South Africa, but according to the Norwegian Biodiversity Information Centre, it is uncertain whether there were natural occurrences in Norway before we began to domesticate the species in the 18th century. All honey bees in Norway now come from domesticated stocks (Ødegaard, 2022). The western honey bee is one of several bees that are eusocial and form colonies consisting of a queen, female workers, and male drones. A beehive contains 50 – 60,000 individuals. In Norway, about 1,300 tons of honey are produced, and there are approximately 1,000 beekeepers registered. In addition to income from the sale of honey, some beekeepers earn revenue from the bees' pollination in horticulture.

Given the extent of beekeeping in Norway, the keeping of honey bees can represent a risk to native biodiversity. This can occur through increased competition, displacement, transmission of pathogens and parasites to wild pollinators. In Norway, 207 species of wild bees are registered in addition to the western honey bee. Moreover, wild pollinating insects represent a group of several thousand species that all use floral resources to varying degrees as a food source.

The Norwegian Environment Agency asks the Norwegian Scientific Committee for Food and Environment to do the following:

1) Conduct a brief summary of available literature on the impact of honey bee keeping on wild pollinating insects

2) Provide an assessment of whether the keeping of honey bees in Norway has, or may have, a negative impact on the population development of wild pollinators. Including:

    - the significance of the number of beehives and their distance to resources used by wild pollinators

    - the importance of hive placement in relation to vulnerable populations of wild pollinators (for example, close to threatened species)

3) Identify and assess possible risk-reducing measures to:

    - help prevent or reduce the risks to wild pollinators associated with beekeeping

Assessment

A guide to the reader

The current opinion provides an overview of the potential impacts managed honey bees may have on wild pollinators and provides a risk assessment within the context of Norway. Additionally, potential risk reducing measures specific to the Norwegian context are identified and evaluated.

In **chapter 1**, we provide background information categorized into six main sections. In section 1.1, we present the biology and distribution of honey bees, including foraging ecology and their role as prey for other species. In section 1.2, we present honey beekeeping in Norway, covering historical and recent developments, subspecies utilization, importation of foreign honey, wax, and bees, along with relevant regulations. In section 1.3, we address honey bee pathogens and parasites relevant to Norway. In section 1.4, we discuss wild pollinators in Norway, including information on relevant habitat types. In section 1.5, we introduce the potential adverse effects of honey beekeeping on wild pollinating insects in Norway and section in 1.6 we present the role of local environmental variation in mediating these effects. In Section 1.7, we introduce our approach to the literature review and risk assessment, conducted in chapters 3 and 4, respectively.

In **chapter 2,** we present the materials and methods used for this opinion. In section 2.1, we detail our literature search methodology, utilizing the "updates of systematic reviews" strategy to complement and update existing systematic reviews by Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022). In section 2.2, we describe our semi-quantitative risk assessment approach, and in section 2.3 we describe our approach for identifying and assessing relevant risk reduction measures.

In **chapter 3**, we present our review of the recent literature, focusing on the potential adverse effects of managed honey bees on wild pollinators. Effects addressed include competition for floral and nesting resources, the transmission of pathogens and parasites from managed honey bees to wild pollinators, and indirect effects via changes in plant communities and predator populations.

In **chapter 4**, we present our risk assessment within a Norwegian context, subdivided into hazard identification, hazard characterization, likelihood of impact, and risk characterization. The hazard identification builds upon the hazards identified in the literature review presented in chapter 3, along with other hazards identified by the project group.

In **chapter 5**, we detail the identification and assessment of relevant risk-reducing measures. This set of measures is based on the hazards identified in chapter 4 and a separate literature search described in Section 2.3.

In **chapter 6,** we present the conclusions and answers to the terms of reference.

In **chapter 7,** we detail the data gaps and uncertainties associated with our findings.

In the **appendices**, we provide additional information. Appendix I provides information from Norges Birøkterlag (hearing expert) on the status of honey beekeeping in Norway, Appendix II provides documentation of literature search, Appendix III provides a spreadsheet with the scoring of studies included in our review of the recent literature after full text-screening, Appendix IV provides a table summarising the conclusions of the risk assessment, and Appendix 5 provides a table listing the scientific, English and Norwegian names of all organisms mentioned in the opinion.

1 Introduction

There is growing concern over the global decline in species richness, population sizes, and range sizes of both wild and managed insect pollinators (Potts et al., 2010; Powney et al., 2019; Deutsch et al., 2023; Ulyshen & Horn, 2023). The consequence of these changes are declines in the quantity and quality of pollination services in both wild plant communities and entomophilous crops (Potts et al., 2010; Burkle et al., 2013; IPBES, 2017). Authors of several studies have suggested that negative effects of managed honey bees might be a contributing factor to the declines in wild pollinators (Mallinger et al., 2017; Iwasaki & Hogendoorn, 2022).

1.1 Honey bee distribution and biology

Honey bees are social insects that live in colonies consisting of a queen, female workers, and male drones. While foraging from flower to flower for pollen and nectar, they disperse pollen, facilitating pollination and yields of entomophilous plants (Rollin & Garibaldi, 2019) and supply honey for apiculture (Crane, 1999). All honey bees in Norway are managed, but they can occasionally swarm and temporarily establish colonies in the wild.

1.1.1 Global distribution and geographical variation

The western honey bee (*Apis mellifera*, hereafter honey bee(s) unless otherwise specified) includes multiple subspecies naturally distributed across Europe, the Mediterranean, tropical Africa and the near East (Ruttner, 1988). Humans have introduced this species for honey production and crop pollination to all continents except Antarctica (Meixner et al., 2013). Honey bees show considerable geographical variation, resulting from local adaptation to regionally varying factors of climate and vegetation. This variation has led to the recognition of more than 24 subspecies, 12 of which are found in Europe (Meixner et al., 2013; Tihelka et al., 2020).

1.1.2 Post-glacial range expansion across Europe, Scandinavia, and Norway

During the last glaciation, honey bees were absent in Europe north of the Alps (Ruttner et al., 1990). Approximately 8,000 years ago during the first post-glacial warm period, swarms of the subspecies European dark bee (*Apis mellifera mellifera*) spread east across Europe from the Pyrenees to the Ural Mountains and farther north than any other lineage (Ruttner et al., 1990). The original range of the European dark bee covered the British Isles north to Scotland and Ireland, Central Europe north of the Alps, northern Poland, and east to the Ural Mountains (Ruttner, 1988; Ruttner et al., 1990).

In Scandinavia, honey bees seem to have been restricted north to southern Sweden, narrowly tracing the northern limits of cold-sensitive trees, such as lindens (*Tilia)* and hazels (*Corylus)*. Although the current natural range limit of hazel is approximately 62°N, pollen records from hazel found in peat deposits dating back to the Bronze Age indicate that honey bees might have existed as far north as 64°N during the relatively warm period following the last Ice Age (Crane, 1999).

Historical northern limits in Sweden are available from an inventory of managed hives by the Royal Command throughout Sweden in 1751. At that time, no hives were recorded north of 60°N, which includes the area around the Oslofjord. The historic distribution again suggests the potential for natural presence of honey bees in southeastern Norway, from where hives most likely were sourced for early apiculture and honey harvest (Crane, 1999).

Ruttner (1988) suggested that it is not the prolonged winter that is the natural limiting factor for honey bees in the north, but rather the lack of suitable protected nesting sites in hollow trees. In the wild, there is no evidence for permanent colonies to have existed north of the Oslo region, at about 60°N (Hansson, 1989, personal communication in Crane, 1999) but honey bees are today kept in managed hives up to 70°N latitude in Norway.

1.1.3 Floral resources used by honey bees in Norway

Honey bees tend to focus their foraging activities on a few, mass-flowering species to optimize their foraging efficiency at the colony level (Cohen et al., 2021). This foraging behaviour coupled with high local abundance often makes honey bees highly effective crop pollinators (Rader et al., 2009; Cohen et al., 2021). The effectiveness of honey bees as pollinators lies in the high frequency of visits rather than in how effectively individual bees pollinate single flowers (Page et al., 2021). In Norway, the most important plants used by managed honey bees vary among districts (Bratlie, 1976). In Eastern Norway and the fjord districts of Western Norway, the flowers of hazel (*Corylus*), willow (*Salix*), alder (*Alnus*), and maple (*Acer*) trees are important pollen sources in April (Kirkevold & Gjessing, 2003). In May, dandelions (*Taraxacum*) and fruit trees are important for colony development. In June, important sources of pollen and nectar are bilberry (*Vaccinium myrtillus*), raspberry (*Rubus ideaus*), clover (*Trifolium*), and honeydew from tree leaves. In July and August, various heathers are important, particularly in areas with shallow or sandy soils and in mountain terrain and on the coast of Southern Norway. On the southwest coast of Norway, bell heather (*Erica cinerea*) can be locally important. In some areas on the coast, local district communities have supported regular burning and grazing of the coastal heaths to boost heather growth for fodder for grazing livestock, in competition with other plants and trees. Honey beekeeping in these areas has been an integral part of the traditional use of these landscapes for centuries around the North Sea. This management practice coincides with the European dark bee having a later phenology which matches well the abundant and late blooming heathers.

Insect pollinated crops, such as oilseed *Brassica* varieties and fruit trees, are mass flowering, providing floral resources beyond what is found in naturally occurring wild plant communities and are consequently attractive foraging habitats for managed honey bees. Managed honey bees will in addition often forage from wild flowers surrounding the orchards or crop fields and possibly compete with wild pollinators for wild floral resources. The potential for competition depends on the number of managed honey bees and the size of the orchards or fields. However, outside crop mass-flowering periods, food resources used by managed honey bees can overlap with co-occurring wild pollinators (Rasmussen et al., 2021). However, Ro-Poulsen (2023) found limited support for floral resource overlap between managed honey bees and wild bees in plant species rich Danish grasslands. Heathlands, especially coastal heathlands, have been heavily reduced during the past 50 years (Hovstad et al., 2018), which may have increased the of competition between managed honey bees and wild pollinators in the remains of this flower rich habitat type (see Herbertsson et al., 2016). In addition, beekeepers move hives during the season in some regions in Norway. For instance, from early flowering crops like fruit trees in spring to late flowering plants like heather in late summer.

1.1.4 Honey bees' ecological role as prey

Managed honey bees can offer an abundant resource for predators because of their large colony sizes and hence locally high densities (Bromley, 1948). Managed honey bees therefore encounter, and sometimes fall prey to, predators such as birds, crab spiders, robber flies, dragonflies, and the European beewolf (*Philanthus triangulum*) during foraging bouts. Other predators such as the European hornet (*Vespa crabro*) can also prey on honey bees at the apiary (reviewed in Cini et al., 2018). In addition to these native predators, invasive species such as the yellow-legged hornet (*Vespa velutina*) which has recently been introduced to Europe (Monceau et al., 2014; VKM et al., 2022) also prey on managed honey bees.

1.2 Honey beekeeping in Norway

1.2.1 Historical presence and early beekeeping in Norway

Ruttner (1988) found that no honey bees were kept in Norway before the 19th century. However, excavation from Oslo has documented a swarm or hive of honey bees dating from AD 1175-1225, suggesting their early presence and possible relationship to humans during the High Middle Ages (Kenward, 1988). Crane (1999) reported that honey bees were kept in the Oslo area in 1740, with one farmer managing 40 hives for several years. Moreover, she reports that it was not uncommon to observe honey bees being kept near farmhouses in 1774. Thus, although honey bees may not have been continuously present in Norway since the glaciation, they have at least occurred occasionally over the past 800 years in Norway, with attempts to manage them dating back to at least the 1740s and the establishment of the Norwegian Beekeepers' Association (*Norges Birøkterlag*) in 1884.

1.2.2 Honey bee subspecies in Norway

The traditional bee used for honey production in Norway is the European dark bee (*Apis mellifera mellifera*). Since the turn of the twentieth century, there has been an increasing interest from beekeepers for other subspecies or mixed breeds, which to a large extent have replaced the European dark bee in many parts of Norway. However, the latter is still dominant in the districts of Agder and Rogaland and the coastal areas of Western Norway. The motivation for conserving this subspecies is in part due to their foraging in heathlands, which flower from mid-July to September in a period when the European dark bee colonies are strongest (has the highest population size).

During the last century the Carniolan honey bee (*Apis m. carnica*) has become increasingly popular in Norway and the Nordic countries (Nielsdatter et al., 2021).

Especially for honey production in the eastern inland areas of Southern Norway, the Carniolan honey bee became popular because of its rapid colony development in spring, which makes the colony size optimal for honey harvest on raspberry during the long and rich nectar production in June and early July. The Carniolan honey bee also forages on heather under migratory beekeeping in the heathlands in the eastern mountains of southern Norway.

A third honey bee type that has been introduced to Norway is the mixed breed called "buckfast". This honey bee is a result of a cross between several subspecies of *A. mellifera* made in England about a century ago. The buckfast bee is considered less aggressive than the European dark bee and is less stressed when the beekeeper manages the beehives.

1.2.3 Current beekeeping in Norway

A recent report from AgriAnalyse (Bunger, 2020), presents the status of honey beekeeping in Norway and includes future perspectives for Norwegian beekeepers. The report states that honey production is the main product of the beekeeping activity. In Norway, the market for commercial pollination services with honey bees is still under development, mainly in the fruit and berry districts of Vestland county. Several studies have documented the importance of honey bees for Norwegian fruit production. Nielsen at al. (2017) found that >97% of the flower visits in two raspberry fields in southeastern Norway were conducted by managed honey bees. Similarly, Vestheim (2022) found that >80% of visits to apple flowers were conducted by managed honey bees in ten studied orchards in western Norway. It is worth noting that, although managed honey bees sometimes contribute to higher yields, they can reach extreme densities which can have the opposite effect (Saez et al., 2014; Rollin & Garibaldi, 2019). The report by AgriAnalyse (Bunger, 2020) also found that a main driver behind beekeeping was a perception of beekeeping contributing to biodiversity and ecosystem functions. In total, 56% of the beekeepers report this cause as the main reason for their activity, and this motivation was higher among new beekeepers than beekeepers with more experience (Bunger, 2020).

The Norwegian Beekeepers Association (*Norges Birøkterlag*) reports an increasing interest in honey beekeeping in Norway over the last years (Norges Birøkterlag, 2020). After a period of decline in beehives in Norway, the number of beehives has increased steadily since 2013. The increase in hive numbers is not only because beekeepers have increased their stock but also because of an increase in the number of beekeepers as seen in the increase of members in the association that went from 2900 to 4100 during the period 2014 – 2019, particularly in and near urban areas. Since not all beekeepers in Norway are members of the Norwegian Beekeepers Association (80% are members according to *Norges Birøkterlag*), there is no complete overview of numbers of honey bee hives in Norway. The Norwegian Food Safety Authority has an overview, but the overview is incomplete (*Norges Birøkterlag*, Appendix I).

Documentation of the honey production in Agder county (Statsforvalteren i Agder, 2024) shows an increasing interest in honey beekeeping in the last 15 years, but also the effect of the sanitation following a regional outbreak of European foulbrood during the fall of 2010 and in 2011, which reduced the number of active beekeepers and the number of beehives in the region. The drop in numbers of beehives in this region may have camouflaged an increased interest of honey beekeeping in the National statistics during this period. In 2009, there were 91 businesses with honey production in the region. In 2011, a total of 11,000 beehives were screened for occurrence of the *Melissococcus plutonius* (the pathogen causing European foulbrood - EFB) in the outbreak area that covered all of Aust-Agder and a small part of Vest-Agder. In 2012, after the major sanitation of EFB had been performed, the number of businesses with honey production was reduced to 62. In 2021, the number had again increased to 144 businesses registered with 9,422 beehives. Presumably, the number of beekeepers has increased but the number of beehives is lower than 15 years ago, indicating fewer professional beekeepers and more beekeepers with a low number of beehives in Agder county. This situation may reflect the national development of honey beekeeping in Norway over the same period.

1.2.4 Norwegian import of honey, wax, and honey bees

The import of honey to Norway from other countries was low in volume before 2010. "Honningcentralen SA" is the main distributor of Norwegian honey from medium and large volume beekeepers in Norway (see https://honning.no/). The cooperative is owned by the beekeepers following the Nordic producer-owned distribution and wholesale organization model. In a period of reduced production of Norwegian honey, Honningcentralen began distributing honey imported from developing countries and later from the global market. This secured honey to the Norwegian market in addition to supporting an expansion of Honningcentralen making it now possible to handle larger volumes serving the retail market.

The volume of honey sold in the Norwegian market has increased gradually over the last 20 years. During this period, Norwegian high-quality honey has been able to sustain sales volumes despite competition with cheaper imported honey. During the last decade, more whole-sale companies have been established for importing honey for distribution within Norway. The honey market in Norway has changed to become more international, but the volume of honey that is distributed directly from the Norwegian apiaries to the consumers locally has also increased considerably. See www.norbi.no for more information on the Norwegian Beekeeper's Association.

1.2.5 Regulations for beekeeping in Norway

In Norway, several laws and regulations are relevant for beekeeping. These include registering of placing of beehives, animal health and welfare, pathogen and disease regulations, plant disease regulations, regulations related to honey production, and export and import regulations. These are all described in detail on the webpages of the Norwegian Food Safety Authority www.mattilsynet.no.

The Food act (*Matloven*) regulates animal health in Norway and the animal health regulation (*Dyrehelseforskriften*) lists several pathogens and macroparasites that can infect or infest honey bees. The regulation places the agents on different lists depending on the severity of the harm the pathogens or macro parasites might cause to honey bees. The list status for the different agents is found in Table 1.3-1.

The animal breeding act (*Lov om husdyravl*) regulates breeding honey bees (details in: *Forskrift om avlsfremmende tiltak på bier*). There are designated areas for pure breeding of the different honey bee subspecies to avoid mixed breeds that can be more aggressive and often less efficient honey producers. The European dark bee (*Apis mellifera mellifera*) has separate breeding areas in Agder, Rogaland (Flekkefjord, Lund, Sokndal and Sirdal), Vestland (Bømlo, Fitjar and Stord) and Buskerud (Ål and Hol) (Norges Birøkterlag, not dated a). Much of eastern Norway is regulated as breeding areas for Carniolan honey bees (*Apis mellifera carnica*), as are the areas around Saltdal and Bodø in northern Norway. It is not allowed to keep other subspecies or mixed breeds in those districts than what is regulated. To keep pure lines, breeding stations for bees are located in remote areas usually far from human settlements. It is not allowed to keep or move bees other than those used at the breeding stations closer than 20 km from the station.

There are no regulations, or even recommendations, regarding stocking rates or placing of hives, e.g., in relation to nature reserves. However, an informal regulation of hive density, based on bee keepers monitoring of honey yields, has seemed to work well so far, at least among commercial beekeepers. Beekeepers generally move their hives to areas that produce the highest output of honey, consequently to where floral resources are abundant. Honey production results alone might therefore regulate the number of beehives that are kept in different areas. Given the lack of regulations and that there is an increasing number of non-commercial beekeepers, the harvesting may in some areas exceed carrying capacity and potentially cause competition with wild pollinators for floral resources.

Reduced sugar tax for feeding bees after honey harvest has been negotiated by the Norwegian Beekeepers Association. For beekeepers with more than a certain number of hives, typically six, the national tax on imported cane sugar can be deducted from the income tax by an annual application to the government.

1.3 Honey bee pathogens and parasites relevant in a Norwegian context

The possibility that honey bee apiaries can spread parasites and diseases to wild bees or other pollinators is widely acknowledged (Malinger et al., 2017; Nanetti et al., 2021; Cila et al., 2022; Iwasaki & Hogendoorn, 2022; Deutsch et al., 2023).

For this opinion, we have defined pathogens as unicellular microparasites that can cause disease, and parasites as multicellular organisms that negatively affect their host. The selection of pathogens and parasites in Table 1.3-1 is based on hands-on knowledge from monitoring of the situation in Norwegian beekeeping (H. Sørum[1], personal communication, April 3, 2024). Exotic diseases that might arrive in Norway are included as they might be imported from areas where they are emerging in Europe or by container or similar global shipping activity.

Before the introduction of the mite *Varroa destructor* to Oslo in 1990, the pathogens that were seen or considered to cause clinical disease in Norwegian honey bees were *Paenibacillus larvae* (the cause of American foulbrood), *Melissococcus plutonius* (the

[1]Professor Henning Sørum is head of the laboratory at the Norwegian University for Life Sciences responsible for screening for bee pathogenic bacteria, fungi, and parasites in Norway, under assignment from the Norwegian Food Safety Authority. Henning Sørum is also a member of the VKM project group that drafted this opinion.

cause of European foulbrood), *Ascosphera apis* (the cause of chalkbrood) and *Vairimorpha* species (the cause of nosemosis). The disease stonebrood caused by *Aspergillus* species has not been observed in Norway, despite the occurrence of the *Aspergillus* fungi in the environment. After the introduction of *Varroa destructor*, there has been a focus on viral diseases that were expected to increase because of the infestation. So far, there have been limited outbreaks of viral diseases in honey bees after 1990, possibly a result of the necessary control of the infection load of *V. destructor* in colonies. A limited number of studies reveal the many viruses potentially pathogenic to honey bees and possibly to wild pollinators already exist in Norwegian honey bees, even in honey bees without *V. destructor* infestation. There are three viruses that seem to increase in number in bee colonies with *V. destructor* infestation, DWV, SBV and BQCV.

From the extensive list of honey bee pathogens and parasites found world-wide (see Nannetti et al., 2021), we have assessed those deemed to be of current, and future, importance for honey bees in Norway, with a potential for spillover to wild pollinators. The selection includes bacterial, fungal, and viral pathogens as well as parasitic mites and the small hive beetle. For detailed information on the pathogens and parasites listed in Table 1.3-1, see section 4.2.2.

Table 1.3-1. Pathogens and parasites of honey bees in Norway: Current presence, historical records, and potential importation risks.

Common name of disease or parasite	Scientific name of pathogen	Type of organism	Current listing status in Norway*	Currently present	Historically present	Risk of future import
American foulbrood	*Paenibacillus larvae* subsp. *larvae*	Bacterium	List 2, notifiable to WOAH	No	Yes	Yes
European foulbrood	*Melissococcus plutonius*	Bacterium	List 2, notifiable to WOAH	No	Yes	Yes
Chalkbrood, ascosferosis	*Ascosphaera apis*	Ascomycete fungus	Not listed	Yes	Yes	Yes? (Virulent strains)
Stonebrood, aspergillosis	*Aspergillus flavus/fumigatus*	Ascomycete fungus	List 2	No	Yes	Yes? (Virulent strains)
Nosemosis nosematosis,	*Vairimorpha apis* (previously *Nosema apis*)	Fungus (microsporidian)	Not listed	Yes	Yes	Yes? (Other strains?)
Nosemosis nosematosis,	*Vairimorpha ceranae* (previously *Nosema ceranae*)	Fungus (microsporidian)	Not listed	Yes	Yes	Yes? (Other strains?)
Sacbrood (SBV)	Iflaviridae: *Morator aetatulas*	RNA virus	Not listed	Yes (not as disease regularly)	Yes (rare cases secondary to *V. destructor* infestation)	Yes? (More virulent strains)
Deformed wing virus (DWV)	Iflaviridae: *Iflavirus aladeformis*	RNA virus	Not listed	Yes (not as disease regularly)	Yes (rare cases secondary to *V. destructor* infestation)	Yes? (More virulent strains)

Black queen cell virus (BQCV)	Dicistroviridae: *Triatovirus nigereginacellulae*	RNA virus	Not listed	Yes (not as disease regularly)	Yes (rare cases secondary to *V. destructor* infestation)	Yes? (More virulent strains)
Israeli acute paralysis virus (IAPV)	Dicistroviridae: *Aparavirus israelense*	RNA virus	Not listed	Yes, very limited level	Unknown	Yes?
Varroa mite, varroosis	*Varroa destructor*	Parasitic mite	List 3, notifiable to WOAH	Yes	Since 1990	Yes?
Tracheal mite, acarapiosis	*Acarapis woodi*	Parasitic mite	List 3	Yes (asymptomatic)	Since 2002 in Sogn og Fjordane (part of Vestland county)	Yes?
Tropilaelaps mite	*Tropilaelaps mercedesae*	Parasitic mite	List 2, notifiable to WOAH	No	No	No (without larvae in winter, low risk, climate change?)
Small hive beetle	*Aethina tumida*	Omnivore beetle	List 2, notifiable to WOAH	No	No	Yes

*For information on listing of diseases in Norway, see *Forskrift om dyrehelse* (https://lovdata.no/dokument/SF/forskrift/2022-04-06-631/*#&)
National List 1 diseases (formerly A-diseases) are extremely serious, and an outbreak would necessitate extensive control measures.
National List 2 diseases (formerly B-diseases) are serious, and systematic control is required to manage the disease.
National List 3 diseases (formerly C-diseases) are diseases that are important for the Norwegian Food Safety Authority to monitor. These can be relatively common diseases or rarer ones.

1.4 Wild pollinators in Norway

In Norway, plants are pollinated primarily by insects or wind. Those insects not managed and native to Norway are often called wild pollinators to distinguish them from managed pollinators, chiefly honey bees.

Numerous insects, including bees, wasps, moths, butterflies, hoverflies, flies, and beetles, play a crucial role in pollinating crops and wild plants (Ollerton, 2017). Pollinators mostly feed on nectar as a source of carbohydrates and to a varying extent pollen, where pollen is often required for ovary development (Cane, 2016; Cane et al., 2017). For bees, pollen is an essential larval source of proteins and sterols, but also provides lipids and other important nutrients for adults and their larval offspring (Dobson & Peng, 1997).

Wild pollinators vary as to which flowers they are attracted to. Some pollinator species are specialized (oligolectic) on certain genera or families, whereas other pollinators have a more generalist feeding strategy across multiple plant families (polylectic). A recent report suggests that approximately 24% of all insects in Norway are considered pollinators (Sydenham et al., 2023). From a plant's perspective, the efficacy of insect pollination varies greatly. Large and furry bees are often considered effective pollinators because they can deposit substantial amounts of pollen per flower visit (Willmer et al., 2017). Other groups of insects are also important pollinators. Even at northern latitudes in Europe, moths may play a role in pollination, with much of the actual flower visits taking place during nighttime (Anderson et al., 2023). The great variety of insect species, life history traits and floral preferences among wild pollinators contributes to the pollination of a wide range of plant species (Sydenham et al., 2023).

Checklists for all insect species found in Norway are available through the Norwegian Biodiversity Information Centre (www.artsdatabanken.no); they are updated based on new literature reports, such as those for bees and hoverflies (Reverté et al., 2023). Currently, a total of 211 species of bees have been recorded in Norway, of which one species is the European honey bee, 35 species are bumble bees, and the last 175 species are mostly solitary bees (Ødegaard, 2023). Of these, 12 species have not been recorded during the last 50 years and are most likely extinct in Norway, and approximately 28% are red-listed in the categories ranging from Near Threatened (NT) to Regionally Extinct (RE). Moreover, many species have a relatively restricted distribution in Norway, occurring mainly in the southeastern parts of the country, or occur in specific habitats or are dependent on specific host plants. Many pollinator groups, including hoverflies, have been less studied in Norway, and thus status of these species is less well known. In Norway, 357 species of hoverflies have been recorded (Artsdatabanken, not dated), of which 20% are red-listed in the categories from NT to RE.

Lastly, several regions in Norway have been poorly sampled, even for important pollinator groups like solitary bees. Thus, low estimates of regional pollinator diversity from online databases may reflect low sampling effort and not necessarily low species diversity.

For the risk assessment of exploitative competition (see chapter 4), we have divided the wild pollinators in Norway into three groups. These groups contain species that share certain ecological traits and assessing the groups separately allows for considering this. The groups are:

- *Oligolectic bees with high dietary overlap*: These are bees that rely on a limited diversity of floral resources, which are chiefly shared with managed honey bees.

- *Bumble bees*: They share some of the colony traits with managed honey bees, namely being social insects with a colony active throughout the flowering season. Some bumble bees will have a very broad foraging range and others a narrow range (oligolectic). Assessments of bumble bees are provided in the context of both homogenous and heterogenous landscape and/or abundant and scares availability of floral resources. Herbertsson et al. (2016) found that this will have a different effect on the potential for competition even for the same species.

- *Other pollinators* – This includes the remaining bees in addition to butterflies, flies, beetles, and all other pollinators. For many species, little is known about their foraging preferences and diet width under Norwegian conditions and on how they may respond to competition from managed honey bees.

1.4.1 Nature types for pollinators

Wild pollinators rely on habitats that provide nesting or larval substrates and floral resources (Sydenham et al., 2023). For many species, including wild bees (Westrich, 1996), habitat patches that provide nesting substrates are not necessarily the same habitat patches that provide floral resources. Some species of hoverflies have their larvae in water bodies (Bartsch, 2009), butterfly larvae often develop on specific plants (Gaden et al., 2023), and a high proportion of bees have their larvae in existing cavities such as beetle burrows in dead wood or in the ground (Westrich, 1996; Scheuchl & Willner, 2016), which may be found in habitats not associated with a rich flora. This dependency on multiple resources means that pollinators rely on landscapes that provide both nesting substrates and floral resources, both of which can be a limiting factor for populations. Notably, except from forage specialist bees such as the large scabious mining bee (*Andrena hattorfiana*), which exclusively collects pollen from field scabious (*Knautia arvensis*; Larsson & Franzén, 2007), many species of wild bees rely on a diversity of plants occurring within close ranges of their nests, to ensure that the nutritional requirements of their larvae are met (Vaudo et al., 2024). For most pollinators in Norway, there is limited knowledge on their dietary preferences.

Important habitat types in Norway for pollinators include seminatural habitats, including road verges, forest- and field edges, and extensive pastures and other semi-natural grasslands that provide floral resources and often also substrates for species whose larvae live in the ground or on host plants (Kapfer et al., 2022; Sydenham et al., 2023). Old growth or secondary forest, as well as isolated and sun exposed old trees, provide valuable substrates for many hoverflies whose larvae feed of the sap of trees and for many bees and beetles whose larvae may develop in existing cavities or even produce cavities when feeding on the tree (Westrich, 1996; Bartsch, 2009;

Stokland et al., 2012; Scheuchl & Willner, 2016; Sydenham et al., 2023). Nutrient rich ponds can also provide substrates for hoverfly larvae. The traditional cultural landscape includes many of these habitat types in the form of extensively managed grasslands, coppiced trees, alleyways of large deciduous trees, forest patches that were not accessible for logging, stone hedges, and small ponds that were used as water reservoirs. In the modern agricultural landscape, many of these habitat types are rare and often located further apart than typical foraging ranges for pollinators.

Wild pollinators are found in many different habitats and use a wide variety of food resources. Both natural and semi-natural habitats are regarded as important for many wild pollinators, such as wildflower meadows. Specialist species, which have limited ability to adjust their realised foraging niche, may be particularly vulnerable to loss of flower-rich environments, especially if these habitats are highly fragmented and limited in size. Indeed, Rasmussen et al. (2022) compared contemporary samples of the wild bee fauna to century old records from the same region (Lolland, Denmark) and showed that bees with narrow diets have disappeared from the fauna. The coastal heathlands have, for instance, largely been reduced over the last 50 years in Europe, as well as in Norway, and is currently a red-listed nature type in the EU and Norway (Hovstad et al., 2018). Several wild pollinators are especially associated with heathlands or other open habitats along the coast, species such as the heather mining bee (*Andrena fuscipes*), the large carder bee (*Bombus muscorum*), and the heather colletes (*Colletes succinctus*). It is possible that the inability of certain bees to adjust their foraging may also make them more sensitive to competition for floral resources (as suggested by Rasmussen et al., 2022).

1.5 Potential negative effects of honey bees on wild pollinators

Negative effects of managed honey bees on wild pollinators can be direct or indirect. Direct effects include different types of competition for floral resources or nesting sites. In theory, competition for nest sites could occur between honey bees and wild pollinators. However, in Norway, all honey bees are managed, and the number of cavity nesting bees is limited (only some bumble bees). The Norwegian Beekeepers Association estimates that 5-10% of the colonies swarm, but the probability of establishing a nest, surviving the winter, and not being infected with varroa mites (*Varroa destructor*) and associated pathogens, is extremely low (B. Dahle, Norges Birøkterlag, Appendix I). Therefore, honey bees are not found to any relevant extent in the wild in Norway, and competition for nesting sites is not relevant in this context and will not be treated further in this opinion. Indirect effects of managed honey bees on wild pollinators include the transmission of pathogens or parasites, as well as changes in the species composition of plant communities through alterations in floral resource availability, and in altered predation pressures.

The project group have used the Environmental Impact Classification for Alien Taxa (EICAT) framework, developed by the International Union for the Conservation of Nature (IUCN) (IUCN 2020) to categorize impact mechanisms. EICAT is a simple, objective, and transparent unified classification of alien taxa based on the magnitude of their environmental impacts in recipient areas (Blackburn et al., 2014).

The project group has identified three potential EICAT mechanisms though which managed honey bees can negatively influence wild pollinators in Norway. These are:

- Competition for floral resources (aligned with mechanism 1, "Competition", in the EICAT system);
- Transmission of pathogens, including parasites (aligned with mechanism 4, "Transmission of disease to native species" in the EICAT system).
- Indirect effects either via changes in plant communities or via changes in predation pressure on native pollinators, due to the presence of managed honey bees (aligned with mechanism 12, "Indirect impact through interactions with other species", in the EICAT system);

The mechanisms are treated in more detail in section 4.1 "Hazard identification", below.

1.6 The role of local environmental conditions in mediating effects

The potential for managed honey bees to negatively affect populations of wild pollinators, directly or indirectly, depends on local conditions. In Swedish landscapes, bumble bee densities were negatively influenced by the presence of managed honey bees in structurally simple agricultural landscapes, but this effect was not found in landscapes with high amounts of seminatural habitat, and consequently more diverse floral resources (Herbertsson et al., 2016). This suggest that managed honey bees are more likely to affect wild pollinators via exploitative competition when their stocking densities are sufficiently high to make floral resources a limiting factor. In natural settings, bees will be limited by both nest site availability and floral resources (Thomson & Page, 2020), further complicating the issue. Thus, the competition for floral resources is much more generalizable across wild pollinators while competition for nesting resources will be limited to taxa nesting in larger cavities.

For indirect effects, such as honey bee mediated propagation and spread of invasive plants, the impact of managed honey bees will likely be context dependent. Urban areas typically have a higher density and diversity of invasive plants (de Barros Ruas et al., 2022) and the potential for managed honey bees to mediate their further spread is therefore higher. Urban areas can also have a species rich wild pollinator fauna compared to agricultural landscapes (Baldock et al., 2015), although this has never been studied in Norway. Wild pollinators that depend on few native plant species will be more at risk from the spread of invasive plants compared to pollinators that can utilize a diversity of plants and maybe even benefit from invasive plants. One example of such a floral rich invasive plant, with high invasion potential also in Norway, is the warty-cabbage (*Bunias orientalis*) with flowers that are visited by managed honey bees but also a suite of other pollinators. In Norway, specialized bees sensitive to reductions in the availability of flowers include those specialized on field scabious (*Knautia arvensis*) such as the large scabious mining bee (*Andrena hattorfiana*); on composites (Asteraceae), such as the scarce black mining bee (*Andrena nigriceps*) and the hawks-beard mining bee (*A. fulvago*); on bellflowers (Campanulaceae) such as the harebell carpenter bee (*Chelostoma campanularum*); or with strong preferences for legumes

(Fabaceae), such as the short-haired bumblebee (*Bombus subterraneus*), the great yellow bumblebee (*B. distinguendus*), the red-shanked carder bee (*B. ruderarius*) and several solitary bee species. However, if, where, and to what extent, these plant species are at particular risk of competitive exclusion from invasive plants in Norway, is unknown.

Furthermore, the impact of indirect effects of managed honey bees on wild pollinators is likely to change over time. In Europe, a more virulent strain of the deformed wing virus has emerged in honey bees (McMahon et al., 2016), suggesting that current impacts of honey bee associated diseases on wild pollinators may not be indicative of their future effects. The spillover effect of predation pressure can also increase over time, if non-native predators, such as the yellow-legged hornet (*Vespa velutina*) should reach Norway (Barbet-Massin et al., 2013; VKM et al., 2022).

Because of these context dependencies, it is difficult, if not impossible, to generalize across studies if one cannot simultaneously account for the process-specific context dependency they are associated with.

1.7 Assessing potential risks of honey bees to wild pollinators in Norway

Two recent systematic reviews have directly assessed the research relevant to the concerns addressed in this opinion (Mallinger et al., 2017; Iwasaki & Hogendoorn, 2022). We have updated and supplemented these reviews to check if their conclusions are still valid. This opinion is based on our updated versions of the conclusions of these reviews and on extracting further information from their sources, specific to Norwegian conditions. In addition, we have used our knowledge of the scientific literature, including our own work, to conduct risk assessments related to the identified potential hazards in Norway.

2 Methodology and Data

2.1 Literature search and selection

To provide a review of the literature on how keeping of managed honey bees affect wild pollinators, the project group conducted a rapid review, using the "updates of systematic reviews" approach. This approach aimed to update and supplement existing systematic reviews on the topic by Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022). The literature review focused on the effects of honey bees (*Apis mellifera*) on wild pollinators, specifically addressing three key areas: (i) competition for floral and nesting resources, (ii) transmission of pathogens and parasites, and (iii) indirect effects via changes in plant communities.

2.1.1 Search string

Following the two previous systematic reviews (Mallinger et al., 2017; Iwasaki & Hogendoorn, 2022), the literature search was performed in ISI Web of Science Core Collection using a modified version of the search string utilized in the studies by Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022), to allow for alternate forms. The search string used was:

> ("Apis mellifera" OR "honey bee$" OR honeybee$) AND (competition OR disease$ OR pathogen$ OR (pollin* AND (exotic OR invasive)))

The search thus covered all the literature that would have been covered by the original search string:

> ("Apis mellifera" OR "honey bee" OR honeybee) AND (competition OR disease OR pathogen OR (pollin* AND (exotic OR invasive)))

as well as additional literature using plural forms. As the search was designed to update and supplement the existing systematic reviews, the search was limited to literature published after the search performed by Iwasaki & Hogendoorn (2022), i.e. between 1 August 2021, and the present (19 October 2023). The search was performed by the library for the healthcare administration, which provides research support at the Norwegian Institute of Public Health. The search resulted in 941 records (see Appendix II), which were all subject to title and abstract screening.

2.1.2 Title and abstract screening

Title and abstract screening of records was performed by the project group using Rayyan (Ouzzani et al., 2016) and the inclusion/exclusion criteria established in Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022).

We thus evaluated every record returned by our search for whether it broadly addressed one of our three topical areas:

i. competition between honey bees (*Apis mellifera*) and wild pollinators
ii. transmission of pathogens, including pathogenic parasites, from honey bees (*Apis mellifera*) to wild pollinators
iii. effects of honey bees (*Apis mellifera*) on plant communities (natives vs. exotics)

Records that did not broadly fall into the three topical areas and review papers were excluded. Additionally, we excluded records that were not peer-reviewed (e.g. theses, conference proceedings) and records not published in English. This as to follow the protocol used in the two earlier reviews.

To harmonize the title and abstract screening within the project group, we initiated the process with a subset of 100 records. These records underwent independent screening by each project member using Rayyan (Ouzzani et al., 2016) with blinding activated (i.e., scores not visible). Upon completion the blinding was deactivated, and any conflicts were resolved through plenary discussion for better alignment.

The remaining 841 records were split into sets that were evaluated in pairs from the project group with blinding activated and conflicts were resolved by discussion after screening was completed. A total of 82 out of the 941 records (8.7%) were retained for full-text screening and data extraction.

2.1.3 Full-text screening and data extraction

Full text screening was performed using the inclusion and exclusion criteria established in Mallinger et al. (2017, page 5):

> "To be included in our review, studies thus needed to measure some response metric of either wild bees or plants (dependent variables, e.g. foraging behaviour, abundance, reproductive rates) and relate that to a measured or assumed aspect of managed bee "intensity" (independent variable, e.g. presence/absence, before/after introduction, distance from colony, abundance). A study measuring pathogen presence in only managed bees, for example, were not included if it did not also measure a wild bee response, regardless of any implications for wild bees discussed within the paper."

Information from the papers included after full-text screening (45 out of 82, 55%) were extracted following similar methodology to that provided by Iwasaki & Hogendoorn (2022) and expanding on a modified version of the spreadsheet included in their supplementary materials (see Appendix III).

Each article was scored based on whether the authors reported negative, positive, mixed, or no effects from honey bees. To maintain consistency across all three topical areas and with the reviews by Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022), scores were assigned from the viewpoint of native pollinators or native plants.

Scores were categorized as negative (-1), no effect (0), or positive (1). Negative scores indicate that, based on the data, authors concluded harm or potential harm. This occurs, for instance, when authors conclude (potential) negative consequences for the reproductive output of the native pollinator under investigation, relying on observations of resource overlap and shortages. A score of no effect (0) suggests a non-significant impact, while positive effects (1) imply some benefit from the presence of honey bees for the native pollinator studied. In the context of pathogens, harm signifies that pathogen prevalence had demonstrated the potential to increase, or that the pathogen would negatively impact the fitness, abundance, or diversity of the native pollinator under study. No effect in the context of pathogens implies that there was no measurable effect on pathogen prevalence. Notably, no positive outcomes were associated with pathogen studies. Scores were tallied for each category of interest (bee competition, plant interaction, pathogen effects) and discussed collectively.

The results from the literature review were evaluated alongside the previous results provided by Mallinger et al. (2017) and Iwasaki & Hogendoorn (2022).

2.2 Risk assessment

We adopted a semi-quantitative risk assessment approach, as previously utilized by VKM (e.g. VKM et al., 2023). Here, risk is defined as the combination of the potential magnitude of the impact of a hazard and the likelihood that the hazard will occur, as assessed by VKM. We also assess the confidence of our estimates of magnitude of potential impact, likelihood of impact, and overall risk for each of the hazards identified.

The conclusions of the risk assessment are presented in figures, such as that of Figure 2.2-1.

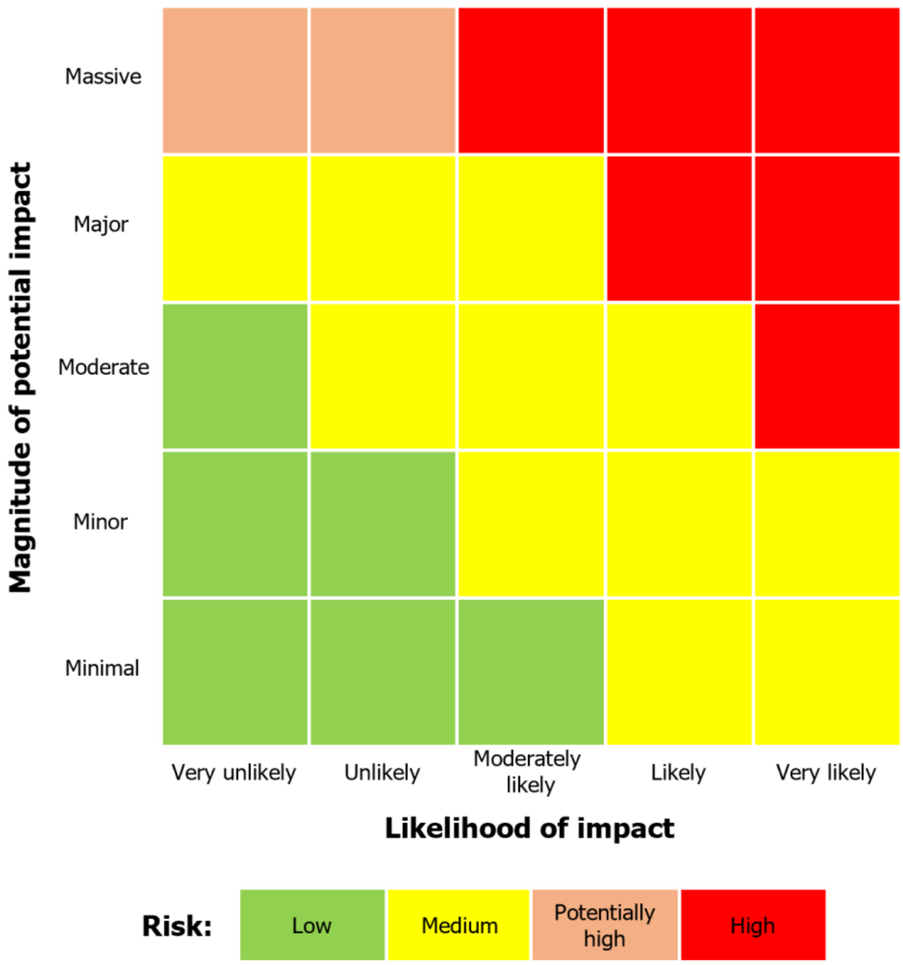


Figure 2.2-1. Risk characterization. The risk characterization (Low, Medium, Potentially high, or High) is based on the likelihood that a hazard will occur and the magnitude of the potential impact of that hazard on wild pollinators in Norway. The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*).

A description of the ratings used in the risk assessment can be found in Tables 2.2-1–2.2-3 below.

Table 2.2-1 Ratings used for the assessment of the magnitude of the impact.

Rating	Descriptors
Minimal	No known impact on wild pollinators
Minor	Potential impact on wild pollinators, but not usually increased mortality
Moderate	Impact may cause moderate reduction in viability and adaptability of wild pollinators
Major	Impact may cause severe reductions in local populations with consequences for wild pollinators and ecosystem functions and services
Massive	Impact may cause severe reductions in wild pollinators (local extinctions), with severe consequences for ecosystem functions and services

Table 2.2-2 Ratings used for the assessment of likelihood of impact.

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

Table 2.2-3 Ratings used for describing the level of confidence.

Rating	Descriptors
Low	There is limited information on the specific subject, in particular from comparable environmental settings. Subjective expert judgements may be used without supporting evidence. Little peer reviewed literature available and there are limited empirical and quantitative data to support the assessment.
Medium	Relevant information on the specific subject is available, but only limited information from comparable environmental settings. Some subjective expert judgements are used. 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 used. Primarily peer reviewed literature is used and there are empirical and quantitative data to support the assessment.

We performed the risk assessment in a Norwegian context based on the hazards identified in the systematic review, supplemented with additional information on the

Norwegian context. Information on Norwegian context included information on wild pollinators in Norway (e.g. species lists, general knowledge on pollinator groups not found in Norway (e.g. stingless bees) and the Norwegian Red List of Threatened Species), information on important pollinator habitats, including red-listed habitat types, and floral resources in Norway, and information on beekeeping in Norway to allow for adequate consideration of context dependence in the risk analysis.

The risk assessment involved four standardized steps: hazard identification, hazard characterization, likelihood of impact, and risk characterization.

- Under "Hazard identification", we described the specific hazard and provided reasons for its consideration in the current assessment. We also presented the known effects of the hazard, supported by examples of documented impacts from other countries.
- Under "Hazard characterization", we described the potential magnitude of the impact of the hazard under Norwegian conditions. The potential magnitude of the impact of specific hazards was subsequently categorized from "Minimal" to "Massive," as detailed in Table 2.2-1.
- Under "Likelihood of impact", we assessed how likely it is that the characterized hazard will occur. Likelihood intervals ranged from "Very unlikely" to "Very likely", as described in Table 2.2-2. The likelihood is based on subjective assessments (also referred to as expert judgement), rather than frequency-based likelihood or specific modelling that estimate the likelihood.
- Finally, under "Risk characterization", we characterized the risk to wild pollinators in Norway posed by the specific hazard. We categorized the risk as either "Low," "Moderate," or "High," based on the magnitude of the potential impact and the overall likelihood of occurrence. This characterization aligns with the matrix presented in Figure 2.2-1.

For "Hazard characterization", "Likelihood of impact" and "Risk characterization" we also rated the confidence level for each estimate as detailed in Table 2.2-3.

2.3 Risk reducing measures

Risk reducing measures relevant for the Norwegian context were identified and assessed based on the outcomes of the risk analysis and a separate literature search.

The search string to identify risk reducing measures was as follows:

> ("Apis mellifera" OR "honey bee$" OR honeybee$) AND (competition OR disease$ OR pathogen$ OR (pollin* AND (exotic OR invasive))) AND (management OR mitigation OR "risk-reducing" OR conservation) NEAR/3 (measure$ OR action$)) OR (guidance$ NEAR/4 (hive$ OR beehive$ OR "wild bee$"))

The search was performed in ISI Web of Science Core Collection (19 October 2023, updated 6 May 2024) and CAB Abstracts (3 November 2023, updated 6 May and 5 June 2024) with no time limitation (see Appendix II). The search was performed by the library for the healthcare administration which provides research support at the Norwegian Institute of Public Health. The search resulted in 61 articles which were all subject to title and abstract-screening using Rayyan (Ouzzani et al., 2016) by a member of the project group.

The effectiveness, certainty, and potential harms of risk reducing measures were assessed following the approach developed by Conservation Evidence (see section 5.4).

3 Synthesis of the available literature on the influence of honey beekeeping on wild pollinating insects

The negative effects of managed bees on wild bees were the focus of a systematic literature review by Mallinger et al. (2017), based on the literature published from 1900 throughout 2016. Their work was updated and extended up to August 2021 by Iwasaki and Hogendoorn (2022). We used the a slightly modified version of their search protocol to find any further publications on these topics, but only included papers where honey bees were the "managed bees" (see section 2.2).

3.1 Results from previous reviews

The systematic review by Mallinger et al. (2017) was for populations of managed (or introduced) bees generally, but most of the 146 studies that fit their inclusion criteria concerned honey bees. Of those studies addressing competition with other pollinators, 82% concerned honey bees, and of those studies that addressed indirect effects of honey bees due to their direct effects on plant communities including the spread of non-native plants, 88% concerned honey bee effects. In the growing literature on pathogens, 60% of the articles included in their study addressed effects of honey bees on other pollinators (primarily on other bees). The main findings of managed bees (primarily, honey bees) can be summarized as follows:

- Competition with wild pollinators for floral or nesting resources: of 72 studies, ca. 50% reported negative effects, 20% reported mixed effects (i.e. more than one out of positive, negative and no effect), and a little more than 25% reported no effects.
- Transmission of pathogens: 70% of 25 studies reported potential negative effects of managed bees on wild bees.
- Changes in plant communities, including effects of managed bees on the spread of non-native plants and decline of native plants: for 41 studies, effects were roughly equally divided among negative, positive, and no or mixed effects.

It should be noted that most of the studies reviewed by Mallinger et al. (2017) demonstrated the *potential* for impact; they did not measure direct effects on wild bee fitness, abundance, or diversity.

The systematic review by Iwasaki and Hogendoorn (2022) adopted the search and filter criteria of Mallinger et al. (2017) and added 69 more recently published articles. One was later excluded, leaving 216 studies resulting in 229 outcomes. In addition to the variables examined by Malinger et al. (2017), they also looked for effects of disparities in body size between the managed bees and native pollinators. We filtered their data to eliminate studies not concerning honey bees, and their main findings can then be summarized as follows (note that their categorizations were slightly different than those used by Mallinger et al. (2017)):

- Competition with other bees: of 68 studies, 66% found negative effects and 33% found no effects.
- Transmission of pathogens: of 37 studies, 84% reported negative effects.
- Competition with other insects and effects on plant communities and pollination networks: of 57 studies where scores were presented, 67% found negative effects, 12% were neutral, and 21% reported positive effects (most frequently, exotic *Apis* bees increasing reproductive output of native plants). However, only 7% (4 studies) found direct negative effects on plant communities.
- Iwasaki & Hogendoorn found 65 studies in which they could compare body sizes of honey bees with those of co-occurring wild bees (their Table 2). Competitive effects were only severe for honey bees vs larger sized bees (mainly bumble bees, 17 of 22 studies). When wild bees were of similar or smaller size, there were about equal numbers of studies reporting negative effects (13/24 studies) as reporting no effects (11/24).

3.2 Results from the most recent research

Our search of the newest literature resulted in 45 additional studies focusing on effects of honey bees (*Apis mellifera*) on wild pollinators (see Figure 3.2-1 and Appendix III with our list of papers). The more recent studies that we reviewed do not change the conclusions one can draw from the two older review papers. We found:

- Competition with other bees: of 22 studies, 67% found negative effects and 33% reported no effects.
- Transmission of pathogens: of 16 studies that were scored, 63% reported negative effects and 37% reported no effects.
- Effects on plant communities (and pollination networks): seven papers focused on these aspects, of which 57% (4) reported negative effects, 29% (2) reported no effects, and 14% (1) reported positive effects.

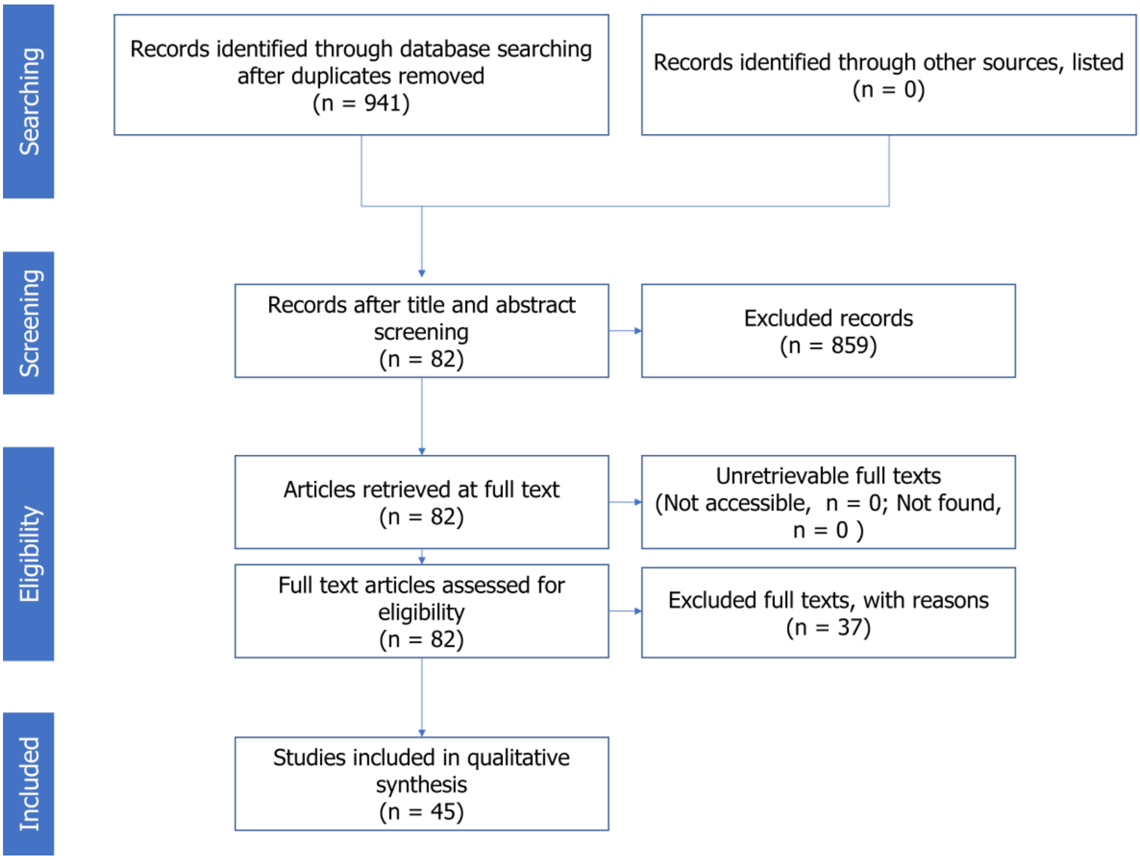


Figure 3.2-1. Flow diagram summarizing the literature search. For description of search methodology, see section 2.1 and Appendix II.

3.3 Conclusions from the literature review

3.3.1 Potential of competition with native pollinators

Based on the two previous reviews (Mallinger et al., 2017 and Iwasaki & Hogendoorn, 2022) and our own review of the recent literature, we conclude that under certain conditions, managed honey bees have measurable negative effects on wild bees or other wild pollinators with which they share floral resources. Most of the published studies were of effects on bumble bees, stingless bees, or solitary bees; few measured the effects on other pollinating insects or vertebrates (e.g. birds or bats). In both observational and experimental studies, researchers observed that, when honey bees were abundant (such as close to hives), visits by wild pollinators were reduced compared with situations where honey bees were less common or absent. Many studies reported that the presence of honey bees displaced one or more wild species completely or reduced the diversity of wild pollinators. However, the broad surveys plus the most recent research revealed that negative effects were often dependent on such factors as time of day, temperature, season, landscape structures, which plants were studied, or the identity of the wild pollinators and their degree of dietary specialization.

Few studies have investigated fitness effects (summarized in Wojcik et al., 2018). In terms of outcome, bumble bees and solitary bees have been mainly studied in relation to resource competition, suggesting negative effects. Effects on bumble bees included negative developmental or reproductive consequences, such as smaller workers (Goulson and Sparrow, 2009), lower brood production and fewer males and queens (Thomson, 2004), as well as fewer and smaller queens (Elbgami et al., 2014). Solitary and semi-social bees have also been shown to respond with lower reproductive output in the presence of honey bees (Hudenwenz and Klein, 2015; Sugden and Pyke, 1991; Paini and Roberts, 2005).

In about one-fourth of the studies, no negative effects of introduced or native honey bees on wild bees were found. These studies all involved other bees as potential competitors; they were from all parts of the world and included both observational and experimental research. In most of these studies, the effects measured were number of visits to flowers or amounts of pollen removed or deposited. In a few studies, researchers examined native bee abundance, wild bee species composition, or wild bee species richness. In most cases, the lack of observed competition was thought to be due to the wild bees largely using other floral resources; other explanations were that a given plant species was visited at different times of day or that potential competitors had different optimal temperatures for foraging.

3.3.2 Potential for transmission of pathogens to wild pollinators

Honey bees can transmit pathogens to native pollinators, especially other bee species. Pathogen spillover is a relatively new research field and many of the studies that were reviewed simply sequenced for the presence/absence of serious honey bee pathogens (usually viruses) in co-occurring native pollinators. That is, the wild pollinators did not display clinical symptoms of the pathogens. Several more recent studies have shown that genetically identical strains of pathogens can be found in both honey bees and co-occurring bee species (Singh et al., 2010; Ravoet et al., 2014; Radzevičiūtė et al., 2017) and in hoverflies (Bailes et al., 2018). Some studies have found that proportions of infected wild bees are higher or only contain pathogens where honey bees are present (e.g. Genersch et al., 2006; Fürst et al., 2014; Dias et al., 2023). The investigation by Radzevičiūtė et al. (2017) of 32 species of wild bees in European and Central Asian apple orchards recorded presence of several honey bee-associated viruses in representatives of four different hymenopteran families. Replication of deformed wing virus (DWV) was found in only one of the solitary bee species they looked at. However, the same survey found replication of black queen cell virus (BQCV) in half of the tested wild bee individuals, including species in *Osmia*, *Andrena*, *Xylocopa*, and *Bombus* (see also Tehel et al., 2022)

A small number of studies reported transmission of pathogens between honey bees and wild pollinators, such as bumble bees (Melathopoulos et al., 2017; Alger et al., 2019; Gusachenko et al., 2020). We emphasize that even when transmission or shared pathogens are observed, the pathogenicity of the microbe, for the wild pollinators, is not always known. Dolezal et al. (2016) found negligible fitness effects in bumble bees when fed or injected with honey bee pathogens. In a more recent study, Schauer et al.

(2023) found that a DWV strain taken from honey bees could not replicate in the red mason bee (*Osmia bicornis*) in which the virus had previously been detected, though the virus remained infectious for honey bees.

There is a potential for transmission of pathogens causing diseases of concern to apiculture from managed honey bees to wild pollinators. Such diseases could reduce the fitness of wild pollinators. The reviews found considerable evidence for sharing of honey bee pathogens between honey bees and native or managed bumble bee species, and a growing number of studies have shown that at least DWV can exploit a variety of species of bumble bees as hosts (reviewed in Schauer et al., 2023). Fleites-Ayil et al. (2023) concluded that at least BQCV and DWV may well be generalist bee viruses, in that they have been shown to be able to replicate in bees of the genera *Apis*, *Bombus* and *Melipona*.

Studies have demonstrated the mechanisms for interspecific transmission (usually, via pollen or nectar of shared floral resources), and in at least a few systems the transmission was from introduced honey bee colonies to the native species. Recent large-scale reviews have found that some viral pathogens that have been studied in honey bees are found in a wide variety of wild pollinators (Levitt et al., 2013; Nanetti et al., 2021; Brettell et al., 2020; Piot et al. 2022; Deutsch et al., 2023; Dias et al., 2023).

3.3.3 Effects of honey bee diseases on other pollinators

The actual effects of pathogens known to be highly virulent in honey bees have, as far as we know, only been investigated in any detail in bumble bees and stingless bees (Graystock et al., 2013; Tehel et al., 2016) but never in wild populations. Fürst et al. (2014) found that DWV fed (literally) to the managed species *Bombus terrestris* reduced host lifespan and Fleites-Ayil et al. (2023) reported that both BQCV and the two main lineages of DWV lowered survival of workers of the social stingless bee (*Melipona beecheii).* In general, very little is known about the effects of honey bee-associated pathogens on wild species of pollinating insects. An aspect that has recently been gaining attention is the possibility for pathogens to become more virulent in managed honey bees (McMahon et al., 2016), potentially increasing their negative impacts on wild pollinators (Grozinger & Flenniken, 2019). This has, however, never been studied. The primary or original sources of infective pathogens in husbandry animals are normally wild animal species. However, the risk of disease development in dense managed populations of husbandry is higher than in wild animals. It is also worth mentioning that spillover can occur both ways, i.e., from managed animals to wild animals, including pollinators, and vice versa (spillback) (Graystock et al., 2015).

3.3.1 Effects on plant communities and pollinator networks

Honey bees can indirectly reduce the resources provided by plant communities to wild pollinators if they decrease the success of native plants or increase the success of resource-poor or inaccessible non-native plants. Negative effects on other pollinating insects (such as hoverflies) can also alter plant communities by disturbing pollination services to native plants. Effects on other potential pollinators ranged from simply reduced floral visits due to presence of honey bees (Taylor & Whelan, 1988; Aizen & Feinsinger, 1994) to honey bees completely replacing endangered native pollinators (Kato et al., 1999), which may be due to exploitative competition (see section 3.3.1

and 4.1.1.1) or other mechanisms. Norfolk et al. (2018) found that honey bees displaced specialized wild bees as pollinators of local range-restricted native plants, for example, and Hung et al. (2018) cite numerous studies showing that, when present in large numbers, honey bees can out-compete and displace wild pollinators by dominating the most abundant plant species.

Only a few field studies concerned plant-pollinator networks; seven reported in the two previous review papers and three included now by us. Of the seven studies summarized in Iwasaki & Hogendoorn (2022), four studies were observational, and three studies were experimental. In these studies, honey bee abundance was associated with decreased pollinator abundance or species richness and with decreased wild pollinator visitation rates to native plants, as well as with disruptions of pollinator networks. Results of the three most recent studies were mixed. Gómez-Martinez et al. (2022) found a negative relationship between honey bee abundance and wild pollinator richness but did not analyze effects of honey bees on the 20 plant-pollinator networks they studied. The other two studies did not find negative effects of honey bees on networks or on wild pollinator species richness (Cini et al., 2022; Capellari et al., 2022).

4 Risk assessment

4.1 Hazard identification – impact mechanisms

In this section, we identify the mechanisms by which managed honey bees might pose a risk to wild pollinators in Norway and describe why these particular mechanisms are assessed. Regarding the risk from exploitative competition (see section 4.1.1.1), we have conducted separate risk assessments for different pollinator groups (see section 1.4). For the other hazards, we have assessed the risk posed to the entire wild pollinator community.

Two recent systematic reviews have synthesized the literature documenting the effects of managed honey bees on wild bees. Mallinger et al. (2017) focused on three impact mechanisms, namely (1) competition for floral and nesting resources (nesting resources are not relevant here), (2) transmission of pathogens and parasites, and (3) indirect effects via changes in plant communities, including the spread of exotic plants and decline of native plants. Iwasaki and Hogendoorn (2022) addressed the same potential impacts using the same search strategy. Based on these systematic reviews and our update of them where we assessed the most recent literature, as well as our own expert judgement, the project group has identified three potential mechanisms through which managed honey bees can negatively influence wild pollinators in Norway. These are:

- Direct effects via competition for floral resources (aligned with mechanism 1, "Competition", in the EICAT system).

- Indirect effects via transmission of pathogens or parasites (aligned with mechanism 4, "Transmission of disease to native species" in the EICAT system).

- Indirect effects via changes in plant communities or via changes in predation pressure on native pollinators, due to the presence of honey bees (aligned with mechanism 12, "Indirect impact through interactions with other species", in the EICAT system).

4.1.1 Resource competition

Competition is an interaction that influences populations and distributions of species with overlapping fundamental niches (Armstrong & McGehee, 1980). Interspecific competition occurs when resources within the fundamental niches of the competing species are limited.

Honey bees are not found in the wild in Norway. This is partly due to adverse climatic conditions, in winter, limiting the survival of permanent colonies in the wild north of the Oslo region at 60°N (Hansson, 1989, personal communication in Crane, 1999). But, since honey bees are kept in managed hives up to 65°N latitude in Norway, or even in Tromsø at nearly 70°N latitude (G. Velle, personal communication, April 3, 2024), it has been suggested that it is not the prolonged winter that is the limiting factor, but rather the lack of suitable nesting sites in hollow trees (Ruttner, 1988). Therefore, we see no potential for competition for nesting resources in a Norwegian context, and this issue will not be treated further in this opinion. Honey bees, and other pollinators may also use plant resins as hive construction material. We do, however, not see competition for nest building materials as a potential risk to wild pollinators and have therefore not treated this further in this opinion. Furthermore, there are no close relatives to managed honey bees in Norway, so hybridization with wild pollinators is not an issue and therefore not treated further in this opinion.

In the case of competition between managed honey bees and wild pollinators, there is a potential for competition for floral resources. All bees, including honey bees, as well as numerous other insects, such as butterflies and moths, flies, beetles, and others, forage on pollen and nectar found in flowers. Dietary overlap may cause competition between managed honey bees and wild pollinators if they, to a significant degree, share floral resources and limited amounts of pollen and nectar is available. Pollinating insects vary in their degree of specialisation with respect to the flowers they forage on. Honey bees are generalists and prefer open and easily accessible flowers and they are less capable of accessing nectar and pollen in highly closed and complex flowers. They live in large societies and communicate the location of floral resources to their colony kin. To optimize foraging, they might fly long distances, up to several kilometres, to areas with abundant floral resources, focusing their foraging on flowers of one single plant species. Honey bees are therefore used for crop pollination and often seen in abundance in entomophilous crop fields. In Norway, managed honey bees are often placed close to fruit orchards in spring and moved to areas with abundant heather (*Calluna vulgaris*) in late summer. The number of beehives involved in this migration beekeeping is, however, not known. The degree to which wild pollinators have overlapping floral preference with managed honey bees varies considerably among species. A recent review focusing on the potential competition from managed honey bees on wild bees in Denmark (Rasmussen et al., 2021) suggested that threatened wild bee species, with at least 70% dietary overlap with managed honey bees should be targeted for management and conservation measures. There are, however, no detailed overview of the dietary preference of most pollinators in Norway, so their dietary overlap with managed honey bees is currently not possible to quantify. A thorough assessment of dietary overlap between managed honey bees and wild pollinators in Norway is beyond the scope of this opinion.

4.1.1.1 Exploitative competition

Exploitative competition occurs when a species depletes the resources available to other species in the community (Torné-Noguera et al., 2016; Nielsen et al., 2017). Because of their large numbers and efficient foraging, eusocial bees, such as honey bees and bumble bees, can reduce the nectar and pollen available to other pollinators (Balfour et al., 2015; Nielsen et al., 2017; Henry & Rodet, 2018; Wignall et al., 2020; Page & Williams, 2023). Indeed, based on the weight of pollen pellets collected by honey bees in June-August, Cane & Tepedino (2017) estimated that a strong honey bee colony can collect pollen equivalent to the needs of 100,000 solitary bee larvae. The abundance of managed honey bees within wildflower communities is negatively correlated to the availability of nectar and pollen in flowers and is related to shifts in the foraging patterns of wild bees (Page & Williams, 2023). Furthermore, the few studies available on fitness effects due to exploitative competition have shown reduced reproduction in both bumble bees and solitary bees (summarised in Wojcik et al., 2018). Floral resource collection from managed honey bees has been shown to suppress the visitation frequency from bumble bees in the generalized flowers of raspberries (*Rubus ideaus*) (Nielsen et al., 2017) and bramble (*R. fruticosus* species complex) where it has been shown that both managed honey bees and bumble bees individually and jointly suppress large-bodied solitary bees (Wignall et al., 2020). However, managed honey bees are not necessarily the superior competitor, as seen in experimental plots with lavender flowers (*Lavandula x intermedia*) being visited by bumble bees and managed honey bees, where exploitative competition from bumble bee foraging suppressed honey bee visitation rates (Balfour et al., 2015). The presence of exploitative competition is likely to be greatest during periods with few floral resources and when managed honey bee colonies are fully developed. In Norway, this will typically be after the flowering of bramble in mid-June, and before the extensive flowering of heather (*Calluna vulgaris*) in August. Several wild bee species red-listed in Norway, have their activity peak in late June through July. Ten of these are regarded as threatened (Ødegaard et al., 2021), and thus of conservation concern: the large scabious mining bee (*Andrena hattorfiana*), the scarce black mining bee (*A. nigrospina*), the great yellow bumblebee (*Bombus distinguendus*) the short-haired bumblebee (*B. subterraneus*), the hairy-legged mining bee (*Dasypoda hirtipes*), the tufted furrow bee (*Lasioglossum nitidiusculum*), *Megachile alpicola* (no English common name), the hairy-footed leafcutter bee (*M. lagopoda*), the clover blunthorn bee (*Melitta leporina*), and the maritime mason bee (*Osmia maritima*). For these species, it is possible that competition with managed honey bees can pose a particularly high threat. However, this risk is likely to vary among locations and regions, both in terms of landscape elements and wild pollinator communities and stocking densities of managed honey bees. In August, when managed honey bees are moved to the heathlands, a new situation appears. During the flowering of heather, flower resources are no longer scarce, but competition may instead occur because of high honey bee stocking densities relatively to heather when heathlands are fragmented.

We conclude that exploitative competition from managed honey bees can alter the foraging choices and fitness of wild bees and other wild pollinators (Henry & Rodet, 2018; Wojcik et al., 2018; Page & Williams, 2023). Managed honey bees can potentially have negative impact on the fitness of wild pollinators in general and especially for wild bees with peak activity periods in June and July.

4.1.1.2 Interference competition

Interference competition for floral resources occurs when managed honey bees directly disturb the foraging of wild pollinators, physically excluding them from accessing floral resources and reducing their foraging efficiency. Pollinators strive to maximize the returns from their foraging activity, and a change in foraging patterns resulting from interference competition can potentially reduce their fitness. In their review, Iwasaki & Hogendoorn (2022) identified only a limited number of studies assessing interference competition from honey bees and the results from these studies were inconclusive and depended on local circumstances such as temperature and resource availability. They suggested that the documented examples of interference competition are most likely outliers and exceptions, rather than proofs of a strong and general process (Iwasaki & Hogendoorn, 2022).

4.1.2 Transmission of pathogens and parasites

All animals are prone to viral, bacterial, fungal, and parasite infections. Risk of infection is also the case for honey bees and other pollinators. Although most pathogens and parasites are host specific, honey bee pathogens have been detected in wild bees as well as in some other flower visiting insects. There is therefore a potential for pathogen transfer from managed honey bees to wild pollinators, most likely through visits to the same flowers. Honey bee pathogens have been detected in bumble bees, including deformed wing virus (DWV) (e.g. Genersch et al., 2006; Fürst et al., 2014; Cilia et al., 2021), *Vairimorpha ceranae* (Graystock et al., 2013), black queen cell virus (BQCV) (Tlak Gajger et al., 2021), and Israeli acute paralysis virus (IAPV) (Jones et al., 2021) among others. Doublet et al. (2024) found that IAPV only found at very low levels, also in the Nordic countries, and that the virus load does not increase in response to *Varroa destructor* infestation. IAPV is highly pathogenic in laboratory experiments, but does not seem to be of any importance in the Nordic countries and several other countries around the globe, as for now. IAPV is therefore not risk assessed further in this opinion.

The transmission of pathogens and parasites from managed honey bees to other pollinators (known as pathogen spillover: Daszak et al., 2000) is a rapidly expanding research area (Mallinger et al., 2017; Nanetti et al., 2021; Iwasaki & Hogendoorn, 2022; Deutsch et al., 2023). Advances in molecular techniques have recently enabled detailed surveys of the pathogens causing managed honey bee diseases in co-occurring wild pollinators (Pislak Ocepek et al., 2021; Tlak Gajger et al., 2021; Nanetti et al., 2021; Cilia et al., 2022; Piot et al., 2022) and wasp predators of honey bees (summarized in Eroglu, 2023).

If managed honey bee pathogens are found to be carried in wild pollinators, particularly where a given virus is more prevalent in non-native honey bees than in native wild bees, the implication that has been drawn is that managed honey bees have infected wild pollinators (Fürst et al., 2014; McMahon et al., 2015; Radzeviciute et al., 2017; Fleites-Ayil et al., 2023). This implication is also supported in cases where pollinator populations with and without nearby apiaries have been compared and the diseases are only or mainly found in wild pollinators near apiaries (Müller et al., 2019; Pislak Ocepek et al., 2022). Even stronger evidence for pathogen spillover comes from studies showing that wild native bees have the same or nearly the same viral haplotypes as introduced managed honey bees (Tlak Gajger et al., 2021; Fleites-Ayil et al., 2023). The implication (in some studies, the assumption) that transmission of diseases is generally from managed honey bees to wild pollinators—and not the other way around—is however, largely untested (Dias et al., 2023). The assumption has been confirmed in laboratory experiments showing that deformed wing virus (DWV) was readily transmitted from managed honey bees to *Bombus terrestris* via contact between infected and noninfected bees and via shared food sources, while transmission in the reverse direction did not occur (Tehel et al., 2022). We emphasize that the degree and direction of transmission of many other pathogens is unknown.

4.1.2.1 Pathogens

There are no studies documenting that the two most important bacterial pathogens to the honey bee, *Paenibacillus larvae* causing American foulbrood and *Melissococcus plutonius* causing European foulbrood, cause disease in wild non-*Apis* pollinating insects (Fünfhaus et al., 2018). However, the potential for transmission of other diseases between managed honey bees and wild bees is well documented (Tehel et al., 2016; Müller et al., 2019; Murray et al., 2019; Deutsch et al., 2023). While managed honey bee associated viruses, bacteria, and fungi may be common in wild bees (but overlooked), experimental infection of wild bees with viruses taken from managed honey bees have often failed to find any pathogenicity (e.g. Dolezal et al., 2016; Müller et al., 2019; Tehel et al., 2020). However, strains of the same virus may vary considerably in virulence (Chen et al., 2014; Tehel et al., 2019) and the virulence of viruses may rapidly evolve with high stocking densities of honey bees; further, interactions with other viruses and with environmental stressors such as pesticides can result in increasing pathogenetic potential for some viruses (McMenamin et al., 2016; Galbraith et al., 2018; McCormick et al., 2023).

Tehel et al. (2016) report in an opinion paper that deformed wing virus (DWV) has been found in both domesticated and wild pollinators, not necessarily as a result of spillover from managed honey bees. They do, however, suggest that the virus may impact wild pollinators by spillover of DWV from strongly infected domesticated honey bee populations. In a later, experimental study, Tehel et al. (2022) found that DWV was readily transmitted from managed honey bees to bumblebees but that transmission in the opposite direction did not occur, nor was the virus transmitted further from bumble bees to uninoculated bumble bees. Native ranges and history of spread of honey bee pathogens are largely unknown.

In a Norwegian context, we have identified the following diseases as most relevant for this risk assessment (see also section 1.3 and Table 1.3-1):

- Bacterial diseases
    - American foulbrood, caused by *Paenibacillus larvae*
    - European foulbrood, caused by *Melissococcus plutonius*
- Ascomycete fungal diseases
    - Chalkbrood, ascosferosis, caused by *Ascosphaera apis*
    - Stonebrood, aspergillosis, caused by *Aspergillus* moulds
- Microsporidian fungal disease
    - Nosemosis (also known as nosematosis), caused by *Vairimorpha apis* (previously *Nosema apis*) and *Vairimorpha ceranae* (previously *Nosema ceranae*)
- RNA virus diseases
    - Sacbrood virus (SBV)
    - Deformed wing virus (DWV)
    - Black queen cell virus (BQCV)

4.1.2.2 Parasites

Several parasites can infect honey bee hives. Based on the current situation in Norway and in Europe, we have identified four parasites relevant for this risk assessment: *Varroa destructor* and tracheal mites (*Acarapis woodi*), both currently present in Norway; *Tropilaelaps* mites and small hive beetles (*Aethina tumida*), currently not found in Norway. Small hive beetles are found in other European countries, while the distribution of *Tropilaelaps* mites is currently in temperate and tropical Asian countries. Small hive beetles are not parasites in a strict sense, but attack honey bee hives and cause damage and are therefore treated together with the parasites in this opinion. The mites have been found in colonies of ten native species of *Apis* but are not known to attack other wild bees or other pollinators (Chantawannakul et al., 2018); small hive beetles, too, can infest colonies of other species of social bees (Neumann et al., 2016). *V. destructor* can be a vector for several bee viruses that might spread to managed honey bees and then to native bees (see section 4.1.2.1). In general, honey bee colonies infected by parasites are weaker and their individuals more prone to diseases. Parasite-infected hives may therefore act as fungal, bacterial, and viral hot spots with an increased probability of spillover to wild pollinators. In a Norwegian setting, we have identified the following parasites relevant for this risk assessment (see also Table 1.3-1):

- *Varroa destructor*, causing varroosis
- Tracheal mite, causing acarapiosis
- Tropilaelaps mite
- Small hive beetle (not parasite in the strict sense)

4.1.3 Indirect impact through interactions with other species

This opinion deals with the effects of managed honey bees on wild pollinators, and not plant communities *per se.* We do, however, see the potential for managed honey bees indirectly affecting wild pollinators through their pollination of certain plants, including alien invasive species, favoring their reproduction and consequently leading to changes in plant community composition which can impact populations of wild pollinators.

Also, managed honey bees are food for predators, such as native and alien hornets (see VKM et al., 2022), and if the abundance of managed honey bees is high this can facilitate population increases for predators and can, potentially, lead to increased predation pressure on insects in general, including wild pollinators. We have however, found no study addressing this issue, so this is a speculation, based on general ecological theory. We also acknowledge that the effect might also be opposite, such that abundant managed honey bees might ease the predation pressure on native pollinators if the predators prefer feeding on managed honey bees.

4.1.3.1 Altered plant communities

Through selectively pollinating flowers from certain preferred plant species, consequently increasing their reproductive success, managed honey bees in abundance can alter plant community structure and dynamics. If changes in the plant community, stemming from the pollination services from managed honey bees, result in a reduction in floral resource availability to wild pollinators, this might cause negative effects for wild pollinator populations (Stout & Tiedeken, 2017). The opposite might also happen, i.e. that pollination by managed honey bees leads to strong populations of important forage plants for other pollinations (Hung et al., 2018), but this is not relevant within the context of this opinion.

Managed honey bees will forage on and often prefer widely distributed both native and invasive plants (Wood et al., 2018; Urbanowicz et al., 2020), especially if they are locally dense, have many flowers per plant or are larger plants (Bauer et al., 2017; Cohen et al., 2021; Penberthy et al., 2023). Examples of instances where managed honey bees forage from, and thereby potentially pollinate, invasive plants include the highly invasive warty-cabbage *(Bunias orientalis*), wintercress *(Barbarea vulgaris*), and sweet clovers *(Melilotus* sp.) in Oslo, Norway (Davey et al., 2023). Invasive plants such as warty-cabbage can outcompete and reduce the diversity of the native flora (Woitke & Dietz, 2002; Sandvik et al., 2020) and thereby the floral resource availability and diversity that native pollinators depend on (Stout & Tiedeken, 2017). By promoting invasive plants at the expense of other plant species, managed honey bees can have indirect, negative, effects on wild bees and other pollinators that rely on plants that are outcompeted by invasive species.

4.1.3.2 Altered predation pressures

Compared to pathogen transmission, predator ‘transmission’ from managed honey bees to wild pollinators is less well documented. Widespread beekeeping can increase the populations of honey bee predators that may prey on other insects as well. The main prey of the European beewolf (*Philanthus triangulum*) is honey bees, but the beewolf is known to also prey on medium-sized wild bees such as yellow-legged mining bee *(Andrena flavipes*) and bull-headed furrow bee *(Lasioglossum zonulus*) (Else, 1997), especially where few honey bees are present (Blösch, 2000, reviewed in

Olszewski et al. 2022). With increasing temperatures, the European beewolf is expected to expand its home range, potentially colonizing Norway in the future (Olszewski et al., 2022). Other predators whose populations can be augmented by managed honey bees are European hornet (*Vespa crabro)*, which has recently recolonized Norway, and the yellow-legged hornet (*V. velutina)* and Japanese hornet *(V. mandarinia*) currently not present in Norway (VKM et al., 2022). These hornets are generalist predators but known to prey heavily on managed honey bees (see VKM et al., 2022 and references therein). Though speculative, there could be situations where wild pollinator fauna will become the selected prey of honey bee predators. For instance, if honey bee stocking densities in an area are suddenly reduced, such as when beehives are moved from bramble to *Calluna* sites, or after local disease outbreaks, residing predators may be forced to switch to alternative prey which can include wild pollinators and other insects.

4.2 Hazard characterization

In this section, we characterize the hazards identified in section 4.1 by describing the magnitude of their potential impact in a Norwegian context. Here, we assess the placing of each hazard along the *Y*-axis in the figures presented in the risk characterization found in section 4.4 (see also Figure 2.2-1). We also present the confidence level for the magnitude of the potential impact of the hazards should they occur.

4.2.1 Resource competition

Bees are central place foragers and must find food sources within a certain range from their nest. Depending on the species, the foraging range varies from a few hundred meters, or less, to several kilometres, in the case of honey bees. Other pollinating insects in Norway are drifters, such as flies and butterflies, and can cover large areas in search of food, without having to return to a nest. For competition to occur, there must be dietary overlap and limited amounts of floral resources within the foraging range of the wild pollinators. The foraging range of wild bees is correlated with bee size, with smaller bees having shorter ranges. A recent study from Denmark showed that total dietary overlap between managed honey bees and wild bees is not common (Rasmussen et al., 2022). Dietary requirements are, however, not known in detail for most Norwegian pollinators. Some oligolectic bees specialize on flowers of certain plant species that might be prone to floral resource competition if honey bees also prefer their favourite food source.

4.2.1.1 Exploitative competition

For oligolectic bees and bees with narrow floral preferences such as the short-haired bumblebee (*Bombus subterraneus*) and the great yellow bumblebee (*B. distinguendus*) or species such as the critically endangered large scabious mining bee (*Andrena* *hattorfiana*) that have large dietary overlap with honey bees with peak activity periods from mid-June through July, we assess the magnitude of the potential impact of exploitative competition from managed honey bees to be **major** with **medium confidence**. Based on studies of exploitative competition from honey bees on bumble bees in landscapes with contrasting vegetative structure (Herbertsson et al., 2016), we have assessed the magnitude of the potential impact of exploitative competition for bumblebees in both homogeneous and heterogeneous landscapes. For bumble bees in homogeneous landscapes or landscapes with limited floral resources, we assess the magnitude of the potential impact of exploitative competition from managed honey bees to be **moderate** with **medium confidence.** For bumble bees in heterogeneous landscapes or landscapes with abundant floral resources, we assess the magnitude of the potential impact of exploitative competition from managed honey bees to be **minor** with **medium confidence.** Both assessments of bumble bees are based on the fact that they are also social bees, with some overlap in foraging preferences and that they are relatively similar or larger in size to honey bees, a trait often used to predict potential for competition.

Other wild pollinators in Norway are a very diverse group of insects for which limited knowledge exists on floral preferences and dietary overlap with managed honey bees. They may not share floral resources or activity period during the season, with honey bees, and might seek alternative floral resources if honey bees are utilizing their preferred flowers. We therefore assess the magnitude of the potential impact of exploitative competition from managed honey bees on other wild pollinators to be **minor** with **low confidence**.

4.2.1.2 Interference competition

Only a few international studies, none from Norway, have given limited support for interference competition between honey bees and wild pollinators to occur (Hudewenz and Klein, 2015). As far as we know, no study has quantified the negative effects of interference competition. For wild pollinators in Norway, we therefore assess the magnitude of the potential impact of interference competition from managed honey bees on wild pollinators to be **minimal** with **medium confidence**.

4.2.2 Transmission of pathogens and parasites

Several pathogens potentially causing disease in managed honey bees and other insects are found in nature, but to what extent they cause disease in wild pollinators, with negative population level effects are largely unknown. A growing number of studies have, however, shown a causal connection between pathogen prevalence in managed honey bees and wild bees, especially but not exclusively native and managed species of bumble bees.

4.2.2.1 Pathogens

Bacterial diseases

American foulbrood

American foulbrood (AFB) is a fatal disease of honey bee larvae caused by the bacterium *Paenibacillus larvae* (Generich et al., 2006; Jurat-Fuentes & Jackson, 2012; Fünfhaus et al., 2018). The infection occurs in the intestine of larvae resulting in uptake of toxins that impact the whole larvae. The larvae die after the cell lids have been made to cover the cell prior to pupation, which is the reason for the name "closed" foulbrood.

Due to the lack of studies showing disease in wild pollinators, we assess the magnitude of the potential impact from spillover of *P. larvae*, the cause of American foulbrood, from managed honey bees to wild pollinators to be **minimal** with **low confidence.**

European foulbrood

European foulbrood (EFB) is a fatal disease of honey bee larvae, caused by the bacterium *Melissococcus plutonius* (Jurat-Fuentes & Jackson, 2012; Fünfhaus et al., 2018). The bacterium is an enterococcal type of bacterium linked to the intestine of the larvae. When the bacterium multiplies in the larval mid-gut, the bacteria compete for the nutrients and the larvae mainly dies from starvation. The larvae appear twisted in the cells usually just a few days after hatching. The larvae turn brown and black and die before cell lids are made which gave the name "open foulbrood". In some cases, there are only a few diseased and dead larvae; in other cases, most larvae are affected. The colony may collapse in the first year of infection or, in cases with less virulent strains of *M. plutonius,* it can survive for some years depending on the cleaning effectivity of the colony or the management by the beekeeper. It is a widespread, economically important disease in many countries (Forsgren et al., 2005; Deutsch et al., 2023). While some healthy appearing larvae in infected colonies do have low levels of *M. plutonius*, larvae from colonies with no signs of infection rarely do so, indicating that *M. plutonius* is not ubiquitous in honey bee populations (Forsgren et al., 2005).

Infections of EFB have been detected in managed tropical stingless bees (*Melipona* spp: Teixeria et al., 2020), but we are not aware of any study showing infections in wild pollinators found in Europe or Norway. As for the causative agent of AFB there has been no detection of *M. plutonius*, the causative agent of EFB, in Norwegian honey bees since 2011 except for a few cases in the survey programme and follow-up after the outbreak of EFB in Agder in 2010. We do not expect *M. plutonius* to be currently present in the Norwegian fauna. If the pathogen had been occurring in wild pollinators, either as a normal background occurrence or as a result of spillover to wild pollinators from the Agder outbreak, we would have expected to detect secondary cases during the 13 years since the outbreak was detected and sanitized.

Due to the lack of studies showing disease in wild pollinators found in Europe, we assess the magnitude of the potential impact from spillover of *M. plutonius,* the cause of European foulbrood, from managed honey bees to wild pollinators to be **minimal** with **low confidence.**

Ascomycete fungal diseases

Chalkbrood, ascosferosis

The fungus *Ascosphaera apis*, the cause of chalkbrood, infects and kills larvae and pupae. Larvae are infected by consuming spores; adult bees are not susceptible to the fungus but spread it via food sharing and transmit the disease within and between beehives (Aronstein & Murray, 2010).

A. apis is found throughout the world and in Norway infections are not uncommon. The strains found in Norwegian honey bees seem to exhibit a low level of virulence, and clinical disease mostly occurs when the bees are unable to maintain optimal hive temperatures during cold spring seasons (Lund, 2023).

Due to the lack of studies showing disease in wild pollinators, we assess the magnitude of the potential impact from spillover of *A. apis,* the cause of chalkbrood, from managed honey bees to wild pollinators to be **minimal** with **low confidence.**

Stonebrood, aspergillosis

Several soil fungi in the genus *Aspergillus* are moulds known as pests on cereal grains, legumes, and nuts and they may also pose threats to human health (Beccimanzi & Nicoletti, 2022). These opportunistic moulds can also infect larvae, pupae and adult honey bees, producing a condition known as stonebrood.

The fungi in the genus *Aspergillus* are globally distributed, but the disease is rare (Seyedmousavi et al., 2015). *A. flavus* is the most frequently reported cause of stonebrood, but several dozen species of *Aspergillis* have been isolated from dead or diseased honey bees (Seyedmousavi et al., 2015; Beccimanzi & Nicoletti, 2022).

The bee disease stonebrood has not yet been diagnosed in Norway.

Due to the lack of studies showing disease in wild pollinators and the fact that the disease has never been diagnosed in Norway, we assess the magnitude of the potential impact from spillover of *Aspergillus* moulds, the cause of stonebrood, from managed honey bees to wild pollinators to be **minimal** with **low confidence.**

Microsporidian fungal disease

Nosemosis

The disease nosemosis is caused by the microscopic microsporidian parasites *Vairimorpha ceranae* and *V. apis* (in earlier literature referred to as *Nosema ceranae* and *N. apis*: see Tokarev et al., 2020) that can induce intestinal symptoms, primarily in adult bees. Microsporidians are unicellular parasites recently reclassified as fungi. The symptoms can sometimes be severe, leading to the loss of infested bee colonies. This microscopic parasite produces spores that can persist in the environment for years.

These two *Vairimorpha species* are the most severe pathogens of honey bees worldwide (Nekoei et al., 2023) and *Vairimorpha* is prevalent in all beekeeping environments in Norway (H. Sørum, personal communication, April 15, 2024). *V. ceranae* has been shown to occur in bumblebee colonies worldwide, where it can affect bumblebee worker longevity (Fürst et al., 2014; Pislak Ocepek et al., 2021). *V. ceranae* can be found in a wide variety of solitary and social bees and wasps as well as in hoverflies (Cilia et al., 2022; Deutsch et al. 2023).

In Norway, there are no restrictions associated with infections caused by species in the genus *Vairimorpha*. Beekeepers can mitigate the risk of disease through optimal and hygienic management protocols, including careful cleaning of the bottom part of the hives after the initial flights in early spring when adult bees empty their intestines following the long winter in the hive.

Several species of *Vairimorpha* parasitize a variety of insects and it has been suggested that both species of *Vairimorpha* described above can infect bumble bees and solitary bees in Norway (Norges Birøkterlag, not dated b). We are not aware of any study describing *Vairimorpha* infections in wild pollinators in Norway. To what extent they negatively affect non-*Apis* bees, and other insects, in the wild is largely unknown.

Vairimorpha pathogens do occur in numerous wild pollinators, but we assess the magnitude of the potential impact of spillover of *Vairimorpha*, the cause of nosemosis, from managed honey bees to wild pollinators to be **minor** with **medium confidence.** The confidence level is based on studies showing only minor effects of the pathogens in wild pollinator species.

RNA virus diseases

Sacbrood virus (SBV) is caused by a complex of closely related viral strains in the *Iflavirus* genus (Huang et al., 2021). It is a widespread viral disease that can cause high mortality in honey bee hives. Infected larvae die soon after their cells are capped; a liquid, rich in SBV, is produced inside the larval skin resulting in a dead sac that can be drawn out from the cells.

There has been observed a handful of cases of sac-brood disease in Norway, with characteristic clinical syndromes, after the parasitic varroa mite (*Varroa destructor*) established. However, there is no widespread occurrence of SBV in Norwegian honey bees.

SBV has been detected in a wide variety of arthropods (Levitt et al., 2013), but there are no records of disease symptoms in wild pollinators. We assess the magnitude of the potential impact from spillover of SBV from managed honey bees to wild pollinators to be **minor** with **low confidence.**

Deformed wing virus (DWV) is a globally distributed RNA virus that causes wing and abdominal deformities of honey bees and has killed billions of honey bees across the globe (Chen et al., 2014). DWV is one of the most important threats to apiculture and is a causal factor for the collapse of infected honey bee colonies. DWV is transmitted between and within colonies by the parasitic varroa mite (*Varroa destructor)*: viral loads of DWV are significantly higher after a hive has been colonized by *V. destructor* (Martin et al., 2012).

In Norway, there have been observations of individual bees with deformed wings that were shown to be infected with DWV (verified by molecular tests). These were cases where beehives with heavy infestation of *V. destructor* had not been managed properly to reduce the level of *V. destructor* infestation (H. Sørum, personal communication, April 15, 2024). Although DWV can infect bumble bees, buff-tailed bumblebee (*Bombus terrestris*) seems to be resistant towards it (Gusachenko et al., 2020; Tehel et al., 2020; but see Genersch et al., 2006; Fürst et al., 2014); Streicher et al. (2022) found that pathogenicity of DMV for buff-tailed bumblebee depended on transmission mode. In the red mason bee (*Osmia bicornis*) the virus does not seem to cause infections (Schauer et al., 2020).

Based on the small number of reports showing that wild bees can be infected, but those studied showing limited signs of disease, we assess the magnitude of the potential impact from spillover of DWV from managed honey bees to wild pollinators to be **minor** with **medium confidence.**

Black queen cell virus (BQCV) is a common RNA virus now found world-wide. BQCV can cause fatal disease in honey bee queen larvae and pupae (which turn brown-black when they die). However, the virus is often benign when present. There is some evidence that virulence is associated with how the virus is transmitted, and that BQCV transmitted to new colonies by feeding by *V. destructor* causes much higher mortality than when transmitted from bee to bee (Al Naggar & Paxton, 2020). Individual bee mortality is usually low but much higher when bees are infected by both BQCV and *Vairimorpha apis* or when bees are stressed by pesticides.

Disease outbreaks caused by BQCV have not been seen in Norway, but the disease agent has been detected in healthy honey bees by molecular techniques (H. Sørum, personal communication, April 15, 2024).

BQCV is prevalent in a wide variety of both solitary and social bees and wasps (Cilia et al., 2022; Deutsch et al. 2023), in hoverflies (Cilia et al., 2022), and flower-visiting Lepidoptera (Pislak Ocepek et al., 2022). There is some evidence that both wild and managed bumblebees infected by BQCV suffer the same effects as honey bees (Genersch et al. 2006).

Based on the small number of reports showing that wild bees can be infected, but those studied showing limited signs of disease, we assess the magnitude of the potential impact of spillover of BQCV from managed honey bees to wild pollinators to be **minor** with **medium confidence.**

4.2.2.2 Parasites

***Varroa destructor*, varroosis**

Varroa destructor (varroa mites) feed on both adults and brood of honey bees. *V. destructor* is a causative factor for the collapse of infected honey bee colonies, especially in combination with potentially deadly viruses such as DWV and BQCV (see 4.2.2.1).

Varroa destructor infestation, varroosis, leads to a weakening of the immune system of infected bees. This weakening of the immune system facilitates the reproduction of several viruses to levels that can induce disease, ultimately impacting bee colonies via reduced productivity and elevated winter losses (Doublet et al., 2015; Melathopoulos et al., 2017).

Among the most prevalent secondary diseases associated with uncontrolled *V. destructor* infestation are the sac-brood virus (SBV), deformed wing virus (DWV), and black queen cell virus (BQCV). International studies (Levitt et al., 2013; Brettell et al., 2020; Nanetti et al., 2021; Deutsch et al., 2023; Dias et al., 2023) including a study in which Norwegian samples from honey bees are analyzed (Doublet et al., 2024), indicate that many viruses occur naturally in honey bees and other insects and that they can increase, and cause disease, in bees weakened by *V. destructor* infestation or pesticide exposure (Doublet et al., 2015; Melathopoulos et al., 2017). *Varroa destructor* have never been found to infest insects other than species of *Apis*, so any potential hazard must be indirect, through spread of pathogens (see 4.2.2.1).

Varroosis is listed on List 3 by the Norwegian Food Safety Authority and efforts will be made accordingly, should it be discovered.

Since *V. destructor* only infect species of *Apis*, we assess the magnitude of the potential impact of spillover of *V. destructor*, the cause of varroosis, from managed honey bees to wild pollinators to be **minimal** with **high confidence.**

Tracheal mite, acarapiosis

The tracheal mite (*Acarapis woodi)* is considered one of the most important pathogens of honey bees (Beverley, 2012; Stolbova, 2021; Nekoei et al., 2023). These microscopic mites inhabit the tracheal pipes (respiratory system) of adult bees, producing the condition beekeepers refer to as acarapiosis or acarine disease. Infection by tracheal mites results in paralysed and flightless bees, increased spring mortality, and high winter mortality, thus presenting a significant concern in countries where the mite is widespread. The tracheal mite is widespread in North and South America, central Africa, Europe, and Asia (Beverley, 2012). Tracheal mites have never been found to infect insects other than species of *Apis*, so any potential hazard must be indirect, through spread of pathogens (see 4.2.2.1).

Acarapiosis is listed on List 3 by the Norwegian Food Safety Authority and efforts will be made accordingly, should it be discovered.

Since tracheal mites have never been observed to infect insects outside the *Apis* genus, we assess the magnitude of the potential impact of spillover of *A. woodi*, the cause of acarapiosis, from managed honey bees to wild pollinators to be **minimal** with **high confidence.**

Tropilaelaps mite

Tropilaelaps mercedesae feed primarily on the hemolymph of bee larvae and pupae but they can also attack crippled adult bees (Phokasem et al., 2019; Ling et al., 2023). When feeding on larvae and prepupae, *T. mercedesae* mites are potential vectors of honey bee viruses, particularly DWV (de Guzman et al., 2017; Phokasem et al., 2019; Gao et al., 2021). However, several studies have suggested that the major impact of these mites is via their feeding behavior, which reduces bee immune responses (Ling et al., 2023). Like *Varroa destructor*, feeding by *T. mercedesae* kills immature honey bees or leads to deformed pupae and adults. We are not aware of any reports showing that *T. mercedesae* can infest other insects, so any potential hazard must be indirect, through spread of pathogens (see 4.2.2.1).

The tropilaelaps mite is listed on List 2 by the Norwegian Food Safety Authority and efforts will be made to eradicate it from the Norwegian honey bee population accordingly, should it be discovered.

Since these mites have never been observed to infect insects outside the genus *Apis*, we assess the magnitude of the potential impact of spillover of *T. mercedesae* from managed honey bees to wild pollinators to be **minimal** with **high confidence.**

Small hive beetle

The small hive beetle (*Aethina tumida*) is not a parasite in the strict sense, but an ecological generalist known to feed on a wide variety of organic substances, even fresh fruit. It has also been found to infest nests of wild bees. Its biology and distribution are reviewed in detail in Neumann et al. (2016). The species is native to sub-Saharan Africa, where it is a minor pest of honey bee colonies. Where it has been introduced, the beetle proliferates rapidly in infested colonies, causing extensive damage to bee larvae, honey, and wax; feeding activity of a hive beetle population can destroy an entire hive within a couple of weeks, even in strong colonies. Strict measures have thus far limited its spread within the EU, where it has only established local populations in Italy.

The small hive beetle is listed on List 2 by the Norwegian Food Safety Authority and efforts will be made to eradicate it from the Norwegian honey bee population accordingly, should it be discovered.

Due to the limited knowledge on the effects of infections in wild pollinators in Norway, we assess the magnitude of the potential impact of transmission of the small hive beetle from honey bees to wild pollinators to be **moderate** with **medium confidence.**

4.2.3 Indirect impact through interactions with other species

Altered plant communities resulting from the invasion of an alien species or predation pressure on wild pollinators *per se* cannot necessarily be ascribed to the presence of managed honey bees. For the below mentioned hazards to be relevant in the context of the current opinion, the impact of the hazards must be due to the altered plant communities and increased predation pressure stemming from the presence of managed honey bees. Both processes can have negative effects on wild pollinators, but to be relevant in this context the additional effect of managed honey bee presence must be quantified.

4.2.3.1 Altered plant communities

Certain plant species, native and alien, can become dominant in plant communities by becoming invasive and outcompeting less competitive species including species that may be important food sources for wild pollinators. However, to what extent the dominance of a plant species stems from increased pollination services from managed honey bees is usually unknown. In the invasive species literature, several aspects of the "ideal weed" are highlighted (see e.g. Sakai et al., 2001). Most "weed" traits mentioned in the literature are non-reproductive, and when mentioned, the combination of sexual and vegetative reproduction seems to be beneficial. Therefore, most plants that become invasive do so not solely due to honey bee-mediated reproduction, but in theory it might be the case. We are, however, not aware of any study directly investigating the effect on wild pollinators due to altered plant communities caused by managed honey bees.

For wild pollinators in Norway, we therefore assess the magnitude of the potential impact of altered plant communities as a result of managed honey bee presence to be **minimal** with **low confidence**.

4.2.3.2 Altered predation pressures

If predators, such as hornets or the European beewolf, can forage freely on abundant managed honey bees, they may thrive and increase their populations. Higher predator populations may then increase the predation pressure also on other prey, such as wild pollinators. Densities of managed honey bees may change from year to year and over the season, causing increased predation pressure on the native entomofauna when the honey bee population suddenly decreases. Hornets can prey on a vast array of wild insects (VKM et al., 2022), though they appear to have problems hunting bumble bees, but can still have negative effects on bumble bee colony development (O'Shea-Wheller, 2023). The European hornets is still relatively rare in Norway, and its distribution is limited to the southern part of the country. We are not aware of any other predator to honey bees that might occur in population densities relevant to cause any negative effect on native pollinators due to increased population sizes caused by the presence of managed honey bees.

For wild pollinators in Norway, we therefore assess the magnitude of the potential impact of altered predation pressures as a result of managed honey bee presence to be **minimal**, with **high confidence**.

4.3 Likelihood of impact

In this section, we assess the probability of occurrence for the each of the hazards identified in section 4.1. These assessments form the basis for the placing of each hazard along the *X*-axis in the figures presented in the risk characterization section 4.4 (see also Figure 2.2-1). We also present the confidence level for our estimate of the likelihood of each of the hazards occurring.

4.3.1 Resource competition

The foraging ecology of honey bees and the nature of beekeeping operations in Norway suggest that honey bees generally forage in floral resource hot spots (mass-flowering plants) and on flowers from a limited number of plant species.

4.3.1.1 Exploitative competition

For oligolectic bee species with strong dietary overlap with honey bees, we assess the likelihood of impact from exploitative competition from managed honey bees to be **unlikely**, with **low confidence**. The assessment is based on the limited number of oligolectic bees found in Norway and the limited knowledge regarding their ability to seek alternative food sources should honey bees be exploiting their preferred flowers. For bumble bees, in both homogeneous and heterogeneous landscapes and/or landscapes with abundant or limited floral resources, we assess the likelihood of impact from exploitative competition from managed honey bees to be **unlikely** with **medium** confidence. This assessment is based on the landscape configuration found in Norway, where even the most intense agricultural landscapes are much more heterogeneous than those found further south in Europe, e.g. in Southern Sweden (see Herbertsson et al., 2016). For other pollinators, we assess the likelihood of impact from exploitative competition from managed honey bees to be **very unlikely** with **low confidence** based on the limited knowledge on floral preferences, dietary flexibility and the extent to which floral resources are a limiting factor for this diverse group of insects.

4.3.1.2 Interference competition

Few international studies, and none from Norway, have detected interference competition between honey bees and wild pollinators. Sakai et al. (2001) suggested that those few studies detecting interference competition were outliers and that interference competition most likely occurs only under particular circumstances. For wild pollinators in Norway, we therefore assess the likelihood of impact from interference competition from managed honey bees to be **very unlikely** with **high confidence**.

4.3.2 Transmission of pathogens and parasites

For pathogens and parasites to be of relevance for this assessment they need to spill over from managed honey bees to wild pollinators and result in symptoms with negative population effects for the wild pollinators. Pathogen prevalence in wild pollinators in areas with managed honey bees, but not in areas without, suggest the potential for spillover, but does not directly transform into disease or negative population effects in wild pollinators.

4.3.2.1 Pathogens

Bacterial diseases

American foulbrood

Historically, minor outbreaks of American foulbrood (AFB) have been observed in the Norwegian honey bee population along the coasts of Agder and Østfold counties. These outbreaks have been rare, with an average occurrence of one outbreak every 5-10 years since the turn of the millennium (Rakkestad, Sarpsborg, Halden). In the past two decades, a handful of outbreaks have also occurred further inland in the districts of Østlandet (Solør, Hadeland and Kviteseid).

The sources of AFB outbreaks in Norway remain unknown, though discussions have pointed to the potential role of old equipment and suboptimal sanitation practices after previous outbreaks. For the past 20 years, foreign honey has been imported to Norway, and it has been documented that some of these honey batches contain spores of *Paenibacillus larvae*. It has therefore been hypothesized that the inland outbreaks of AFB may have been caused by honey bees accidentally accessing imported and contaminated honey.

The most recent clinical case of American foulbrood was observed in Kviteseid, Telemark in July 2023. Prior to this, a minor outbreak occurred south of Halden in the fall of 2022, with suspicions that it may have been transmitted from an ongoing AFB outbreak in the neighbouring districts of Sweden. As of January 2024, despite ongoing monitoring no active occurrences of AFB are currently known in Norway (H. Sørum, personal communication, April 15, 2024).

Real-time PCR technology in the honey bee diagnostic activity commissioned by The Food Safety Authority in Norway has rarely detected the causative agent of American foulbrood (*Paenibacillus larvae*) in Norwegian honey bee populations. This has been systematically tested since 2020 (H. Sørum, personal communication, April 15, 2024).

American foulbrood is listed on List 2 by the Norwegian Food Safety Authority and efforts will be made to eradicate it from the Norwegian honey bee population accordingly, should it be discovered.

We assess the likelihood of spillover of *P. larvae*, the cause of AFB, from managed honey bees to wild pollinators to be **very unlikely** with **high confidence**. The confidence level is based on the limited presence of the causal agent in Norway.

European foulbrood

Historically there has been a scarcity of information concerning the prevalence of *Melissococcus plutonius*, the cause of EFB, in Norway. A non-verified outbreak is reported to have occurred in 1980 (H. Sørum, personal communication, April 15, 2024). In 2010, however, a substantial EFB outbreak surfaced in Agder, which spread to Telemark and Hedmark (H. Sørum, personal communication, April 15, 2024). A total of 36 beekeepers were found to have apiaries afflicted with the clinical symptoms of EFB, prompting comprehensive sanitation measures that included the eradication of all affected bees. Additionally, organic materials such as wax and equipment that could not be disinfected were either incinerated or otherwise destroyed. The eradication efforts extended to the destruction of a total of 3,000 beehives within the outbreak area during the fall of 2010.

Since the spring of 2011 real-time PCR has been implemented for the diagnostic assessment of potentially contaminated apiaries within the outbreak area (H. Sørum, personal communication, April 15, 2024; see also https://www.nrk.no/sorlandet/kontroll-pa-apen-yngelrate-1.7650301). DNA from M. plutonius was detected in 46 apiaries in 2011 and all were destroyed before any symptoms developed. In 2012, only 5 apiaries were detected to have *M. plutonius* and they were also destroyed. Over the past 13 years, only a few apiaries with DNA from *M. plutonius* have been detected in the outbreak zone and they have all been destructed and the equipment and buildings sanitized. Notably, in the last decade, only those apiaries originally identified with clinical EFB in 2010, which resumed production following sanitation, were subsequently found to harbour *M. plutonius*. The outbreak is now considered under control and *M. plutonius* is most likely eradicated in Norway. There was no detection of *M. plutonius* in feral swarms of honey bee colonies in Agder during the EFB outbreak, and continuous monitoring efforts have ensured that all beehives within the outbreak zone have undergone multiple tests for the presence of *M. plutonius* since 2011 (Dahle, 2021).

Within the Norwegian honey bee population, *M. plutonius* has not been detected beyond the outbreak zone (Dahle, 2023). A consequence of this unique epizootic situation is that it is possible to employ quantitative PCR for detection of the *M. plutonius* in healthy beehives, allowing for sanitation measures to be implemented based on the occurrence of healthy carrier populations with the causative agent of EFB before symptoms develop. If there had been a situation with occurrence of healthy or mostly healthy carrier honey bee colonies as a general situation when a more pathogenic strain was imported it had not been possible to use the sensitive rt-PCR-technology to identify bee colonies with very low level of *M. plutonius* of the highly pathogenic variant that caused the clinical Agder-outbreak discovered in 2010 (Dahle, 2023).

The original source of the EFB outbreak in Agder remains unidentified. However, it is highly likely that the disease was introduced through private import of beehives to Arendal on the Sørlandet coast in southern Norway from Continental Europe. Testing has revealed that the imported *M. plutonius* bacterium is highly virulent (Grossar et al., 2023), posing a significant threat to honey bees and honey production in Norway.

Without the identification of the outbreak, followed by thorough sanitation, the use of antibiotics would have been required to control the disease and sustain future honey production in Norway.

As of January 2024, despite ongoing monitoring no active occurrences of EFB are currently known in Norway (H. Sørum, personal communication, April 15, 2024).

As a result of the use of sensitive diagnostic methods as real-time or quantitative PCR technology in the honey bee disease diagnostic activity related to The Food Safety Authority in Norway (NMBU) we conclude that, despite some rare detections, there has not been a general occurrence of the causative agents of European foul brood (*Melissococcus plutonius*) in Norwegian honey bee populations. This has been systematically tested since 2011 (H. Sørum, personal communication, April 15, 2024).

European foulbrood is listed on List 2 by the Norwegian Food Safety Authority and efforts will be made to eradicate it from the Norwegian honey bee population accordingly, should it be discovered.

We assess the likelihood of spillover of *M. plutonius*, the cause of EFB, from managed honey bees to wild pollinators to be **very unlikely** with **high confidence**. The confidence level is based on the limited presence of the causal agent in Norway.

Ascomycete fungi

Chalkbrood, ascosferosis

Ascosphaera apis is found throughout the world and in Norway infections are not uncommon. *Ascosphaera apis* has also been found to infect wild bees, such as carpenter bees (Reynaldi et al., 2015).

The disease is considered a manageable disease, and it is occurring mostly in May when the bee colony is building larvae and is related to weather conditions, especially colder temperatures during long periods with rain.

Due to the lack of studies showing disease in wild pollinators, we assess the likelihood of spillover of *A. apis*, the cause of chalkbrood, from managed honey bees to wild pollinators to be **unlikely** with **medium confidence**. The confidence level is based on the presence of the causal agent in Norway.

Stonebrood, aspergillosis

Aspergillus flavus has not been identified or documented in Norwegian honey-bee operations or apiaries (H. Sørum personal communication, April 15, 2024). While *A. flavus* is present in the environment worldwide, including Norway, it is likely that very few strains possess the capability to induce "stonebrood". The primary concern associated with stonebrood is the potential detection of aflatoxins in honey products, as these toxins are highly harmful to humans even at low concentrations and can lead to conditions such as cancer.

Pathogenic fungi from the genus *Aspergillus* have been detected in nests of several species of wild bees (Melville & Dade, 1944; LeCroy et al., 2023) and it has been suggested that spillover from non-native bees to honey bees is the cause of the infections.

In Norway, stonebrood has long been classified as a "List 2" disease by the Norwegian Food Safety Authority. Despite being on "List 2" the Food Safety Authority indicates that if an outbreak occurs it will be treated as a "List 1" disease, with stringent regulation involving the implementation of stamping-out protocols (complete eradication) should the disease be detected (H. Sørum personal communication, April 15, 2024).

Although the pathogen exists in the environment in Norway, stonebrood has not been observed in Norwegian honey bees. We therefore assess the likelihood of spillover of *A. flavus*, the cause of stonebrood, from managed honey bees to wild pollinators to be **very unlikely** with **medium confidence**. The confidence level is based on the absence of the causal agent in Norway.

Microsporidian Fungi

Nosemosis

Over decades nosemosis, caused by *Varimorpha*, has been observed in beehives to varying degrees in Norway (H. Sørum personal communication, April 15, 2024). This fungal infection is normally controlled without clinical symptoms appearing by using optimal hygienic measures in managing the beehives.

Although the microsporidians have been observed in wild pollinators, we are not aware of any study describing *Vairimorpha* infections in wild pollinators in Norway. To what extent they can spill over from honey bees to wild pollinators is largely unknown. We therefore assess the likelihood of spillover of *Vairimorpha* pathogens from managed honey bees to wild pollinators to be **unlikely** with **medium confidence**.

RNA viruses

Sacbrood virus

There has been, at least, one case of sacbrood (SBV) infection in Norway in bees weakened by *Varroa destructor* infestation (E. Rimstad, personal communication, April 4, 2024).

Due to the lack of reports addressing the prevalence and potential disease symptoms in wild pollinators, but the potential for other honey bee viruses (e.g. DWV) to infect wild bees, we assess the likelihood of spillover of SBV from managed honey bees to wild pollinators to be **unlikely** with **medium confidence**.

Deformed wing virus

Beekeepers have observed bees with deformed wings in Norwegian beehives with heavy *V. destructor* infestation (H. Sørum personal communication, April 15, 2024).

Due to good hygienic practices, that keep *V. destructor* infestations under control, Deformed wing virus (DWV) has not caused clinical disease in honey bees in Norway.

Based on the small number of reports showing that wild bees can be infected by DWV, but those studied showing limited signs of disease, we assess the likelihood of impact from spillover of DVW from managed honey bees to wild pollinators to be **unlikely** with **medium confidence**.

Black queen cell virus

There has been no observation or documentation of honey bee disease caused by Black queen cell virus (BQCV) in Norway (H. Sørum personal communication, April 15, 2024). We therefore assess the likelihood of impact from spillover of BQCV from managed honey bees to wild pollinators to be **very unlikely** with **medium confidence**.

4.3.2.2 Parasites

***Varroa destructor*, varroosis**

In 1990, the varroa mite (*Varroa destructor)* was introduced to Norway when a beekeeper imported non-registered beehives to Oslo from outside the country. Since then, *V. destructor* has spread extensively, reaching nearly all beekeeping districts in Norway, including the fruit-producing fjord districts of Western Norway (H. Sørum personal communication, April 15, 2024). The mite extracts lymphatic fluid from both adult bees and pupae, leading to a weakening of the bee population and, if left untreated, significant winter losses. The utilization of organic acids, such as formic acid and oxalic acid, along with the destruction of male brood, has proven effective in reducing the mite numbers, ensuring consistent honey production levels. In other countries, pesticides like organophosphates are used to control the mite population but this practice is prohibited in Norway due to the risk of chemical residues in honey products (H. Sørum personal communication, April 15, 2024).

We are not aware of any reports of *V. destructor* infesting non-*Apis* insects and we therefore assess the likelihood of impact from spillover of *V. destructor* from managed honey bees to wild pollinators to be **very unlikely** with **high confidence**.

Tracheal mite, acarapiosis

In 2002, the tracheal mite (*Acarapis woodi*) was detected in honey bees in four apiaries in Sogn og Fjordane, Norway. There are movement restrictions imposed on honey bees in the Hyllestad and Fjaler districts in Sogn og Fjordane, where this parasite was discovered over two decades ago. As of now, there have been no further detections, and no clinical diseases have been linked to this mite. Since it was reported in Sogn og Fjordane county (now Vestland county), no symptoms from this mite have been observed by Norwegian beekeepers. Probably the tracheal mite is effectively controlled by protocols used in *V. destructor* management (H. Sørum personal communication, April 15, 2024).

We are not aware of any reports of tracheal mites infecting non-*Apis* insects, and we therefore assess the likelihood of impact from spillover of tracheal mites from managed honey bees to wild pollinators to be **very unlikely** with **high confidence**.

Tropilaelaps mite

Tropilaelaps mites (*Tropilaelaps mercedesae*) is currently only found in Asia where it is a major contributor to *Apis mellifera* colony losses in that region (Chantawannakul et al., 2018; Phokasem et al., 2019). The mite is considered an important potential threat to beekeeping in Europe and elsewhere and this species could be a greater problem for honey bee apiaries than *V. destructor*, should it establish outside of its native range. Ling et al. (2023) point out that *tropilaelaps* mites have smaller size, more rapid locomotion, and a greater reproductive rate than *V. destructor* and hence a faster population growth.

Since tropilaelaps mites so far have not been observed in Norway (H. Sørum personal communication, April 15, 2024), and the lack of reports on infestation of non-*Apis* insects, we assess the likelihood of impact from spillover of tropilaelaps mites from managed honey bees to wild pollinators to be **very unlikely** with **high confidence**.

Small hive beetle

Commerce has expanded the native range of the small hive beetle (*Aethina tumida*) dramatically in the last two decades, and it is now widely established in North and Central America (including Hawaii), the Caribbean, and Australia, and there have been outbreaks in Egypt (not established) and the Philippines (fate unknown). In Europe, infestations have been reported in Portugal (not established) and Italy (considered established in at least Calabria) (Cordeiro et al., 2019). The small hive beetle has become a serious pest of managed honey bees in the invaded regions. Within the European Union, as well as Norway, there are established regulations governing diagnostic techniques and sanitation protocols for apiaries in the event of the spread of the small hive beetle beyond Italy or from further introductions from outside Europe (Franco & Ponti, 2021).

Since the small hive beetle has not yet been observed in Norway (H. Sørum personal communication, April 15, 2024) and there is limited knowledge about its ability to establish itself in the country, we assess the likelihood of impact from transmission of the small hive beetle from managed honey bees to wild pollinators, should it arrive, to be **very unlikely** with **medium confidence**.

4.3.3 Indirect impact through interactions with other species

4.3.3.1 Altered plant communities

Due to the number and nature of traits associated with plant species becoming invasive, we assess the likelihood impact of altered plant communities on wild pollinators resulting from increased pollination from managed honey bees to be **very unlikely** with **low confidence.**

4.3.3.2 Altered predation pressures

Since there is only one predator species of arthropod highly specialized on honey bees currently present in Norway (the European hornet), with limited population sizes and presence only in the southern part of the country, we assess the likelihood of impact from increased predation pressure, caused by managed honey bees, on wild pollinators to be **very unlikely** with **high confidence.**

4.4 Risk characterization

In this section, we assess the risks associated with each of the hazards identified in section 4.1, based on the magnitude of their potential impact, described in section 4.2 and the likelihood of the hazard occurring, described in section 4.3. The risks are quantified as **Low**, **Medium**, **Potentially high**, or **High**, as described in section 2.2 and presented in Figure 2.2-1. We also present the confidence level for each risk characterization, based on the confidence levels presented in sections 4.2 and 4.3.

4.4.1 Resource competition

4.4.1.1 Exploitative competition

We have assessed the risk of exploitative competition from managed honey bees for oligolectic bees with strong dietary overlap (>70%) with honey bees, bumble bees and all other wild pollinators separately (see Figure 4.4.1-1). **For oligolectic bees with high dietary overlap**, we assess the risk from exploitative competition from managed honey bees to be **medium** with **low confidence**. This is based on the limited ability of these bees to switch to alternative floral resources should honey bees be exploiting flowers on their preferred plant species. The confidence estimate is decided based on the low confidence associated with the likelihood of impact, due to limited knowledge on the dietary overlap of oligolectic bees and managed honey bees in Norway. **For bumble bees,** we assess the risk from exploitative competition from managed honey bees to be **medium** with **medium confidence** in **homogenous landscapes and/or landscapes with limited floral resources**. **In heterogeneous landscapes, with abundant floral resources**, we assess the risk from exploitative competition from managed honey bees to be **low**, with **medium confidence** since floral resources is not a limiting factor. Here, the confidence level is based on a limited number of studies showing different negative effects on bumble bees, from honey bees, in landscapes of contrasting structure (Herbertsson et al., 2016; Meeus et al., 2021). **For all other pollinators**, we assess the risk from exploitative competition from managed honey bees to be **low** with **low confidence.** Here, the confidence estimate is decided based on the limited knowledge on floral preferences of this diverse group of wild pollinators and their ability to switch forage plants in response to exploitative competition from honey bees under Norwegian conditions. We stress that the potential for exploitative competition is highly context dependent. Plant community composition, abundance of floral resources, and individual pollinator species foraging ranges and ability to switch among foraging plants might mediate the effects of competition.

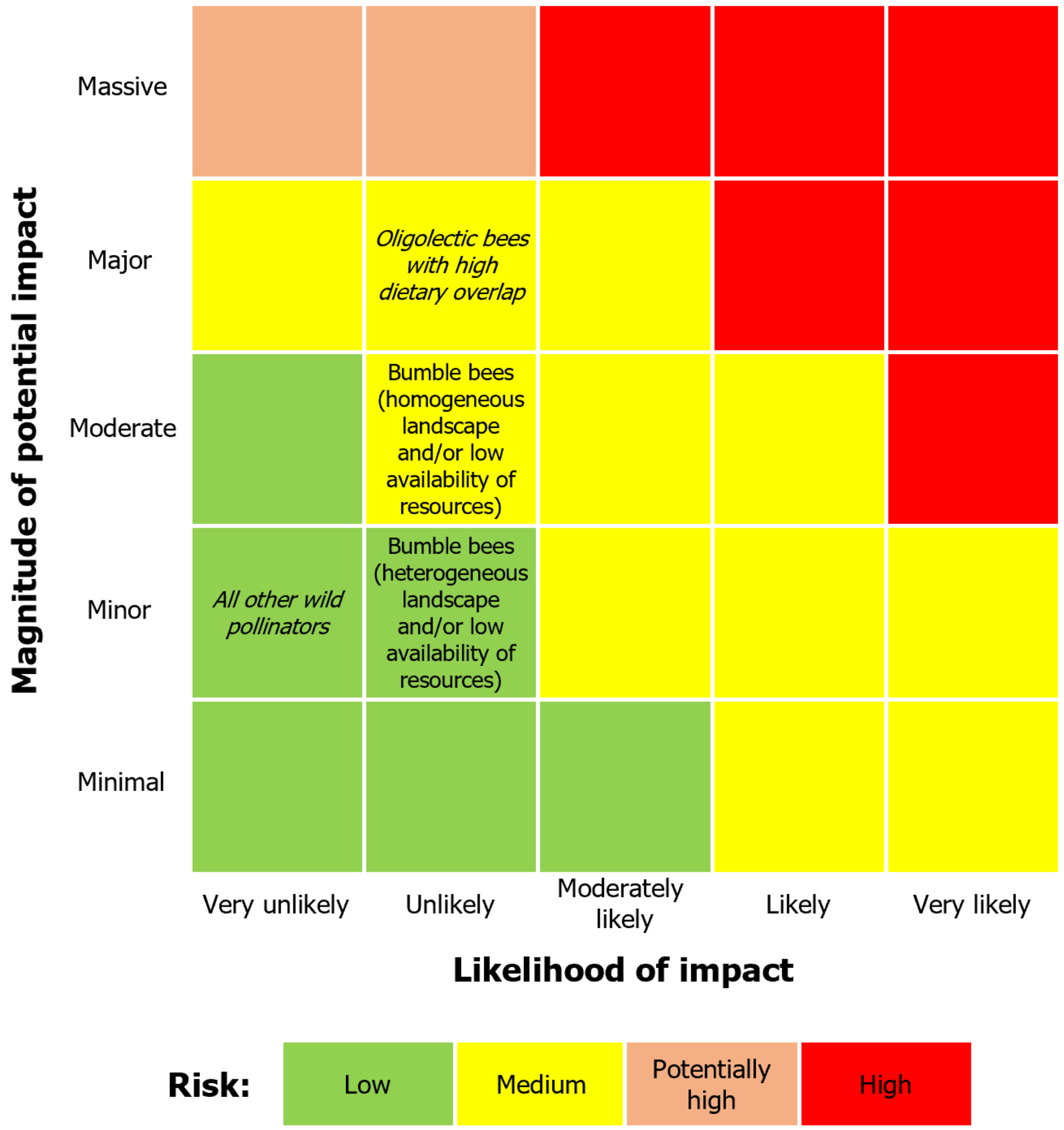


Figure 4.4.1.1-1. Summary of risk characterization of exploitative competition between managed honey bees and wild pollinators in Norway. The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*). We have characterized the risk for oligolectic bees with high dietary overlap with honey bees separately, based on Rasmussen at al. (2021) argumentation that species with >70% dietary overlap could be more prone to exploitative competition. The distinction between heterogeneous and homogeneous landscapes is based on the study by Herbertsson et al. (2016) showing that competition from honey bees was only apparent in homogeneous landscapes. Herbertsson et al. (2016) argue that this is due to heterogeneous landscapes containing a higher diversity of floral resources. We have made the same distinction regarding landscapes with high and low floral resource abundance.

4.4.1.2 Interference competition

We assess the risk of interference competition from managed honey bees on wild pollinators to be **low** with **medium confidence** (see Figure 4.4.1.2-1). The risk characterization is based on the lack of studies that has quantified the negative effects of interference competition and that those studies addressing the issue have given this mechanism limited support. The confidence level is based on the limited number of studies addressing this issue.

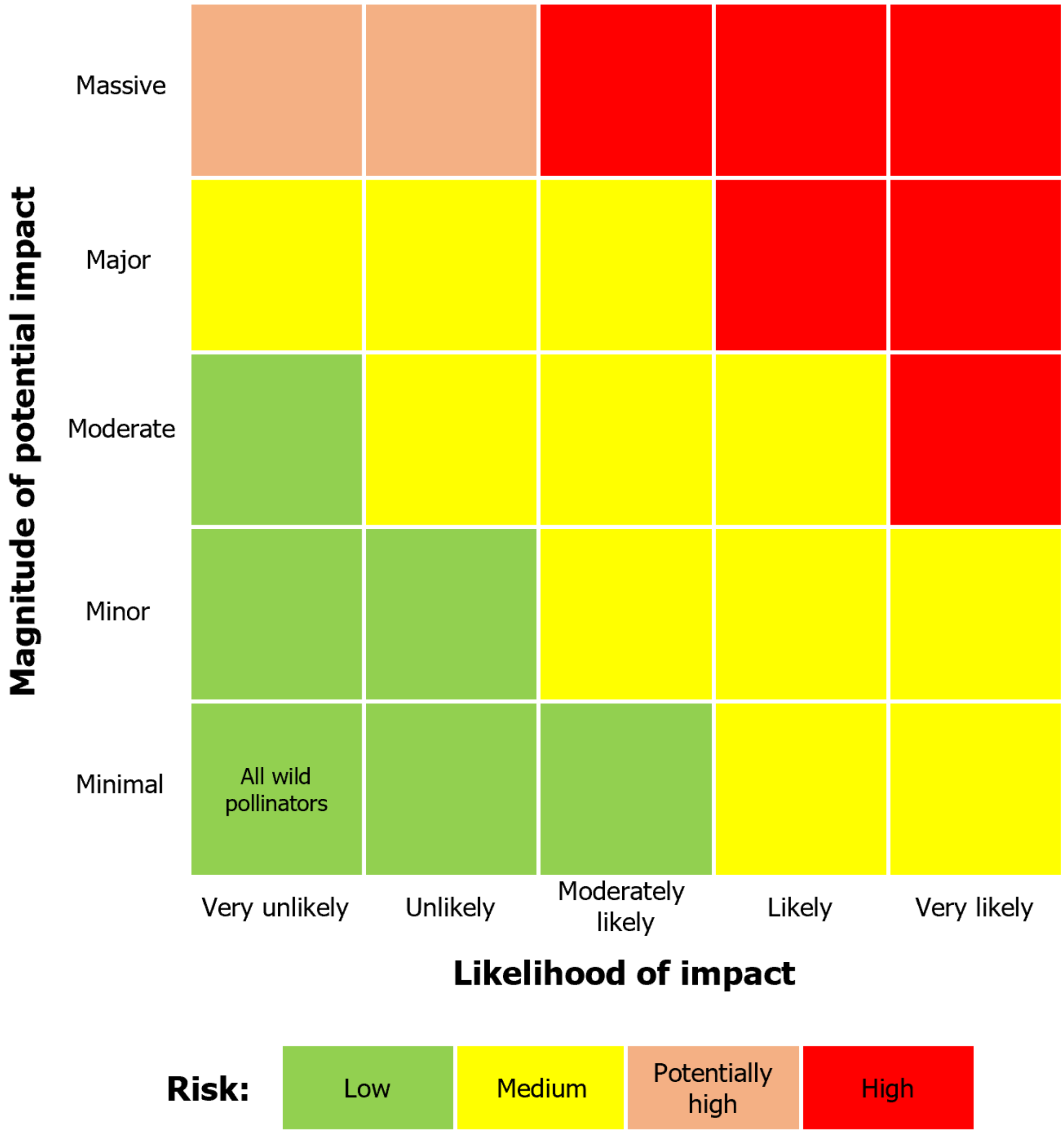


Figure 4.4.1.2-1. Summary of risk characterization of interference competition between managed honey bees and wild pollinators in Norway. The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*).

4.4.2 Transmission of pathogens and parasites

4.4.2.1 Pathogens

Bacterial diseases: American foulbrood and European foulbrood

American foulbrood (AFB) and European foulbrood (EFB) are currently not found in Norwegian beehives. We thus assess the risk of negative impact on wild pollinators from spillover of *Paenibacillus larvae*, the cause of AFB, and *Melissococcus plutonius* , the cause of EFB, from managed honey bees to be **low** with **high confidence** (see Figure 4.4.2.1-1). The confidence level estimate is based on the best evidence to our knowledge that AFB and EFB are currently not found in Norwegian beehives.

Ascomycete fungi: Chalkbrood and stonebrood

The strains of *Ascosphaera apis* (causing chalkbrood) found in Norwegian honey bees seem to exhibit a low level of virulence, and stonebrood has not yet been diagnosed in Norway. We therefore assess the risk of negative impact on wild pollinators from spillover of the pathogens causing chalkbrood and stonebrood from managed honey bees to be **low** with **medium confidence** (see Figure 4.4.2.1-1). The confidence level estimate is based both on the fact that *A. apis*, and fungi in the genus *Aspergillus* are found naturally in the environment, in Norway, but that limited knowledge exists on the potential for spillover from managed honey bees.

Microsporidian fungi: Nosemosis

We assess the risk of negative impact on wild pollinators from spillover of *Vairimorpha* pathogens from managed honey bees to be **low** with **medium confidence** (see Figure 4.4.2.1-1). The confidence level estimate is based both on the fact that nosemosis *Vairimorpha apis* and *Vairimorpha ceranae*, the cause of nosemosis, are found in beehives and in the environment, in Norway. Studies have shown that the fungi causing nosemosis in managed honey bees can infect also wild bees, but we are not aware of any studies assessing the potential for spillover from managed honey bees to other organisms.

RNA viruses: Sacbrood virus (SBV), deformed wing virus (DWV) and black queen cell virus (BQCV)

We assess the risk of negative impact on wild pollinators from spillover of SBV, DWV and BQCV from managed honey bees to be **low** with **medium confidence** (see Figure 4.4.2.1-1). This is due to the very low prevalence of these viruses in Norwegian bee hives (BQCV is not present in Norway). The confidence level estimate is based on the limited knowledge on the viruses' ability to cause disease in natural settings. Several studies have found the viruses in wild pollinators, but we are not aware of any study describing disease outbreaks in the wild.

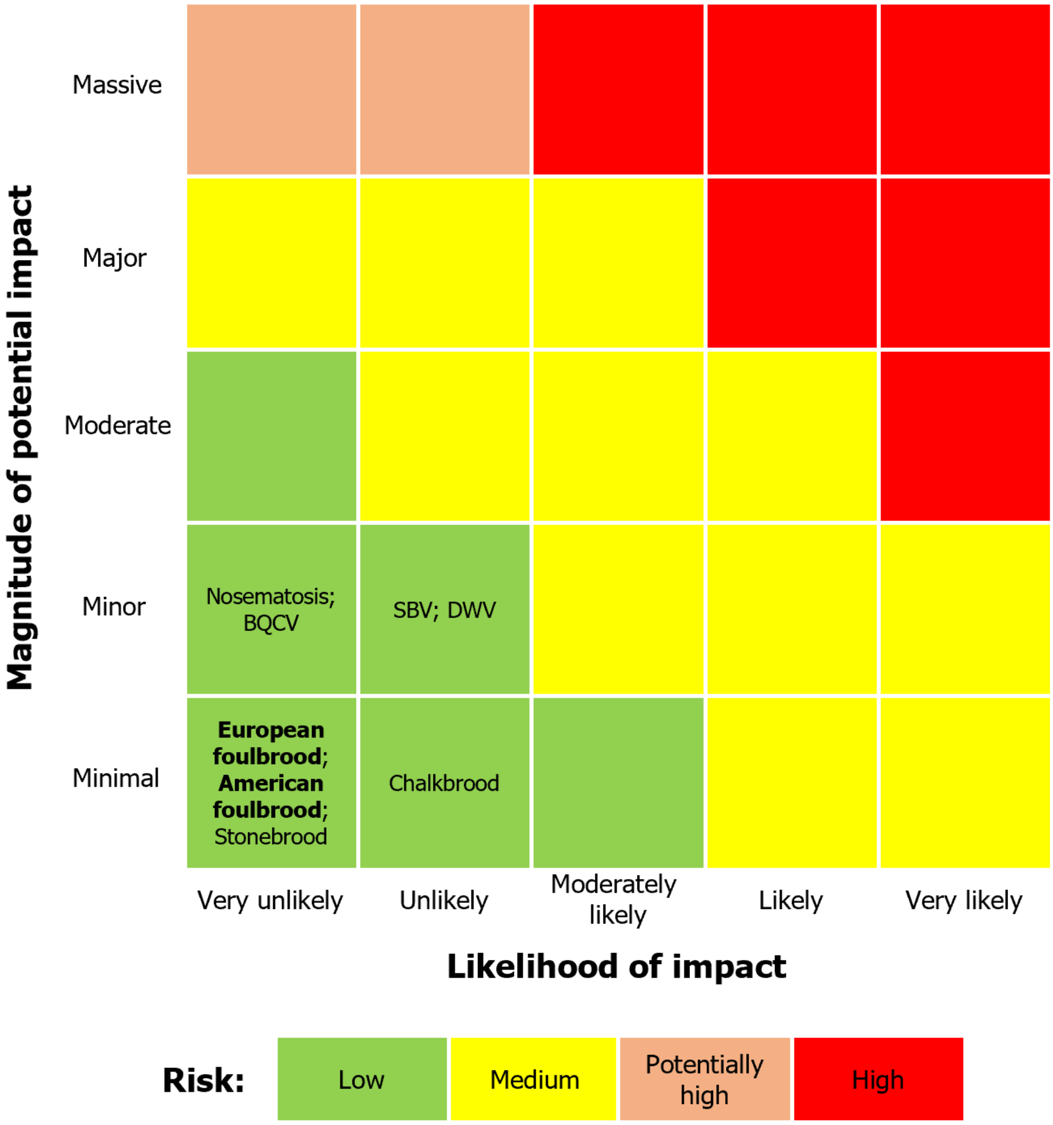


Figure 4.4.2.1-1. Summary of risk characterization of transmission of pathogens between managed honey bees and wild pollinators in Norway. For ease of interpretation, the disease names rather than those of the pathogens potentially causing them are presented in the figure. For the names of the pathogens potentially causing disease after spillover, see text above (section 4.4.2.1). The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*).

4.4.2.2 Parasites and the small hive beetle

Parasitic mites – *Varroa destructor*, tracheal mites and Tropilaelaps mites

None of the mites treated in this risk assessment have been reported to infest other species than honey bees. We stress that mite-infested managed honey bees can be prone to other diseases, consequently increasing the likelihood of disease spillover to wild pollinators, but this risk is treated in other sections of this opinion (4.2.2.2). We therefore assess the **risk** of negative impact on wild pollinators from spillover of parasitic mites from managed honey bees to be **low** with **high confidence** (see Figure 4.4.2.2-1).

Small hive beetle

We assess the **risk** of negative impact on wild pollinators from transmission of the small hive beetle from managed honey bees to be **low** with **medium confidence** (see Figure 4.4.2.2-1)**.** The confidence level estimate is because the beetle has never been found in Norway. However, it is found in Southern Europe and can potentially spread to Norway in the future. The beetle has been shown to infect also other bee species, but there is a lack of knowledge on the extent to which it can cause damage and what species it might affect.

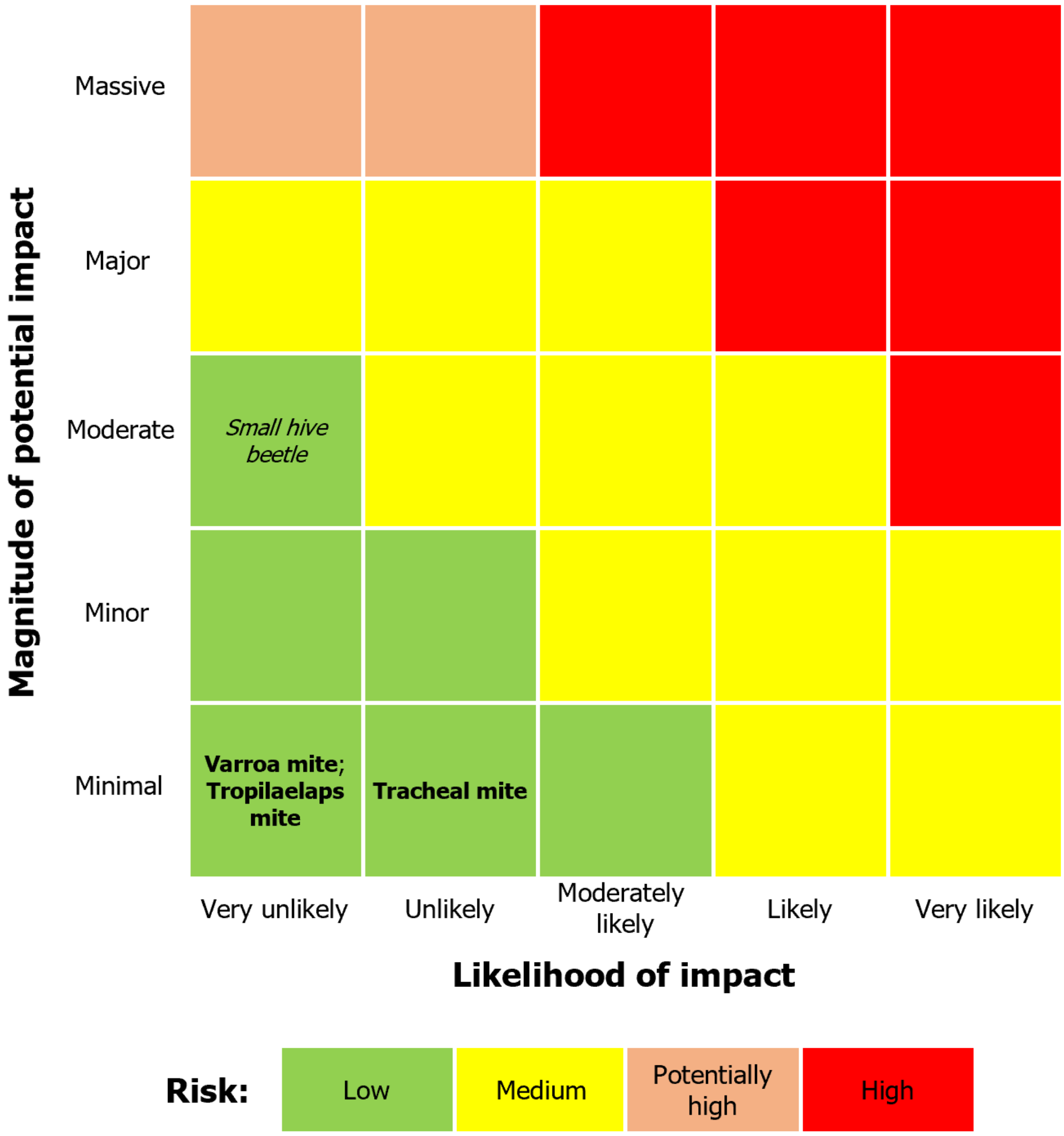


Figure 4.4.2.2-1. Summary of risk characterization of transmission of parasites and the small hive beetle between managed honey bees and wild pollinators in Norway. The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*).

4.4.3 Indirect impact through interactions with other species

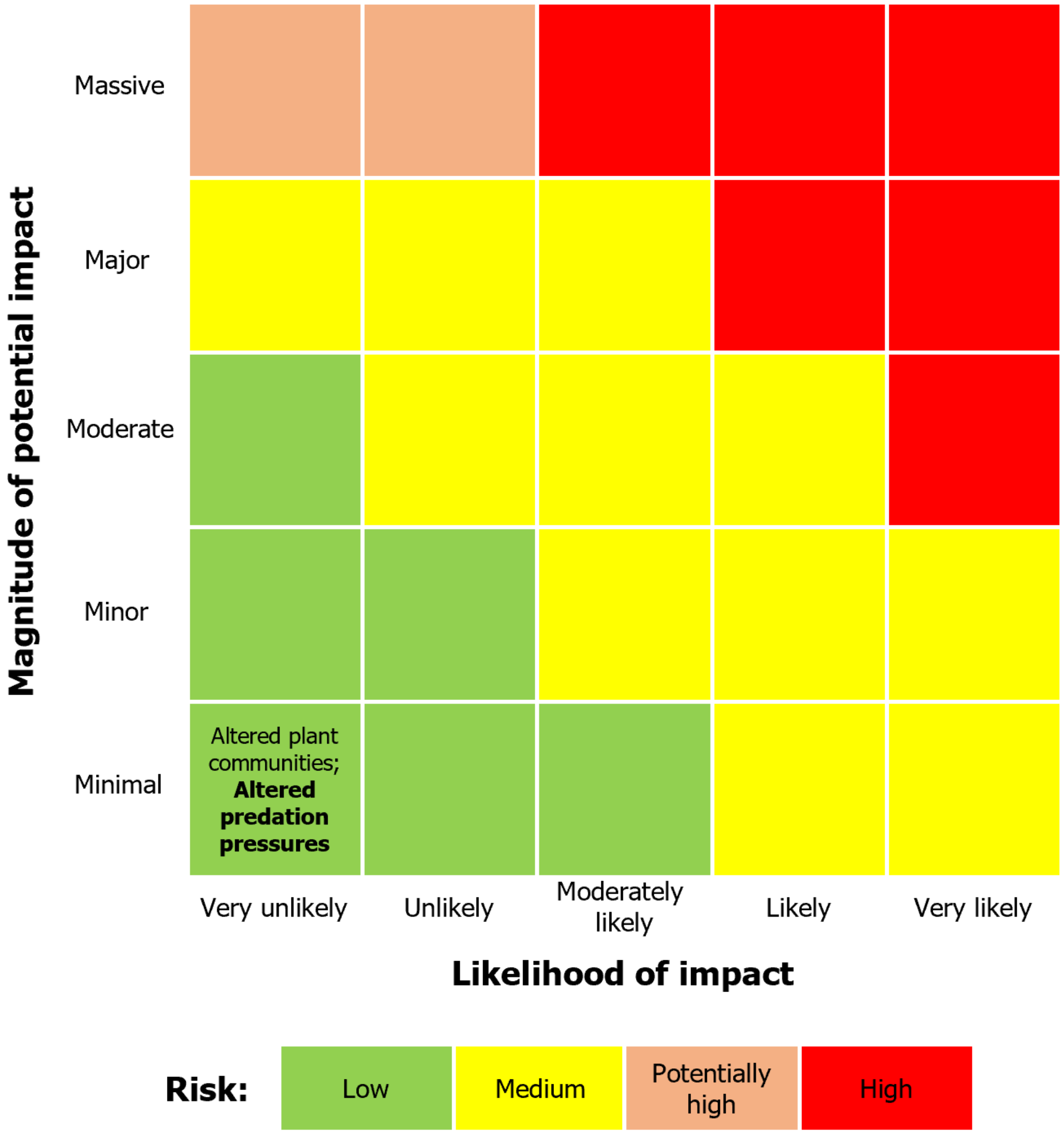


Figure 4.4.3-1. Summary of risk characterization of altered plant communities and altered predation pressures as a result of presence of managed honey bees on wild pollinators in Norway. The overall confidence level of a given risk characterization is indicated by font type (**High**, Medium, *Low*).

4.4.3.1 Altered plant communities

We have assessed the risk of negative impact on wild pollinators from altered plant communities due to selective pollination from managed honey bees to be **low** with **low confidence** (see Figure 4.4.3-1). The risk assessment is based on numerous studies showing that invasiveness in plant species rarely is due to insect pollination. The confidence level is based on the wide variety of, and usually unknown, dietary preferences of wild pollinators and the lack of knowledge on how strong the effect of honey bee pollination is on the invasiveness of plant species.

4.4.3.2 Altered predation pressures

We have assessed the risk of negative effects on wild pollinators from altered predation pressure due to increase in predator populations due to abundant managed honey bee populations to be **low** with **high confidence** (see Figure 4.4.3-1)**.** The risk assessment and confidence level are based on the limited number of potential honey bee predators (only European hornets) and its limited distribution and current population size in Norway.

5 Risk reducing measures

Risk reducing measures of negative effects from honey bees on wild pollinators include several approaches tailored to the type of negative effects of concern. Based on the 61 papers resulting from our literature search (see section 2.4), a total of 11 papers described or discussed risk reducing measures (Figure 5-1). Six of these focused on exploitative competition, while three dealt with pathogens, parasites, and predators. One study emphasised the importance of increased monitoring of pollinators in general, while the final paper suggested conceptual models to optimize beehive management. Thus, our literature search revealed that there are only a limited number of studies investigating how to reduce potential risk from honey bees on other bees and pollinators.

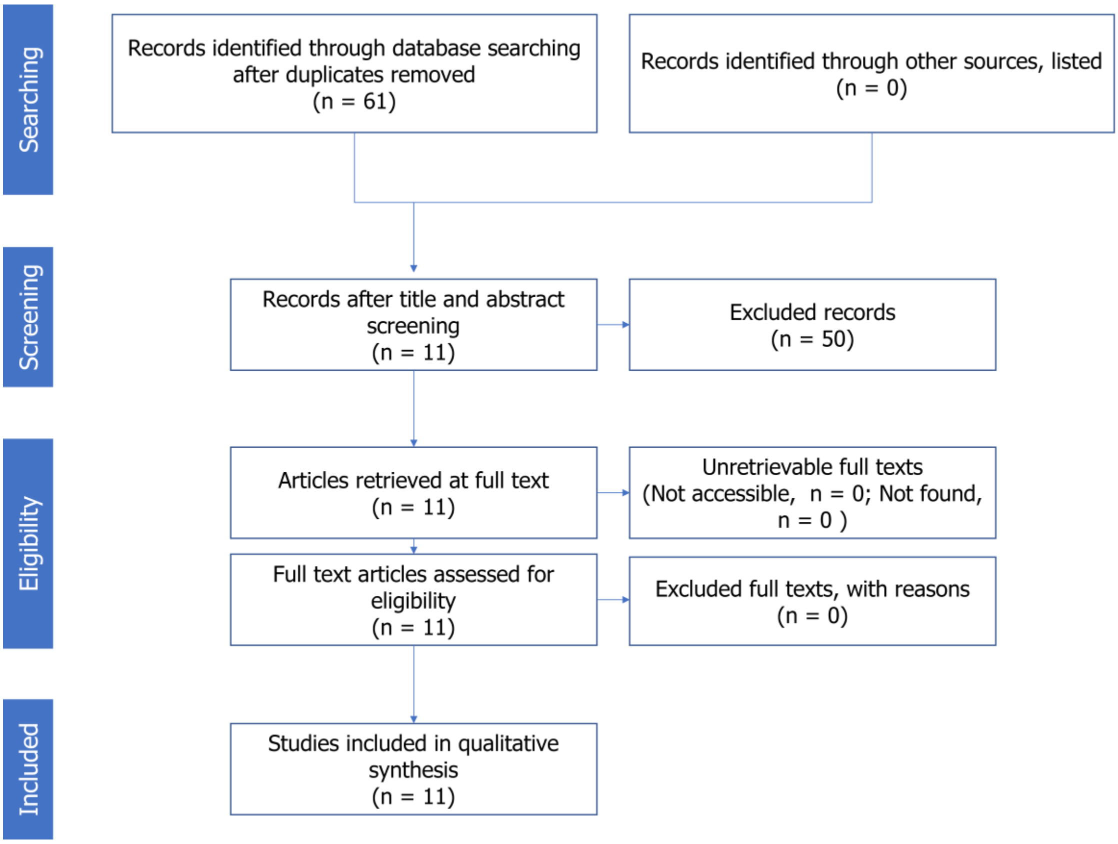


Figure 5-1. Flow diagram summarizing the literature search used to identify risk-reducing measures. For description of search methodology, see section 2.4.

5.1 Risk reducing measures related to exploitative competition for floral resources

One suite of suggested risk reducing measures are related to competition for food resources (nectar and pollen), such as minimum distance from honey bee hives to certain habitat types or areas. Distance to red-listed nature types may be particularly valuable for reducing potential negative effects on wild pollinators. Furthermore, such "buffer zones" could also be considered in areas with known populations of threatened pollinators, such as the large scabious mining bee (*Andrena hattorfiana*). Distance thresholds may be one option, as shown by Henry and Rodet (2018) in protected areas in southern France, where competition was reported from up to 1.1 km around honey bee apiaries. Managed honey bees are known to forage primarily within a 1 km radius and are rarely encountered at distances of 1.5-2.0 km from honey bee hives (Steffan-Dewenter & Tscharntke, 2000). Thus, "buffer zones" to vulnerable habitats/areas may be created, as suggested in a Dutch report (de Groot & Roessink, 2022). However, as also stated in de Groot and Roessink (2022), there might be practical challenges using "buffer zones" with multiple landowners, and the required buffer size is highly dependent on flower resources, both within and outside the buffer zones.

Another risk reducing measure is to restrict the total number of honey bee hives in a given area. Steffan-Dewenter & Tscharntke (2000), who studied exploitative competition in grasslands, suggested for instance a maximum of three honey bee hives per km^2 in Germany. However, the effect of this measure is highly context dependent depending on several factors, including distribution and density of floral resources, as well as other resource needs of both managed honey bees and the wild pollinators. In Norway, this may even depend on (climatic) regions.

The use of wildflower strips and/or managing field margins in agricultural landscapes to promote floral resources are generally used to increase diversity and abundances of wild pollinators (Ouvrard et al., 2018; Rundlöf et al., 2018; Doublet et al., 2022) but may potentially also buffer overlap and competition for food resources with managed honey bees. For instance, Doublet et al. (2022) recently showed that floral provisioning in wildflower strips and field margins decreased niche overlap between managed honey bees and bumble bees. However, Bommarco et al. (2021) showed reduced effects of flower strips on bumble bees when honey bee hives were added in the landscape. Similarly, restoration of semi-natural meadows may reduce potential competition in addition to a general increase in food resources for wild pollinators.

As a result of the National Pollinator Strategy in Norway, management strategies like mowing regimes along roads and in urban areas have been altered to facilitate floral resources for pollinators and may also mitigate competition between managed honey bees and wild pollinators (Norwegian Ministries, 2018). Similarly, as shown by Wehn et al. (2020), the timing of mowing in semi-natural grasslands can be crucial in terms of providing floral resources during the growing season.

Furthermore, seasonal shifts in floral preferences for both managed honey bees and wild pollinators may affect potential competition and is thus of importance to conservation management. Bendel et al. (2019), for example, showed an increase in specialization in both managed honey bees and wild bees towards the end of the season compared to earlier in the season in a grassland landscape. Two studies in grasslands emphasised promoting native floral resources for native bees as these bees were positively associated with native plants, while managed honey bees seemed to prefer exotic plants over native plants (Bendel et al., 2019; Pei et al., 2023).

Furthermore, spatial and temporal maps of cover crops and flowering periods could be used to estimate the carrying capacities of landscapes for supporting wild pollinators and to guide the placement of beehives to reduce the potential for competitive effects, as suggested by de Groot and Rosessink (2022). While knowledge of the needs and use of flowering resources of various wild pollinators in each area is often limited, general knowledge together with distributional data of especially wild bees might indicate important habitat patches. Indeed, effects of honey bee hives are greatest in intensively managed landscapes, such as urban areas (Meeus et al., 2021), and as shown by Herbertsson et al. (2016) the impact of honey bee hives on the density of bumble bees decreases with the availability of seminatural habitat types within a 1 km radius. Thus, modelling approaches that can estimate the honey bee carrying capacity of landscapes to minimize negative effects on wild bees can be used to guide hive placement so as to reduce the impact on wild pollinators.

5.2 Risk reducing measures related to pathogens, parasites, and predators

Diversification measures at field and landscape level mentioned in section 5.1 may in addition to mitigating potential exploitative competition also decrease prevalences and load of pathogens and their vectors (e.g., *Varroa destructor*) (Manley et al., 2023). A focus on honey bee health and hive hygiene is already an important part of beekeeping (see sections 1.2 and 1.3) and limits the probability of pathogen spillover to wild pollinators. Quarantining infected apiaries is another critical measure. In the outbreak of European foulbrood in Agder (see sections 4.2.2 and 4.3.2), caused by the bacterium *Melissococcus plutonius*, a 3 km distance from infected honey bee hives was established as a quarantine boundary (Mattilsynet, 2011). In addition to the usual sanitizing measures for the affected beehives, no bees or apiculture-associated materials were to be moved if they were within 3 km of an infected hive. Restrictions on transport halted transmission to new colonies (H. Sørum personal communication, April 15, 2024). The background for choosing 3 km in 2011 was the presumed maximum flying distance of 5 km round trip for bees from a beehive as well as experience from Switzerland that 1 km was too short a distance to avoid transmission of *M. plutonius* to new colonies (Belloy et al., 2017). Albeit limited to one instance of one disease in one locality, the success with using 3 km suggests that this distance works well to prevent spillover of honey bee pathogens to wild pollinators. However, though logical, to our knowledge there are no studies or established experience that demonstrate that this distance would eliminate the risk of transfer of bee pathogens, in general, from managed honey bees to wild pollinators. Limitation of movement of managed honey bees within Norway is already common practice in AFB and EFB sanitation and is applied to limit the spread of *Varroa destructor*.

Restricting the seasonal movement of honey bees between the European continent and Norway, and limiting the use to native honey bee subspecies, could reduce the risk of importing diseases to Norwegian honey bees and secondarily to wild pollinators. The motivation for moving honey bees from the European continent to Norway seasonally is primarily related to the heather areas in the Norwegian highlands and to some extent the coastal heather areas close to the ferry terminals in the Oslofjord area. There has been an interest from continental beekeepers to bring hives to Norway for the period of mid-July to early September to harvest the valuable heather honey. Current regulations do not allow for this type of cross-border migration beekeeping (Mattilsynet, 2022), but the regulations might be challenged in the future through the EEA agreement.

Importing beehives from continental Europe would increase the risk for spreading pathogens to Norwegian honey bees, and subsequently to wild pollinators. Restricting the movement of honey bees across the Norwegian border would decrease the likelihood of introducing pathogens and parasites to Norwegian honey bees and thus reduce the potential for spillover to wild pollinators.

Monitoring and eradication of emerging pathogens, parasites, and predators of managed honey bees are important measures for apiculture and can also be important measures for wild pollinators as this would reduce the potential for spillover.

5.3 Monitoring and guidelines for placing hives

Currently, no guidelines on hive placement or number of hives allowed are in place in Norway. Designing such guidelines is difficult, due to the strong context dependency of potential risk from managed honey bees on wild pollinators. For guidelines to be useful, increased monitoring of densities of beehives as well as monitoring of wild pollinators is needed. A better understanding of pollinator carrying capacity could be used to guide stocking rates and placements of hives to minimize impacts on wild pollinators. Monitoring of pollinators in general would improve conservation measures as reported in a global study by Halvorson et al. (2021). The presence of threatened wild pollinators and species with high dietary overlap with managed honey bees in an area could be used for making guidelines when placing honey bee hives, as suggested by Rasmussen et al. (2021). Lower honey production could also indicate limited floral resources which again may indicate higher risk of exploitative competition between honey bees and wild pollinators.

Another approach could be to use conceptual models as shown by Mouillard-Lample et al. (2023) where floral resources, ecosystem services, farming systems, beekeepers, stakeholders, and social perceptions from the different actors is integrated to optimize management. Furthermore, Mouillard-Lample et al. (2023) stresses the idea of floral resources as a "common-pool resource" providing multiple ecosystem services despite different perceptions of different actors.

5.4 Evidence for effects of risk reducing measures

Effectiveness of risk-reducing measures can be assessed using a framework of scoring effectiveness of actions, such as those used in *What Works in Conservation* providing expert assessments (Conservation Evidence, not dated). Panels of experts are typically used to compile and determine effectiveness of various actions. So far, such panels have evaluated the following actions to be beneficial towards pollinators in general; planting of flowers, wildflower strips, grass buffer strips and hedgerows, reducing land-use intensity and restoring/creating semi-natural grasslands, especially in arable and pasture fields (see conservationevidence.com for details).

However, no assessment of risk reducing measures regarding the potential negative effects of managed honey bees on wild pollinators are, to the best of our knowledge, currently available. We thus scored the effectiveness, certainty, and harms of the various risk reducing measures described in 5.1-5.3 following the approach developed by Conservation Evidence. Hence, we scored each identified risk reducing measures for:

- Effectiveness: 0% = not effective, 100% = highly effective.
- Certainty of the evidence: 0% = no evidence, 100% = high quality evidence; complete certainty. This is certainty of effectiveness of intervention, not of harms.
- Harms: 0% = none, 100% = major undesirable effects.

All scores are based on a consensus in the project group, and categorization follows Conservation Evidence and is based on a combination of the size of the benefit and harm and the strength of the evidence (see Table 5.4-1). All scores have been evaluated solely based on ecological consequences for wild pollinators; potential negative effects on beekeeping were not considered. We have assessed reducing exploitative competition as likely to be beneficial with medium certainty and low harm in terms of negative effects. Furthermore, using guidelines, conceptual models and intensified monitoring (see 5.3) are also assessed as likely to be beneficial. Reducing pathogens and parasites is an ongoing and successful measure, and pathogen and parasite pressures in Norwegian honey bee hives are generally low compared to other parts of the world. Based on the observed success of this measure, we expect a low risk for wild pollinators regarding spillover of pathogens and parasites from honey bees. Although the uncertainties associated with reducing the probability of spillover of pathogens and parasites to wild pollinators is large, we still expect this risk reducing measure to be likely to be beneficial in the long run.

Table 5.4-1. Effectiveness of identified risk reducing measures based on the approach developed by Conservation Evidence (see conservationevidence.com for details on the method).

Type of measure	Overall effectiveness category	Effectiveness*	Certainty**	Harms***
Reducing exploitative competition	Beneficial	>60%	>60%	<20%
Reducing pathogens, parasites, and predators	Likely to be beneficial	40-60%	40-60%	<20%
Monitoring and guidelines for placing hives	Likely to be beneficial	40-60%	40-60%	<20%

*Effectiveness: 0% = not effective, 100% = highly effective.

**Certainty of the evidence: 0% = no evidence, 100% = high quality evidence; complete certainty. This is certainty of effectiveness of intervention, not of harms.

***Harms: 0% = none, 100% = major undesirable effects.

6 Conclusions (with answers to the terms of reference)

The current opinion provides an overview of the potential impacts managed honey bees may have on wild pollinators and offers a risk assessment within the context of Norway. Additionally, potential risk-reducing measures specific to the Norwegian context are identified and evaluated.

The existing literature suggests that managed honey bees can compete with wild pollinators for floral resources. Most studies have focused on bumblebees or hole nesting solitary bees and very little is known about other flower-visiting insects. Yet, because beekeeping in Norway usually occurs at very low densities, we consider the risk of exploitative competition from managed honey bees to be low for most wild pollinators. For oligolectic bees with strong dietary overlap (>70%) with managed honey bees and for bumble bees in homogeneous landscapes with limited floral resources, we assess the risk of exploitative competition from managed honey bees to be medium. The increased risk to these pollinator groups is based on the potential for exploitative competition from managed honey bees for floral resources. It is, however, important to underline that there may be cases where competition can be of particularly high importance. For example, little is known about the potential impact of managed honey bees on threatened species in Norway. Therefore, the precautionary principle could be considered in management of beekeeping in and near populations of particularly sensitive, threatened species of wild pollinators. For all other potential hazards identified, we assess the risk to wild pollinators from managed honey bees to be low. Most of our assessments are based on information from international, peer-reviewed studies and it has in many cases been necessary to apply expert knowledge to put the risk assessments into a Norwegian context.

Below VKM addresses the Terms of Reference point-by-point.

1) Summary of the literature: A brief review of the available literature on the potential negative effects of managed honey bees on wild pollinating insects is presented in chapter 3 of this opinion. Based on this literature review, VKM concludes that under certain conditions managed honey bees can have clear, measurable, negative effects on wild pollinators with which they share floral resources. Studies have also shown that managed honey bees can facilitate the spread of invasive plant species, potentially altering plant communities and negatively affecting the preferred floral resources for wild pollinators. VKM is, however, not aware of any study investigating the effect on wild pollinators due to altered plant communities caused by managed honey bees. Several bacterial, viral, and fungal pathogens known to infect honey bees have been found in wild pollinators. The detection of honey bee pathogens in wild pollinators may be ascribed to spillover from honey bees, most likely through sharing of floral resources. Many of these pathogens do, however, occur naturally in the environment and to what extent they cause disease in wild pollinators is unknown and undetected for most wild pollinators. Several parasitic mites can infest hives of managed honey bee, but none of these have been shown to infest wild pollinators found in Norway. One common honey bee pest, the small hive beetle, has been found to also infect nests of wild bees. This species is not currently found in Norway.

2) Risk of negative impacts of managed honey bees on wild pollinators: VKM have assessed the risk of beekeeping having negative impact on wild pollinators through three types of hazards; 1) competition for floral resources, 2) spillover of pathogens and parasites, and 3) indirect effects through alterations of plant communities and predator populations (see Appendix IV for a table summarising the outcome of the risk assessment).

1) VKM concludes that there is medium risk of managed honey bees having negative impact on oligolectic bees (species that only forage on a limited number of plant species) with high dietary overlap with honey bees and bumble bees in homogeneous landscapes and/or landscapes with low amounts of floral resources, through exploitative competition. For all other wild pollinators, we have assessed the risk from this hazard to be low. For interference competition, we assess the risk to be low for all wild pollinators in Norway.

2) VKM concludes that the risk of managed honey bees negatively affecting wild pollinators through spillover of pathogens and parasites to be low. The low risk is partly due to the high hygienic standards of beekeeping in Norway, with continuous monitoring and strict measures for eradication that are implemented when disease outbreaks are detected.

3) VKM concludes that the risk of managed honey bees, through selective pollination of certain plants, affecting plant community composition in a way that negatively affect floral resource availability for wild pollinators to be low. Finally, VKM concludes that the risk of managed honey bee predators to negatively affect wild pollinators to be low, as the only potential predator in Norway is the European hornet and it currently occurs in relatively low numbers and only in certain parts of the country.

- **Significance of the number of beehives and distance to resources for wild pollinators**

Since 2013, the number of beekeepers in Norway has steadily increased; in particular, in urban areas. Studies have suggested that a maximum of three bee hives per km^2 would minimize the effect of exploitative competition, but we stress that the number of beehives within an area needed to pose such risk is highly context dependent. In heterogeneous landscapes with abundant floral resources, the number of hives could be higher than in an area where floral resources are scarce. Studies have shown that, despite observations of foraging bouts of several kilometres, the main foraging range of honey bees falls within a 1 km radius from the hive.

- **The importance of the deployment of beehives in relation to how vulnerable populations of wild pollinators are (for example, near threatened species)**

To protect vulnerable pollinator species from floral resource competition from managed honey bees, placing hives more than 1 km from the vulnerable species' preferred foraging habitat could be used as a rule of thumb (see section 5.1 for an example from the Netherlands). To fully stop disease spread (among managed honey bee hives), the Food Safety Authority in Norway have used a 3 km radius around infected apiaries as a quarantine zone, based on the unsuccessful use of a 1 km radius in Switzerland (Belloy et al., 2017). Since VKM assesses the risk of pathogen and parasite spillover from managed honey bees to wild pollinators to be low, VKM concludes that a 1 km distance will likely be sufficient to minimize the risks posed by honey bees to wild pollinators in Norway.

3) Risk reducing measures: VKM has identified three types of mitigation measures that might reduce the risk of negative effects of managed honey bees on wild pollinators (explained in detail in chapter 5).

1. *Management of food resources*. It is plausible that the potential for competition for floral resources is reduced by either reducing the number of managed honey bees or increasing the amount of floral resources in an area, but there is limited scientific evidence quantifying the effects of these measures. To increase the amount of floral resources, both establishing flower strips and promoting native flora in existing habitats have been suggested. Mapping of floral resources can be used to estimate the carrying capacity of an area, for both managed honey bees and wild pollinators and can be used to guide the placement of honey bee hives in the landscape. Mapping of floral resources on larger scales is difficult, and for most wild pollinators their floral preferences and resource needs are unknown. Hence, for such an approach to be valuable, further research is needed. Putting a limit on the number of hives allowed within an area or establishing buffer zones without managed honey bees in a radius around vulnerable pollinator populations can protect wild pollinators and may be a useful strategy to guard populations of sensitive species.

2. *Management of colony health*. Maintaining good health of managed honey bees will reduce the potential for pathogen and parasite spillover to wild pollinators. We have assessed the risk from spillover of pathogens and parasites from managed honey bees to wild pollinators to be low in Norway, for the time being. Currently, the health status of Norwegian managed honey bees is good, due to high competence among the beekeepers and effective surveillance coordinated by the Norwegian Food Safety Authority. Local disease outbreaks

or a general reduction in the health of managed honey bees could potentially increase the risk of spillover to wild pollinators and all means of keeping managed honey bees healthy will mitigate this potential risk.

3. *Needs of wild pollinators*. Increased knowledge on floral resource availability and floral needs and preferences of wild pollinators can be used to guide the number and geographic placing of honey bee hives within a landscape, to minimize the potential for floral resource competition. Better knowledge on dietary overlap between managed honey bees and wild pollinators is also needed for effective mitigation of potential negative effects.

7 Data gaps and uncertainties

There is a lack of knowledge on the floral preferences of many pollinators in Norway. For most species also diet breadth and ability to switch food sources in response to e.g., competition from managed honey bees is largely unknown. Basic studies on the foraging ecology of individual pollinator species are therefore needed to better understand which species might be more prone to floral resource competition from managed honey bees.

Little is known regarding competition between managed honey bees and other pollinators than wild bees, such as hover flies, moths, and beetles. In general, monitoring of populations of wild pollinators over time is needed if one is to detect effects of potential competition. Furthermore, studies on potential competition between managed honey bees and wild pollinators in a Norwegian setting are lacking. There is also a lack of information about pollinator communities in many Norwegian ecosystems, thus further emphasizing the need for future studies to map pollinators, including also other groups than bees. Observed changes in species diversity and populations are often explained by multiple factors. It is therefore crucial to study fitness effects on wild pollinators if one is to disentangle the effects of potential competition between managed honey bees and wild pollinators from those of other factors.

Only a few studies have investigated the impact from managed honey bees on the fitness of wild pollinators, such as potential negative effects on growth, reproductive output, and survival due to competition over shared food resources or due to pathogens. Most studies have not explored fitness effects, merely potential effects due to overlap in resource use, changes in foraging patterns or changes in visitation rates in general. Furthermore, there is also a lack of experimental studies manipulating the number and strength of beehives. Such studies should be conducted in different landscapes including both heterogenous areas and homogenous areas including different amounts of floral resources.

There are also few studies investigating spillover and consequently negative effects of pathogens and parasites from managed honey bees to wild pollinators. Yet, some studies have found virulence of honey bee pathogens in wild bees, such as solitary bees. When bumble bees are experimentally exposed to honey bee pathogens, there seems to be an important difference in virulence depending on whether the virus is injected or ingested (by drinking nectar or sugar water), where the latter has much lower virulence effects. More research is needed to fully understand to what degree experimental results are realistic for natural situations. At least two honey bee-associated viruses (DMV, BQCV) are widely shared with wild pollinators, and a number of others are shared in at least some regions. Though there has been much research into their effects in managed honey bees, little is known about their virulence and epidemiology—and hence, of their impacts—in populations of wild pollinators.

Furthermore, uncertainties exist regarding the effectiveness of risk-reducing measures that involve maintaining a minimum distance from beehives to minimize risk. Efficiency of different threshold distances could therefore be evaluated to determine safe distances that would help ensure isolation of wild pollinator populations from managed honey bees. Future studies should further explore which distances could be recommended for different stocking densities and in different types of landscapes.

8 References

Aizen, M. A., & Feinsinger, P. (1994). Habitat fragmentation, native insect pollinators, and feral honey bees in Argentine "chaco serrano". *Ecological Applications*, 4(2), 378–392. https://doi.org/10.2307/1941941

Al Naggar Y., Paxton R.J. (2020) Mode of transmission determines the virulence of black queen cell virus in adult honey bees, posing a future threat to bees and apiculture. *Viruses*, 12. DOI: 10.3390/v12050535.

Alger, S. A., Burnham, P. A., & Brody, A. K. (2019). Flowers as viral hot spots: Honey bees (*Apis mellifera*) unevenly deposit viruses across plant species. *PloS ONE,* 14(9), e0221800. https://doi.org/10.1371/journal.pone.0221800

Anderson, M., Rotheray, E. L., & Mathews, F. (2023). Marvellous moths! pollen deposition rate of bramble (*Rubus futicosus* L. agg.) is greater at night than day. *PloS ONE*, 18(3), e0281810. https://doi.org/10.1371/journal.pone.0281810

Armstrong, R. A., & McGehee, R. (1980). Competitive exclusion. *The American Naturalist*, 115(2), 151-170. https://www.jstor.org/stable/2460592

Aronstein, K. A., & Murray, K. D. (2010). Chalkbrood disease in honey bees*. Journal of Invertebrate Pathology*, 103(Suppl), S20-9. https://doi.org/10.1016/j.jip.2009.06.018

Artsdatabanken (not dated). *Blomsterfluer Syrphidae*. Retrieved May 6, 2024, from https://www.artsdatabanken.no/taxon/Syrphidae/22699

Bailes, E. J., Deutsch, K. R., Bagi, J., Rondissone, L., Brown, M. J. F., & Lewis, O. T. (2018). First detection of bee viruses in hoverfly (syrphid) pollinators. *Biology Letters*, 14. https://doi.org/10.1098/rsbl.2018.0001

Baldock, K. C. R, Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., Potts, S. G., Vaughan, I. P., & Memmott, J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*, 282(1803), 20142849. https://doi.org/10.1098/rspb.2014.2849

Balfour, N. J., Gandy, S., & Ratnieks, F. L. W. (2015). Exploitative competition alters bee foraging and flower choice. *Behavioral Ecology and Sociobiology*, 69, 1731–1738. https://doi.org/10.1007/s00265-015-1985-y

Barbet-Massin, M., Rome, Q., Muller, F., Perrard, A., Villemant, C., & Jiguet, F. (2013). Climate change increases the risk of invasion by the YYellow-legged hornet. *Biological Conservation*, 157, 4-10. https://doi.org/10.1016/j.biocon.2012.09.015

Bartsch, H. (2009). Nationalnyckeln. *Tvåvingar: Blomflugor. Diptera: Syrphidae: Eristalinae & Mi-crodontinae*. SLU ArtDatenbanken.

Bauer, A. A., Clayton, M. K., & Brunet, J. (2017). Floral traits influencing plant attractiveness to three bee species: Consequences for plant reproductive success. *American Journal of Botany*, 104, 772-781. https://doi.org/10.3732/ajb.1600405

Becchimanzi, A., & Nicoletti, R. (2022). Aspergillus-bees: A dynamic symbiotic association. *Frontiers in Microbiology*, 13, 968963. https://doi.org/10.3389/fmicb.2022.968963

Belloy L., Imdorf A., Fries I., Forsgren E., Berthoud H., Kuhn R., Charrière J.-D. (2007) Spatial distribution of *Melissococcus plutonius* in adult honey bees collected from apiaries and colonies with and without symptoms of European foulbrood. *Apidologie*, 38:136–140. DOI: 10.1051/apido:2006069.

Bendel, C. R., Kral-O'Brien, K. C., Hovick, T. J., Limb, R. F., & Harmon, V. (2019). Plant–pollinator networks in grassland working landscapes reveal seasonal shifts in network structure and composition. *Ecosphere,* 10:e02569. https://doi.org/10.1002/ecs2.2569

Beverley C. (2012) *Acarapis woodi* (honeybee mite). CABI Compendium 2527. DOI: https://doi.org/10.1079/cabicompendium.2527.

Bommarco, R., Lindström, S. A. M., Raderschall, C. A., Gagic, V., & Lundin, O. (2021) Flower strips enhance bumble bee queens and males in landscapes with few honey bee hives. *Biological Conservation*, 263, 109363. https://doi.org/10.1016/j.biocon.2021.109363

Blackburn, T. M., Essl, F., Evans, T., Hulme, P. E., Jeschke, J. M., Kühn, I., Kumschick, S., Marková, Z., Mrugała, A., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Ricciardi, A., Richardson, D. M., Sendek, A., Vilà, M., Wilson, J. R. U., Winter, M., Genovesi, P., & Bacher, S. (2014). A unified classification of alien species based on the magnitude of their environmental impacts. *PLoS Biology*, 12(5), e1001850. https://doi.org/10.1371/journal.pbio.1001850

Blösch, M. (2000). *Die Grabwespen Deutschlands: Lebensweise, Verhalten, Verbreitung. Die Tierwelt Deutschlands 71*. Goecke & Evers.

Bratlie O. (1976). *Bier og birøkt.* Cappelen.

Brettell, L. E., Schroeder, D. C., & Martin, S. J. (2020). RNAseq of deformed wing virus and other honey bee-associated viruses in eight insect taxa with or without *varroa* infestation. *Viruses*, 12. https://doi.org/10.3390/v12111229

Bromley, S. W. (1948). Honey-bee predators. *Journal of the New York Entomological Society*, 56(3), 195-199. http://www.jstor.org/stable/25005271

Bunger, A. A. (2020). Norsk honningsektor - utvikling og framtidsplaner blant norske birøktere. AgriAnalyse. https://www.agrianalyse.no/getfile.php/135371-1583412614/Dokumenter/Dokumenter%202020/Rapport%202-Honningsektoren.pdf

Burkle, L. A., Marlin, J. C., & Knight, T. M. (2013). Plant-pollinator interactions over 120 years: Loss of species, co-occurrence, and function. *Science,* 339, 1611–1615. https://doi.org/10.1126/science.1232728

Cane, J. H. (2016). Adult pollen diet essential for egg maturation by a solitary *Osmia* bee. *Journal of Insect Physiology*, 95, 105–109. https://doi.org/10.1016/j.jinsphys.2016.09.011

Cane, J. H., Dobson, H. E. M., & Boyer, B. (2017). Timing and size of daily pollen meals eaten by adult females of a solitary bee (*Nomia melanderi*) (Apiformes: Halictidae). *Apidologie*, 48(1), 17–30. https://doi.org/10.1007/s13592-016-0444-8

Cane, J. H. & Tepedino, V. J. (2017). Gauging the effect of honey bee pollen collection on native bee communities. *Conservation Letters*, 10, 205-210. https://doi.org/10.1111/conl.12263

Cappellari, A., Bonaldi, G., Mei, M., Paniccia, D., Cerretti, P., & Marini, L. (2022). Functional traits of plants and pollinators explain resource overlap between honeybees and wild pollinators. *Oecologia*, 198, 1019-1029. https://doi.org/10.1007/s00442-022-05151-6

Chantawannakul, P., Ramsey, S., vanEngelsdorp, D., Khongphinitbunjong, K., & Phokasem, P. (2018). *Tropilaelaps* mite: an emerging threat to European honey bee. *Current Opinion in Insect Science*, 26, 69-75. https://doi.org/10.1016/j.cois.2018.01.012

Chen, Y. P., Pettis, J. S., Corona, M., Chen, W. P., Li, C. J., Spivak, M., Visscher, P. K., DeGrandi-Hoffman, G., Boncristiani, H., Zhao, Y., vanEngelsdorp, D., Delaplane, K., Solter, L., Drummond, F., Kramer, M., Lipkin, W. I., Palacios, G., Hamilton, M. C., Smith, B., Huang, S. K., Zheng, H. Q., Li, J. L., Zhang, X., Zhou, A. F., Wu, L. Y., Zhou, J. Z., Lee, M. L., Teixeira, E. W., Li, Z. G., & Evans J. D. (2014). Israeli acute paralysis virus: epidemiology, pathogenesis and implications for honey bee health. *PLoS Pathogens*, 10(7), e1004261. https://doi.org/10.1371/journal.ppat.1004261

Cilia, G., Flaminio, S., Zavatta, L., Ranalli, R., Quaranta, M., Bortolotti, L., & Nanetti, A. (2022). Occurrence of honey bee (*Apis mellifera* L.) pathogens in wild pollinators in northern Italy. *Frontiers in Cellular and Infection Microbiology,* 12, 907489. https://doi.org/10.3389/fcimb.2022.907489

Cilia, G., Zavatta, L., Ranalli, R., Nanetti, A., & Bortolotti, L. (2021). Replicative deformed wing virus found in the head of adults from symptomatic commercial bumblebee (*Bombus terrestris*) colonies. *Veterinary Sciences,* 8(7), 117. https://doi.org/10.3390/vetsci8070117

Cini, A., Cappa, F., Petrocelli, I., Pepiciello, I., Bortolotti, L., & Cervo, R. (2018). Competition between the native and the introduced hornets *Vespa crabro* and *Vespa velutina*: a comparison of potentially relevant life-history traits. *Ecological Entomology*, 43, 351-362. https://doi.org/10.1111/een.12507

Cini, A., Benetello, F., Bonifacino, M., Salvati, V., Monterastelli, L., Pasquali, L., Sistri, G., Dani, F. R., & Dapporto, L. (2022). Simple and informative: applying a basic *Anthophila* monitoring scheme in a simplified insular ecosystem. *Bulletin of Insectology*, 75, 83–95.

Cohen, H., Smith, G. P., Sardinas, H., Zorn, J. F., McFrederick, Q. S., Woodard, S. H., & Ponisio, L. C. (2021). Mass-flowering monoculture attracts bees, amplifying parasite prevalence. *Proceedings of the Royal Society B-Biological Sciences*, 288, 20211369. https://doi.org/10.1098/rspb.2021.1369

Conservation evidence. (not dated). *What works in conservation: Assessing the evidence*. Retrieved May 2, 2024, from https://www.conservationevidence.com/content/page/79

Cordeiro, E. M. G., Soares, P. L., Alves, D. A., & Corrêa, A. S. (2019). Updating the saga of the small hive beetle (*Aethina tumida*): molecular inference of the origin of the South American invasion. *Apidologie*, 50, 273-276. https://doi.org/10.1007/s13592-019-00636-5

Crane, E. (1999). *The World History of Beekeeping and Honey Hunting*. Routledge.

Dahle, B. (2021). Bikuber til Finland, studie av bifolk med spor av sykdommen åpen yngelråte – AVSLUTTET. Norges Birøkterlag. Retrieved April 3, 2024, from https://norbi.no/prosjekter/bikuber-til-finland-studie-av-bifolk-med-spor-av-sykdommen-apen-yngelrate/

Dahle, B. (2023). Åpen yngelråte – utvikler svakt infiserte bifolk klinisk sjukdom over tid? Norges Birøkterlag. Retrieved April 3, 2024, from https://norbi.no/wp-content/uploads/2023/12/Apen-yngelrate-Finland-2023-til-web.pdf

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science,* 287(5452), 443–449. https://doi.org/10.1126/science.287.5452.443

Davey, M. L., Blaalid, R., Dahle, S., Stange, E. S., Barton, D. N., & Rusch, G. M. (2023). Seasonal variation in urban pollen resource use by north temperate European honeybees. *Urban Ecosystems,* 27, 515–529. https://doi.org/10.1007/s11252-023-01458-1

de Barros Ruas, R., Costa, L. M. S., & Bered, F. (2022). Urbanization driving changes in plant species and communities – A global view. *Global Ecology and Conservation*, 38, e02243. https://doi.org/10.1016/j.gecco.2022.e02243

de Groot, A., Roessink, I., Schoonman, M., Smit, J., Zeegers, T., Blacquière, T., Kleijn, D., & Scheper, J. (2022). *Haalbaarheid van context-afhankelijke richtlijnen ter preventie van concurrentie tussen wilde en gehouden bijensoorten op basis van risicoschattingen* (Report 3185). Wageningen University and Research. https://doi.org/10.18174/574230 de Guzman, L. I., Williams, G. R., Khongphinitbunjong, K., & Chantawannakul, P. (2017). Ecology, life history, and management of *Tropilaelaps* mites. *Journal of Economic Entomology,* 110(2), 319-332. https://doi.org/10.1093/jee/tow304

Deutsch, K. R., Graham, J. R., Boncristiani, H. F., Bustamante, T., Mortensen, A. N., Schmehl, D. R., Wedde, A. E., Lopez, D. L., Evans, J. D., & Ellis, J. D. (2023). Widespread distribution of honey bee-associated pathogens in native bees and wasps: Trends in pathogen prevalence and co-occurrence. *Journal of Invertebrate Pathology,* 200, 107973. https://doi.org/10.1016/j.jip.2023.107973

Dias, A. C., Ferreira, J. T., Teixeira, É. W., & Lourenço, A. P. (2023). Honey bee viruses in solitary bees in South America: simultaneous detection and prevalence. *Journal of Apicultural Research,* 63, 122-127. https://doi.org/10.1080/00218839.2023.2190066

Dobson, H. E. M., & Peng, Y. S. (1997). Digestion of pollen components by larvae of the flower-specialist bee *Chelostoma florisomne* (Hymenoptera: Megachilidae). *Journal of Insect Physiology*, 43(1), 89–100. https://doi.org/10.1016/S0022-1910(96)00024-8

Dolezal, A. G., Hendrix, S. D., Scavo, N. A., Carrillo-Tripp, J., Harris, M. A., Wheelock, M. J., O'Neal, M. E., & Toth, A. L. (2016). Honey bee viruses in wild bees: viral prevalence, loads, and experimental inoculation. *PloS ONE*, 11(11), e0166190. https://doi.org/10.1371/journal.pone.0166190

Doublet, V., Doyle, T., Refoy, I., Hedges, S., Carvell, C., Brown, M. J. F. & Wilfert, L. (2022). Increasing flower species richness in agricultural landscapes alters insect pollinator networks: Implications for bee health and competition. *Ecology and Evolution*, 12, e9442. https://doi.org/10.1002/ece3.9442

Doublet, V., Labarussias, M., de Miranda, J. R., Moritz, R. F., & Paxton, R. J. (2015). Bees under stress: sublethal doses of a neonicotinoid pesticide and pathogens interact to elevate honey bee mortality across the life cycle. *Environmental Microbiology,* 17, 969-83. https://doi.org/10.1111/1462-2920.12426

Doublet, V., Oddie, M. A. Y., Mondet, F., Forsgren, E., Dahle, B., Furuseth-Hansen, E., Williams, G. R., Smet, L. D., Natsopoulou, M. E., Murray, T. E., Semberg, E., Yañez, O., de Graaf, D. C., Conte, Y. L., Neumann, P., Rimstad, E., Paxton, R. J., & de Miranda, J. R. (2024). Shift in virus composition in honeybees (*Apis mellifera*) following worldwide invasion by the parasitic mite and virus vector *Varroa destructor*. *Royal Society Open Science*, 11, 231529. https://doi.org/10.1098/rsos.231529

Elbgami, T., Kunin, W. E., Hughes, W. O. H., & Biesmeijer, J. C. (2014). The effect of proximity to a honeybee apiary on bumblebee colony fitness, development, and performance. *Apidologie,* 45, 504-513. https://doi.org/10.1007/s13592-013-0265-y

Else, G. R. (1997). *Philanthus triangulum* (Fabricius, 1775). Bees Wasps & Ants Recording Society.

https://bwars.com/wasp/crabronidae/philanthinae/philanthus-triangulum#:~:text=The%20major%20prey%20species%20throughout,El%2DHefny%2C%201972)

Eroglu, G. B. (2023). Detection of honey bee viruses in *Vespula germanica*: Black queen cell virus and Kashmir bee virus. *Biologia,* 78, 2643-2647. https://doi.org/10.1007/s11756-023-01416-4

Fleites-Ayil, F. A., Medina-Medina, L. A., Quezada Euán, J. J. G., Stolle, E., Theodorou, P., Tragust, S., & Paxton, R. J. (2023). Trouble in the tropics: Pathogen spillover is a threat for native stingless bees. *Biological Conservation*, 284. https://doi.org/10.1016/j.biocon.2023.110150

Forsgren, E., Lundhagen, A. C., Imdorf, A., & Fries, I. (2005). Distribution of *Melissococcus plutonius* in honeybee colonies with and without symptoms of European foulbrood. *Microbial Ecology,* 50, 369–374. https://doi.org/10.1007/s00248-004-0188-2

Forskrift om avlsfremmende tiltak på bier. (2001). Lovdata. https://lovdata.no/dokument/SF/forskrift/2001-04-18-426

Forskrift om kontrollområder for å forebygge, begrense og bekjempe pærebrann (*Erwinia amylovora*). (2020). https://lovdata.no/dokument/SF/forskrift/2020-01-08-51

Franco, M., & Ponti, A. M. (2021, February 11-12). *Update on the epidemiological situation linked to Aethina tumida in Italy* [Conference presentation]. PAFF Standing Committee, Brussels, Belgium. https://food.ec.europa.eu/system/files/2021-02/reg-com_ahw_20210211_aethina_tumida_ita.pdf

Fünfhaus, A., Ebeling, J., & Genersch, E. (2018). Bacterial pathogens of bees. *Current Opinion in Insect Science*, 26, 89-96. https://doi.org/10.1016/j.cois.2018.02.008

Fürst, M. A., McMahon, D. P., Osborne, J. L., Paxton, R. J., & Brown, M. J. (2014). Disease associations between honeybees and bumblebees as a threat to wild pollinators. *Nature*, 506, 364-6. https://doi.org/10.1038/nature12977

Gaden, S., Robinson, Ackery, P. R., Kitching, I., Beccaloni, G. W., & Hernández, L. M. (2023). *HOSTS - a Database of the World's Lepidopteran Hostplants [Data set]. Natural History Museum*. https://doi.org/10.5519/havt50xw

Galbraith, D. A., Fuller, Z. L., Ray, A. M., Brockmann, A., Frazier, M., Gikungu, M. W., Martinez, J. F. I., Kapheim, K. M., Kerby, J. T., Kocher, S. D., Losyev, O., Muli, E., Patch, H. M., Rosa, C., Sakamoto, J. M., Stanley, S., Vaudo, A. D., & Grozinger, C. M. (2018). Investigating the viral ecology of global bee communities with high-throughput metagenomics. *Scientific Reports*, 8, 8879. https://doi.org/10.1038/s41598-018-27164-z

Gao, J., Ma, S., Wang, X., Yang, Y., Luo, Q., Wang, X., Liu, F., Wang, Q., Fu, Z., Diao, Q., & Dai, P. (2021). *Tropilaelaps mercedesae* parasitism changes behavior and gene expression in honey bee workers. *PLoS Pathogens,* 17, e1009684. https://doi.org/10.1371/journal.ppat.1009684

Genersch, E., Forsgren, E., Pentikäinen, J., Ashiralieva, A., Rauch, S., Kilwinski, J., & Fries, I. (2006). Reclassification of *Paenibacillus larvae* subsp. *pulvifaciens* and *Paenibacillus larvae* subsp. *larvae* as *Paenibacillus larvae* without subspecies differentiation. *International Journal of Systematic and Evolutionary Microbiology*, 56(3): 501–11. https://doi.org/10.1099/ijs.0.63928-0

Genersch, E., Yue, C., Fries, I., & de Miranda, J. R. (2006). Detection of *Deformed wing virus*, a honey bee viral pathogen, in bumble bees (*Bombus terrestris* and *Bombus pascuorum*) with wing deformities. *Journal of Invertebrate Pathology,* 91, 61-3. https://doi.org/10.1016/j.jip.2005.10.002

Gómez-Martinez C., Gonzalez-Estevez M.A., Cursach J., Lazaro A. (2022) Pollinator richness, pollination networks, and diet adjustment along local and landscape gradients of resource diversity. *Ecological Applications,* 32:e2634. DOI: 10.1002/eap.2634.

Goulson, D., & Sparrow, K. R. (2009). Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size. *Journal of Insect Conservation*, 13, 177-181. https://doi.org/10.1007/s10841-008-9140-y

Graystock, P., Goulson, D., & Hughes, W. O. H. (2015). Parasites in bloom: flowers aid dispersal and transmission of pollinator parasites within and between bee species. *Proceedings og the Royal Society B*, 282(1813), 20151371. https://doi.org/10.1098/rspb.2015.1371

Graystock, P., Yates, K., Darvill, B., Goulson, D., & Hughes, W. O. (2013). Emerging dangers: deadly effects of an emergent parasite in a new pollinator host. *Journal of Invertebrate Pathology,* 114, 114-9. https://doi.org/10.1016/j.jip.2013.06.005

Grossar, D., Haynes, E., Budge, G. E., Parejo, M., Gauthier, L., Charriere, J-D., Chapuisat, M., & Dietemann, V. (2023). Population genetic diversity and dynamics of the honey bee brood pathogen *Melissococcus plutonius* in a region with high prevalence. *Journal of Invertebrate Pathology*, 196, 107867. https://doi.org/10.1016/j.jip.2022.107867

Grozinger, C. M., & Flenniken, M. L. (2019). Bee viruses: Ecology, pathogenicity, and impacts. *Annual review of Entomology*, 64, 205-226. https://doi.org/10.1146/annurev-ento-011118-111942

Gusachenko, O. N., Woodford, L., Balbirnie-Cumming, K., Ryabov, E. V., & Evans, D. J. (2020). Evidence for and against deformed wing virus spillover from honey bees to bumble bees: a reverse genetic analysis. *Scientific Reports*, 10, 16847. https://doi.org/10.1038/s41598-020-73809-3

Halvorson, K., Baumung, R., Leroy, G., Chen, C., & Boettcher, P. (2021). Protection of honeybees and other pollinators: one global study. *Apidologie*, 52, 535-547. https://doi.org/10.1007/s13592-021-00841-1

Henry, M., & Rodet, G. (2018). Controlling the impact of the managed honeybee on wild bees in protected areas. *Scientific Reports*, 8, 9308. https://doi.org/10.1038/s41598-018-27591-y

Herbertsson, L., Lindström, S. A. M., Rundlöf, M., Bommarco, R., & Smith, H. G. (2016). Competition between managed honeybees and wild bumblebees depends on landscape context. *Basic and Applied Ecology*, 17(7), 609-616. https://doi.org/10.1016/j.baae.2016.05.001

Hovstad, K. A., Johansen, L., Arnesen, G., Svalheim, E. & Velle, L. G. (2018). Semi-natural landscapes. Norwegian Red List of Ecosystems 2018. *Norwegian Biodiversity Information Centre*. Retrived April 10, 2024 from https://www.biodiversity.no/Pages/317603/Semi-natural_landscapes

Huang, W. F., Zhang, Y. K., Mehmood, S., Wang, Z. W., Hou, C. S., & Li, Z. G. (2021). Updating Sacbrood Virus Quantification PCR Method Using a TaqMan-MGB Probe. *Veterinary Sciences*, 8, 6. https://doi.org/10.3390/vetsci8040063

Hudewenz, A., & Klein, A.-M. (2015). Red mason bees cannot compete with honey bees for floral resources in a cage experiment. *Ecology and Evolution*, 5, 5049-5056. https://doi.org/10.1002/ece3.1762

Hung, K. J., Kingston, J. M., Albrecht, M., Holway, D. A., & Kohn, J. R. (2018). The worldwide importance of honey bees as pollinators in natural habitats. *Proceedings of the Royal Society B: Biological Sciences*, 285(1870), 20172140. https://doi.org/10.1098/rspb.2017.2140

IPBES. 2017. The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production., Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

IUCN (2020). IUCN EICAT Categories and Criteria. *The Environmental Impact Classification for Alien Taxa*. (1st ed.). Gland. https://doi.org/10.2305/IUCN.CH.2020.05.en

Iwasaki, J. M., & Hogendoorn, K. (2022). Mounting evidence that managed and introduced bees have negative impacts on wild bees: an updated review. *Current Research in Insect Science*, 2, 100043. https://doi.org/10.1016/j.cris.2022.100043

Jones, L. J., Ford, R. P., Schilder, R. J., & Lopez-Uribe, M. M. (2021). Honey bee viruses are highly prevalent but at low intensities in wild pollinators of cucurbit agroecosystems. *Journal of Invertebrate Pathology,* 185, 107667. https://doi.org/10.1016/j.jip.2021.107667

Jurat-Fuentes, J. L., & Jackson, T. A. (2012). Bacterial entomopathogens. In F. E. Vega & H. K. Kaya (Eds.). Insect Pathology (2nd ed). Academic press.

Kapfer, J., Pedersen, C., Sickel, H., Stokstad, G., & Dramstad, W. (2022). *Hva er god landskap for pollinerende insekter? Og kan vi overvåke dem?* NIBIO report, 8(65). https://hdl.handle.net/11250/2993091

Kato, M., Shibata, A., Yasui, T., & Nagamasu, H. (1999). Impact of introduced honeybees, *Apis mellifera*, upon native bee communities in the Bonin (Ogasawara) Islands. *Research on Population Ecology*, 41, 217–228. https://doi.org/10.1007/s101440050025

Keller, A., Brandel, A., Becker, M. C., Balles, R., Abdelmohsen, U. R., Ankenbrand, M. J., & Sickel, W. (2018). Wild bees and their nests host *Paenibacillus* bacteria with functional potential of avail. *Microbiome*, 6, 229. https://doi.org/10.1186/s40168-018-0614-1

Kenward, H. (1988). Insect remains. In E. Schia (Ed.), *De arkeologske utgravninger i Gamlebyen, Oslo. Volume 5* (pp. 115-140). Alvheim & Eide Akademisk Forlag. https://www.duo.uio.no/handle/10852/98520

Kirkevold, R. R., & Gjessing, T. (2003). *Den store biplanteboken*.

Larsson, M., & Franzén, M. (2007). Critical resource levels of pollen for the declining bee *Andrena hattorfiana* (Hymenoptera, Andrenidae). *Biological Conservation*, 134(3), 405-414. https://doi.org/10.1016/j.biocon.2006.08.030

LeCroy, K. A., Krichilsky, E., Grab, H. L., Roulston, T. H., & Danforth, B. N. (2023). Spillover of chalkbrood fungi to native solitary bee species from non-native congeners. *Journal of Applied Ecology*, 60, 1067–1076. https://doi.org/10.1111/1365-2664.14399

Levitt, A .L., Singh, R., Cox-Foster, D. L., Rajotte, E., Hoover, K., Ostiguy, N., & Holmes, E. C. (2013). Cross-species transmission of honey bee viruses in associated arthropods. *Virus Research,* 176, 232-40. https://doi.org/10.1016/j.virusres.2013.06.013

Ling, T. C., Phokasem, P., Sinpoo, C., Chantawannakul, P., Khongphinitbunjong, K., & Disayathanoowat, T. (2023). *Tropilaelaps mercedesae* infestation is correlated with injury numbers on the brood and the population size of honey bee *Apis mellifera*. *Animals,* 13. https://doi.org/10.3390/ani13081318

Lund, A. B. (2023, January 27). Kalkyngel – hva er det egentlig? Norges Birøkterlag. https://norbi.no/birokt/kalkyngel-hva-er-det-egentlig/

Mallinger, R. E., Gaines-Day, H. R., & Gratton, C. (2017). Do managed bees have negative effects on wild bees?: A systematic review of the literature. *PloS ONE*, 12(12), e0189268. https://doi.org/10.1371/journal.pone.0189268

Manley, R., Doublet, V., Wright, O. N., Doyle, T., Refoy, I., Hedges, S., Pascall, D., Carvell, C., Brown, M. J. F., & Wilfert, L. (2023). Conservation measures or hotspots of disease transmission? Agri-environment schemes can reduce disease prevalence in pollinator communities. *Philosophical Transactions of the Royal Society B*, 378, 20220004. https://doi.org/10.1098/rstb.2022.0004

Martin, S. J., Highfield, A. C., Brettell, L. E., Villalobos, E. M., Budge, G., Powell, M., Nikaido, S., Schroeder, D. C. (2012). Global honey bee viral landscape altered by a parasitic mite. *Science*, 336(6086), 1304–1306. https://doi.org/10.1126/science.1220941

Mattilsynet. (not dated). *Bier*. Retrieved April 26, 2024, from https://www.mattilsynet.no/dyr/produksjonsdyr/bier

Mattilsynet. (2022, June 15). *Import av bier og humler*. https://www.mattilsynet.no/dyr/produksjonsdyr/bier/import

Mattilsynet. (2011). *Retningslinjer for bekjempelse av Åpen yngelråte hos bier*. e-Phorte: 10/242794.

McCormick, E .C., Cohen, O. R., Dolezal, A. G., & Sadd, B. M. (2023). Consequences of microsporidian prior exposure for virus infection outcomes and bumble bee host health. *Oecologia*, 202, 325-335. https://doi.org/10.1007/s00442-023-05394-x

McMahon, D. P., Natsopoulou, M. E., Doublet, V., Fürst, M., Weging, S., Brown, M. J., Gogol-Döring, A. & Paxton, R. J. (2016). Elevated virulence of an emerging viral genotype as a driver of honeybee loss. *Proceedings of the Royal Society B: Biological Sciences*, 283(1833), 20160811. https://doi.org/10.1098/rspb.2016.0811

McMenamin, A. J., Brutscher, L. M., Glenny, W., Flenniken, M. L. (2016). Abiotic and biotic factors affecting the replication and pathogenicity of bee viruses. *Current Opinion in Insect Science,* 16, 14-21. https://doi.org/10.1016/j.cois.2016.04.009

Meeus, I., Parmentier, L., Pisman, M. de Graaf, D. C., & Smagghe, G. (2021). Reduced nest development of reared *Bombus terrestris* within apiary dense human-modified landscapes. *Scientific Reports,* 11, 3755. https://doi.org/10.1038/s41598-021-82540-6

Meixner, M. D., Pinto, M. A., Bouga, M., Kryger, P., Ivanova, E., & Fuchs, S. (2013). Standard methods for characterising subspecies and ecotypes of *Apis mellifera*. *Journal of Apicultural Research*, 52(4), 1–28. https://doi.org/10.3896/Ibra.1.52.4.05

Melathopoulos, A., Ovinge, L., Veiga, P. W., Castillo, C., Ostermann, D., & Hoover, S. (2017). Viruses of managed alfalfa leafcutting bees (*Megachille rotundata Fabricus*) and honey bees (*Apis mellifera* L.) in Western Canada: Incidence, impacts, and prospects of cross-species viral transmission. *Journal of Invertebrate Pathology*, 146, 24-30. https://doi.org/10.1016/j.jip.2017.04.003

Melville, R., & Dade, H. (1944). Chalk Brood Attacking a Wild Bee. *Nature*, 153, 112. https://doi.org/10.1038/153112a0

Monceau, K., Bonnard, O., & Thiéry, D. (2014). *Vespa velutina*: a new invasive predator of honeybees in Europe. *Journal of Pest Science*, 87(1), 1-16. https://doi.org/10.1007/s10340-013-0537-3

Mouillard-Lample, L., Gonella, G., Decourtye, A., Henry, M., & Barnaud, C. (2023). Competition between wild and honey bees: Floral resources as a common good providing multiple ecosystem services. *Ecosystem Services,* 62, 101538. https://doi.org/10.1016/j.ecoser.2023.101538

Müller, U., McMahon, D. P., & Rolff, J. (2019). Exposure of the wild bee *Osmia bicornis* to the honey bee pathogen *Nosema ceranae*. *Agricultural and Forest Entomology*, 21, 363-371. https://doi.org/10.1111/afe.12338

Murray, E. A., Burand, J., Trikoz, N., Schnabel, J., Grab, H., & Danforth, B. N. (2019). Viral transmission in honey bees and native bees, supported by a global black queen cell virus phylogeny. *Environmental Microbiology*, 21, 972-983. https://doi.org/10.1111/1462-2920.14501

Nanetti, A., Bortolotti, L., & Cilia, G. (2021). Pathogens spillover from honey bees to other arthropods. *Pathogens*, 10(8), 1044. https://doi.org/10.3390/pathogens10081044

Nekoei, S., Rezvan, M., Khamesipour, F., Mayack, C., Molento, M. B., & Revainera, P. D. (2023). A systematic review of honey bee (*Apis mellifera*, Linnaeus, 1758) infections and available treatment options. *Veterinary Medicine and Science,* 9, 1848-1860. https://doi.org/10.1002/vms3.1194

Neumann, P., Pettis, J. S., & Schäfer, M. O. (2016). Quo vadis *Aethina tumida*? Biology and control of small hive beetles. *Apidologie,* 47, 427-466. https://doi.org/10.1007/s13592-016-0426-x

Nielsdatter, M. G., Larsen, M., Nielsen, L. G., Nielsen, M. M., & Rasmussen, C. (2021). History of the displacement of the European dark bee (*Apis mellifera mellifera*) in Denmark. *Journal of Apicultural Research*, 60(1), 13–18. https://doi.org/10.1080/00218839.2020.1826111

Nielsen, A., Reitan, T., Rinvoll, A. W., & Brysting, A. K. (2017). Effects of competition and climate on a crop pollinator community. *Agriculture, Ecosystems & Environment*, 246, 253–260. https://doi.org/10.1016/j.agee.2017.06.006

Norfolk, O., Gilbert, F., & Eichhorn, M. P. (2018). Alien honeybees increase pollination risks for range-restricted plants. *Diversity and Distributions*, 24(5), 705-713. https://doi.org/10.1111/ddi.12715

Norges Birøkterlag. (not dated a). Avl og biologi. Retrieved April 26, 2024, from https://norbi.no/avl-og-biologi/

Norges Birøkterlag. (not dated b). Nosema – Vairimorpha. Retrieved April 3, 2024, from https://norbi.no/sykdom-hos-bier/nosema/

Norges Birøkterlag. (2020). Norges Birøkterlags policy vedrørende forholdet mellom honningbier og ville pollinerende insekter. https://norbi.no/documents/2020/06/norges-birokterlags-policy-for-honningbier-vs-ville-insekter.pdf/

Norwegian Ministries. (2018). *National pollinator strategy* (M-0750 E). Norwegian Ministry of Agriculture and Food, Norwegian Ministry of Climate and Environment, Norwegian Ministry of Local Government and Modernisation, Norwegian Ministry of Transport, Communications, Norwegian Ministry of Defence, Norwegian Ministry of Education and Research, Norwegian Ministry of Petroleum and Energy. https://www.regjeringen.no/contentassets/3e16b8410e704d54af40bcb3e687fb4e/national-pollinator-strategy.pdfOllerton, J. (2017). Pollinator diversity: Distribution, ecological function, and conservation. *Annual Review of Ecology, Evolution, and Systematics*, 48(1), 353–376. https://doi.org/10.1146/annurev-ecolsys-110316-022919

Olszewski, P., Dyderski, M. K., Dylewski, Ł., Bogusch, P., Schmid-Egger, C., Ljubomirov, T., Zimmermann, D., Le Divelec, R., Wiśniowski, B., Twerd, L., Pawlikowski, T., Mei, M., Popa, A. F., Szczypek, J., Sparks, T., & Puchałka, R. (2022). European beewolf (*Philanthus triangulum*) will expand its geographic range as a result of climate warming. *Regional Environmental Change,* 22, 129. https://doi.org/10.1007/s10113-022-01987-z

O'Shea-Wheller, T. A., Curtis, R. J., Kennedy, P. J., Groom, E. K. J., Poidatz, J., Raffle, D. S., Rojas-Nossa, S. V., Bartolomé, C., Dasilva-Martins, D., Maside, X., Mato, S., & Osborne, J. L. (2023). Quantifying the impact of an invasive hornet on *Bombus terrestris* colonies. *Communications Biology*, 6, 990. https://doi.org/10.1038/s42003-023-05329-5

Ouvrard, P., Transon, J. & Jacquemart, A. L. (2018). Flower-strip agri-environment schemes provide diverse and valuable summer flower resources for pollinating insects. *Biodivers Conserv*, 27, 2193–2216. https://doi.org/10.1007/s10531-018-1531-0

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan — a web and mobile app for systematic reviews. *Systematic Reviews,* 5, 210. https://doi.org/10.1186/s13643-016-0384-4

Page, M. L., Nicholson, C. C., Brennan, R. M., Britzman, A. T., Greer, J., Hemberger, J., Kahl, H., Müller, U., Peng, Y., Rosenberger, N. M., Stuligross, C., Wang, L., Yang, L. H., & Williams, N. M. (2021). A meta-analysis of single visit pollination effectiveness comparing honeybees and other floral visitors. *American Journal of Botany*, 108(11), 2196-2207. https://doi.org/10.1002/ajb2.1764

Page, M. L., & Williams, N. M. (2023). Evidence of exploitative competition between honey bees and native bees in two California landscapes. *Journal of Animal Ecology*, 92(9), 1802–1814. https://doi.org/10.1111/1365-2656.13973

Paini, D. R., & Roberts, J. D. (2005). Commercial honey bees (*Apis mellifera*) reduce the fecundity of an Australian native bee (*Hylaeus alcyoneus*). *Biological Conservation,* 123(1), 103-112. https://doi.org/10.1016/j.biocon.2004.11.001

Pei, C. K., Hovick, T. J. Limb, R. F. Harmon, J. P. & Geaumont, B. A. (2023). Native and introduced pollinators vary in their seasonal floral resource visitation and selection between native and exotic plant species. *Journal of Applied Ecology,* 60, 1424-1434. https://doi.org/10.1111/1365-2664.14416

Penberthy, T. M., Dillon, M. K., Chen, X., & Donaldson-Matasci, M. C. (2023). Honey bee foraging density depends on plant size. *Animal Behaviour,* 206, 39-51. https://doi.org/10.1016/j.anbehav.2023.09.008

Phokasem, P., de Guzman, L. I., Khongphinitbunjong, K., Frake, A. M., & Chantawannakul, P. (2019). Feeding by *Tropilaelaps mercedesae* on pre- and post-capped brood increases damage to *Apis mellifera* colonies. *Science Reports*, 9, 13044. https://doi.org/10.1038/s41598-019-49662-4

Piot, N., Schweiger, O., Meeus, I., Yanez, O., Straub, L., Villamar-Bouza, L., De la Rua, P., Jara, L., Ruiz, C., Malmstrom, M., Mustafa, S., Nielsen, A., Mand, M., Karise, R., Tlak-Gajger, I., Ozgor, E., Keskin, N., Dievart, V., Dalmon, A., Gajda, A., Neumann, P., Smagghe, G., Graystock, P., Radzeviciute, R., Paxton, R. J., & de Miranda, J. R. (2022). Honey bees and climate explain viral prevalence in wild bee communities on a continental scale. *Science Reports,* 12, 1904. https://doi.org/10.1038/s41598-022-05603-2

Pislak Ocepek, M., Glavan, G., Verovnik, R., Simenc, L., & Toplak, I. (2022). First detection of honeybee pathogenic viruses in butterflies*. Insects*, 13(10), 925. https://doi.org/10.3390/insects13100925

Pislak Ocepek, M., Toplak, I., Zajc, U., & Bevk, D. (2021). The pathogens spillover and incidence correlation in bumblebees and honeybees in Slovenia. *Pathogens*, 10. https://doi.org/10.3390/pathogens10070884

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., Dicks, L. V., Garibaldi, L. A., Hill, R., Settele, J., & Vanbergen, A. J. (2016). Safeguarding pollinators and their values to human well-being. *Nature,* 540(7632), 220–229. https://doi.org/10.1038/nature20588

Powney, G. D., Carvell, C., Edwards, M., Morris, R .K. A., Roy, H. E., Woodcock, B. A., & Isaac, N. J. B. (2019). Widespread losses of pollinating insects in Britain. *Nature Communications,* 10, 1018. https://doi.org/10.1038/s41467-019-08974-9

Rader, R., Howlett, B. G., Cunningham, S. A., Westcott, D. A., Newstrom-Lloyd, L. E., Walker, M. K., Teulon, D. A. J., & Edwards, W. (2009). Alternative pollinator taxa are equally efficient but not as effective as the honeybee in a mass flowering crop. *Journal of Applied Ecology,* 46:1080-1087. https://doi.org/10.1111/j.1365-2664.2009.01700.x

Radzeviciute, R., Theodorou, P., Husemann, M., Japoshvili, G., Kirkitadze, G., Zhusupbaeva, A., & Paxton, R. J. (2017). Replication of honey bee-associated RNA viruses across multiple bee species in apple orchards of Georgia, Germany and Kyrgyzstan. *Journal of Invertebrate Patholology,* 146, 14-23. https://doi.org/10.1016/j.jip.2017.04.002

Rasmussen, C., Dupont, Y. L., Madsen, H. B., Bogusch, P., Goulson, D., Herbertsson, L., Maia, K. P., Nielsen, A., Olesen, J. M., Potts, S. G., Roberts, S. P. M., Sydenham, M. A. K., & Kryger, P. (2021). Evaluating competition for forage plants between honey bees and wild bees in Denmark. *PloS ONE*, 16(4), e0250056. https://doi.org/10.1371/journal.pone.0250056

Rasmussen, C., Sydenham, M. A. K., Schmidt, H. T., & Madsen, H. B. (2022). The native bees of Lolland (Denmark) revisited after 100 years: the demise of the specialists. *Insects*, 13(2), 153. https://doi.org/10.3390/insects13020153

Ravoet, J., De Smet, L., Meeus, I., Smagghe, G. Wenseleers, T., & de Graaf, D. C. (2014). Widespread occurrence of honey bee pathogens in solitary bees. *Journal of Invertebrate Pathology,* 122, 55–58. https://doi.org/10.1016/j.jip.2014.08.007

Reverté, S., Miličić, M., Ačanski, J., Andrić, A., Aracil, A., Aubert, M., Balzan, M. V., Bartomeus, I., Bogusch, P., Bosch, J., Budrys, E., Cantú-Salazar, L., Castro, S., Cornalba M., Demeter, I., Devalez, J., Dorchin, A., Dufrêne, E., Đorđević, A.,. . . Vujić, A. (2023). National records of 3000 European bee and hoverfly species: A contribution to pollinator conservation. *Insect Conservation and Diversity*, 16(6), 758–775. https://doi.org/10.1111/icad.12680

Reynaldi, F. J., Lucia, M., Genchi Garcia, M. L. (2015). *Ascosphaera apis*, the entomopathogenic fungus affecting larvae of native bees (*Xylocopa augusti*): First report in South America. *Revista Iberoamericana de Micología,* 32(4), 261-264. https://doi.org/10.1016/j.riam.2015.01.001

Rollin, O., & Garibaldi, L. A. (2019). Impacts of honeybee density on crop yield: A meta-analysis. *Journal of Applied Ecology*, 56(5), 1152-1163. https://doi.org/10.1111/1365-2664.13355

Ro-Poulsen, H. (2023). *Wild bees and honey bees in semi-natural habitats of Denmark; Effects of beekeeping and management in grasslands and Heathlands*. [Doctoral dissertation, University of Copenhagen, Department of Geosciences and Natural Resource Management]

Rundlöf, M., Lundin, O., & Bommarco, R. (2018). Annual flower strips support pollinators and potentially enhance red clover seed yield. *Ecology and Evolution*, 8(16), 7974–7985. https://doi.org/10.1002/ece3.4330

Ruttner, F. (1988). *Biogeography and taxonomy of honeybees*. Springer-Verlag. https://doi.org/10.1007/978-3-642-72649-1

Ruttner, F., Milner, E., & Dews, J. E. (1990). *The Dark European Honey Bee. Apis mellifera mellifera Linnaeus 1758*. The British Isles Bee Breeders Association. ISBN 1-904623-17-4

Saez, A., Morales, C. L., Ramos, L. Y., Aizen, M. A. (2014). Extremely frequent bee visits increase pollen deposition but reduce drupelet set in raspberry. *Journal of Applied Ecology,* 51(6), 1603–1612. https://doi.org/10.1111/1365-2664.12325

Sakai, A. K., Allendorf, F. W., Holt, J. S., Lodge, D. M., Molofsky, J., With, K. A., Baughman, S., Cabin R. J., Cohen, J. E., Ellstrand, N. C., McCauley, D. E., O'Neil, P., Parker, I. M., Thompson, J. N., & Weller, S. G. (2001). The population biology of invasive species. *Annual Review of Ecology and Systematics,* 32, 305–332. http://www.jstor.org/stable/2678643

Sandvik, H., Hilmo, O., Henriksen, S., Elven, R., Åsen, P. A., Hegre, H., Pedersen, O., Pedersen, P. A., Solstad, H., Vandvik, V., Westergaard, K. B., Ødegaard, F., Åström, S., Elven, H., Endrestøl, A., Gammelmo, Ø., Hatteland, B. A., Solheim, H., Nordén, B., & Gederaas, L. (2020). Alien species in Norway: Results from quantitative ecological impact assessments. *Ecological Solutions and Evidence*, 1(1), e12006. https://doi.org/10.1002/2688-8319.12006

Schauer, A., Bianco, N., Yañez, O., Brown, A., Albrecht, M., & Neumann, P. (2023). Deformed wing virus prevalence in solitary bees put to the test: an experimental transmission study. *Frontiers in Ecology and Evolution,* 11. https://doi.org/10.3389/fevo.2023.1122304

Scheuchl, E., & Willner, W. (2016). *Taschenlexikon der Wildbienen Mitteleuropas: Alle Arten im Porträt*. Quelle & Meyer Verlag.

Seyedmousavi, S., Guillot, J., Arne, P., de Hoog, G. S., Mouton, J. W., Melchers, W. J., & Verweij, P. E. (2015). *Aspergillus* and aspergilloses in wild and domestic animals: a global health concern with parallels to human disease. *Medical Mycology*, 53(8), 765-97. https://doi.org/10.1093/mmy/myv067

Singh, R., Levitt, A. L., Rajotte, E. G., Holmes, E. C., Ostiguy, N., Vanengelsdorp, D., Lipkin, W. I., Depamphilis, C. W., Toth, A. L., & Cox-Foster, D. L. (2010). RNA viruses in hymenopteran pollinators: Evidence of inter-taxa virus transmission via pollen and potential impact on non-*Apis* hymenopteran species. *PloS ONE*, 5, e14357. https://doi.org/10.1371/journal.pone.0014357

Statsforvalteren i Agder 2024 (accessed May 4th 2024). Statistikk over husdyr- og planteproduksjon i Agder. https://www.statsforvalteren.no/nb/agder/Landbruk-og-mat/statistikk/jordbruksstatistikk/husdyr--og-planteproduksjon/

Steffan-Dewenter, I., & Tscharntke, T. (2000). Resource overlap and possible competition between honey bees and wild bees in central Europe. *Oecologia*, 122, 288-296. https://doi.org/10.1007/s004420050034

Stokland, J. N., Siitonen, J., & Jonsson, B. G. (2012). *Biodiversity in dead wood*. Ecology, Biodiversity, and Conservation. Cambridge University Press. https://doi.org/10.1017/CBO9781139025843

Stout, J. C., & Tiedeken, E. J. (2017). Direct interactions between invasive plants and native pollinators: evidence, impacts and approaches. *Functional Ecology*, 31(1), 38-46. https://doi.org/10.1111/1365-2435.12751

Streicher, T., Tehel, A., Tragust, S., & Paxton, R. J. (2022). Experimental viral spillover can harm *Bombus terrestris* workers under field conditions. *Ecological Entomology*, 48(1), 81-89. https://doi.org/10.1111/een.13203

Sugden, E. A., & Pyke, G. H. (1991). Effects of honey-bees on colonies of *Exoneura asimillima*, an Australian native bee. *Australian Journal of Ecology*, 16(2), 171–181. https://doi.org/10.1111/j.1442-9993.1991.tb01044.x

Stolbova V.V. (2021) Current state of *Acarapis* Hirst mites (Acariformes, Tarsonemidae) distribution and honeybees infestation in Russia. *Ukrainian Journal of Ecology*, 11, 291–298. https://doi.org/10.15421/2021_44

Sydenham, M. A. K., Myklebost, H., Jokerud, M., Singsaas, F. T., Töpper, J. P., & Hanssen, O. (2023). *Kartlegging av naturtyper som bidrar med blomsterressurser og larvesubstrater til pollinerende insekter i Norge* (NINA Rapport 2383). Retrieved from https://hdl.handle.net/11250/3107514

Taylor, G., & Whelan, R. J. (1988). Can honeybees pollinate *Grevillea*? *Australian Zoologist*, 24(4), 193–196. https://doi.org/10.7882/AZ.1988.001

Tegnander, P., Nilsen, A. T., & Larsen, E. (2011, May 27). Trolig kontroll på alvorlig bie-sykdom. NRK. https://www.nrk.no/sorlandet/kontroll-pa-apen-yngelrate-1.7650301

Tehel, A., Brown, M. J. F., & Paxton, R. J. (2016). Impact of managed honey bee viruses on wild bees. *Current Opinion in Virology*, 19, 16-22. https://doi.org/10.1016/j.coviro.2016.06.006

Tehel A., Vu Q., Bigot D., Gogol-Doring A., Koch P., Jenkins C., Doublet V., Theodorou P., Paxton R. (2019) The Two Prevalent Genotypes of an Emerging Infectious Disease, Deformed Wing Virus, Cause Equally Low Pupal Mortality and Equally High Wing Deformities in Host Honey Bees. *Viruses* 11. https://www.mdpi.com/1999-4915/11/2/114.

Tehel, A., Streicher, T., Tragust, S., & Paxton, R. J. (2020). Experimental infection of bumblebees with honeybee-associated viruses: no direct fitness costs but potential future threats to novel wild bee hosts. *Royal Society Open Science,* 7(7), 200480. https://doi.org/10.1098/rsos.200480

Tehel, A., Streicher, T., Tragust, S., & Paxton, R. J. (2022). Experimental cross species transmission of a major viral pathogen in bees is predominantly from honeybees to bumblebees. *Proceedings of the Royal Society B,* 289, 20212255. https://doi.org/10.1098/rspb.2021.2255

Teixeira, É. W., Ferreira, E. A., da Luz, C. F. P., Martins, M. F., Ramos, T. A., & Lourenço, A. P. (2020). European Foulbrood in stingless bees (*Apidae: Meliponini*) in Brazil: Old disease, renewed threat. *Journal of Invertebrate Pathology*, 172, 107357. https://doi.org/10.1016/j.jip.2020.107357

Thomson, D. (2004). Competitive interactions between the invasive European honey bee and native bumble bees. *Ecology,* 85(2), 458-470. https://doi.org/10.1890/02-0626

Thomson, D. M., & Page, M. L. (2020). The importance of competition between insect pollinators in the Anthropocene. *Current Opinion in Insect Science*, 38, 55-62. https://dgajoi.org/10.1016/j.cois.2019.11.001

Tihelka, E., Cai, C., Pisani, D., & Donoghue, P. C. J. (2020). Mitochondrial genomes illuminate the evolutionary history of the Western honey bee (*Apis mellifera*). *Scientific Reports,* 10, 14515. https://doi.org/10.1038/s41598-020-71393-0

Tlak Gajger, I. T., Simenc, L., & Toplak, I. (2021). The first detection and genetic characterization of four different honeybee viruses in wild bumblebees from Croatia. *Pathogens,* 10(7), 808. https://doi.org/10.3390/pathogens10070808

Tokarev, Y. S., Huang, W-F., Solter, L. F., Malysh, J. M., Becnel, J. J., & Vossbrinck, C. R. (2020). A formal redefinition of the genera *Nosema* and *Vairimorpha* (Microsporidia: Nosematidae) and reassignment of species based on molecular phylogenetics. *Journal of Invertebrate Pathology,* 169, 107279. https://doi.org/10.1016/j.jip.2019.107279

Torné-Noguera, A., Rodrigo, A., Osorio, S., & Bosch, J., (2016). Collateral effects of beekeeping: impacts on pollen-nectar resources and wild bee communities. *Basic and Applied Ecology*, 17(3), 199–209. https://doi.org/10.1016/j.baae.2015.11.004

Ulyshen, M., & Horn, S. (2023). Declines of bees and butterflies over 15 years in a forested landscape*. Current Biology,* 33(7), 1346-1350.e3. https://doi.org/10.1016/j.cub.2023.02.030

Urbanowicz, C., Muñiz, P. A., & McArt, S. H. (2020). Honey bees and wild pollinators differ in their preference for and use of introduced floral resources. *Ecology and Evolution*, 10(13), 6741–6751. https://doi.org/10.1002/ece3.6417

Valido, A., Rodriguez-Rodriguez, M. C. & Jordano, P. (2019). Honeybees disrupt the structure and functionality of plant-pollinator networks. Scientific Reports, 9, 4711. https://doi.org/10.1038/s41598-019-41271-5

Vaudo, A. D., Dyer, L. A., & Leonard,o A. S. (2024). Pollen nutrition structures bee and plant community interactions. *Proceedings of the National Academy of Sciences*, 121(3), e2317228120. https://doi.org/10.1073/pnas.2317228120

Vestheim, S. K. (2022). *Pollination, wild communities and seed development in apple orchards of Sogn and Hardanger in Western Norway*. [Master's thesis, University of Bergen]. https://hdl.handle.net/11250/3045549

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

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

VKM, Eldegard, K., Flø, D., Kirkendall, L., Malmstrøm, M., Nielsen, A., Rasmussen, C., de Boer, H., Hindar, K., Järngren, J., Kausrud, K., Rueness E., Thorstad, E. B., & Velle, G. (2022). *Assessment of the risks to honey bees and biodiversity in Norway posed by the predatory wasp species Vespa velutina and V. mandarina* (VKM Report 2022:03). Scientific Opinion of the Panel on Alien Organisms and Trade in Endangered Species of the Norwegian Scientific Committee for Food and Environment, Norwegian Scientific Committee for Food and Environment (VKM). https://vkm.no/risikovurderinger/allevurderinger/kjempevepsfraasiarisikoforbiologiskmangfoldogbier.4.6d02983b17b10aa915e7d751.html

VKM, Kirkendall, L., Bryn, A., Flø, D., Malmstrøm, M., Velle, G., Berg, P. R., Geange, S. R., Hindar, K., Kausrud, K., Sandercock, B. K., Thorstad, E. & Nielsen, A. (2023). *Assessment of the risk to Norwegian biodiversity from private import and keeping of Northern Cardinal* (VKM Report 2023:18). Scientific Opinion of the Panel on Biodiversity of the Norwegian Scientific Committee for Food and Environment, Norwegian Scientific Committee for Food and Environment (VKM). https://vkm.no/risikovurderinger/allevurderinger/innforselavrodkardinalrisikofornorskbiologiskmangfold.4.32380f4b186925e54209b2dc.html

Wehn, S., Kallioniemi, E., Vesterbukt, P., Grenne, S.N., Can, J. M., Henriksen, M. V., & L. Johansen (2020). *Skjøtsel av semi-naturlig eng for å ivareta pollinatorer og deres blomsterressurser.* NIBIO report, 6(8). http://hdl.handle.net/11250/2639208

Westrich, P. (1996). Habitat requirements of central European bees and the problems of partial habitats. In A. Matheson, S. L. Buchmann, C. O'toole, P. Westrich, & I. H. Williams (Eds.). *The conservation of bees, Linnean Society symposium series* (18, pp. 1-16). Academic Press. https://www.wildbienen.info/downloads/westrich_40.pdf

Wignall, V. R., Brolly, M., Uthoff, C. Norton, K. E., Chipperfield, H. M., Balfour, N. J. & Ratnieks, F. L. W. (2020). Exploitative competition and displacement mediated by eusocial bees: experimental evidence in a wild pollinator community. *Behavioral Ecology and Sociobiology*, 74, 152. https://doi.org/10.1007/s00265-020-02924-y

Willmer, P. G., Cunnold, H., & Ballantyne, G. (2017). Insights from measuring pollen deposition: quantifying the pre-eminence of bees as flower visitors and effective pollinators. *Arthropod-Plant Interactions*, 11(3), 411–425. https://doi.org/10.1007/s11829-017-9528-2

Woitke, M., & Dietz, H. (2002). Shifts in dominance of native and invasive plants in experimental patches of vegetation. *Perspectives in Plant Ecology, Evolution and Systematics*, 5(3), 165-184. https://doi.org/10.1078/1433-8319-00032

Wojcik, V. A., Morandin, L. A., Adams, L. D., & Rourke, K. E. (2018). Floral resource competition between honey bees and wild bees: Is there clear evidence and can we guide management and conservation? *Environmental Entomology*, 47(4), 822-833. https://doi.org/10.1093/ee/nvy077

Wood, T. J., Kaplan, I., & Szendrei, Z. (2018). Wild bee pollen diets reveal patterns of seasonal foraging resources for honey bees. *Frontiers in Ecology and Evolution*, 6, 210. https://doi.org/10.3389/fevo.2018.00210

Ødegaard, F., Sydenham, M., Staverløkk, A., Lønnve, O. J. (2021). Artsgruppeomtale vepser (Hymenoptera). Norsk rødliste for arter 2021. Artsdatabanken. https://artsdatabanken.no/rodlisteforarter2021/Artsgruppene/Vepser

Ødegaard, F. (2022, October 12). *Honningbie* Apis mellifera *Linnaeus, 1758*. Artsdatabanken. https://www.artsdatabanken.no/Pages/149754/Honningbie

Ødegaard, F. (2023, May 15). *Bier*. Artsdatabanken. https://www.artsdatabanken.no/arter-pa-nett/villbier

Appendix I

Information received from Norges Birøkterlag (høringsekspert) on the status of honey beekeeping in Norway. Questions posed by VKM 27 February 2024 and replies received from Norges Birøkterlag 14 March 2024.

Spørsmål til Norges Birøkterlag fra Vitenskapskomiteen for mat og miljø i forbindelse med oppdraget «Påvirkning fra hold av honningbier (*Apis mellifera*) på ville pollinatorer»

Dato: 27.02.2024

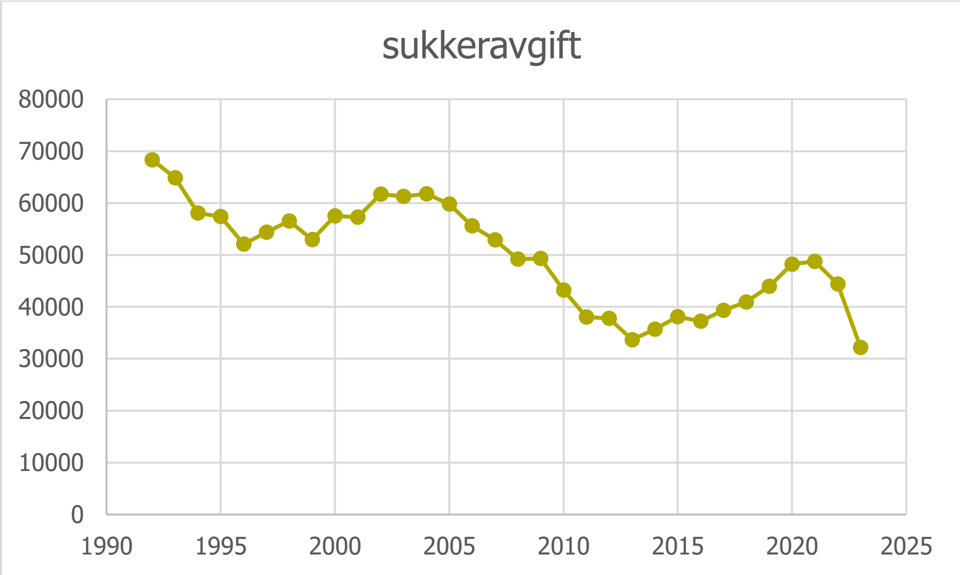
1. Hvor komplett er kartet til Mattilsynet over bikuber (bigårdsplasser) i Norge?
    a. Nøyaktig plassering Kartet til Mattilsynet gir et bilde over geografisk utbredelse av honningbier i Norge, men det har en rekke mangler: 1. En rekke bigårdsplasser er registrert i feil koordinatsystem, bl.a. en rekke bigårdsplasser som tilsynelatende befinner seg Sverige, Østersjøen og Norskehavet. 2. Ikke alle birøktere har registrert bigårdsplassene sine. Vi er usikre på hvor stor denne feilkilden er, men når det oppstår utbrudd av meldepliktige bisjukdommer dukker det som regel opp flere uregistrerte bigårdsplasser. 3. En rekke registrerte bigårdsplasser inneholder ikke bier siden birøkteren har avviklet biholdet, men ikke avregistrert bigårdsplassene. Norges Birøkterlag hadde for 2 år siden en plan om å gjennomføre en større dugnad i organisasjonen for å bedre kvaliteten på dataene siden dette er i næringas interesse, både ved sjukdomsutbrudd og ved opprettelse av nye bigårdsplasser, men utskifting av ansatte ved sekretariatet medførte at dette ble utsatt på ubestemt tid.
    b. Antall kuber (styrke på bifolkene) Kartet gir ingen informasjon om antall bifolk (bifamilier/bikolonier), eller styrke på bifolkene som har en stor sesongvariasjon. Det er også slik at en del birøktere har registrert flere bigårdsplasser enn de som brukes fast. Dette er med på å gi birøkteren fleksibilitet. Forøvrig er bikuber er en betegnelse på bienes bolig, tilsvarende som kyr holder til i et fjøs.
    c. Flytting gjennom sesongen. Ved registrering av bigårdsplass oppgis det om det er en stasjonær plass (hvor bifolkene er plassert i hoveddelen av året) eller om det er en vandreplass som brukes i en begrenset tidsperiode. Kartet gir ingen informasjon om tidsperioden biene er på en spesifikk bigårdsplass. Mange vandreplasser er ikke i bruk hvert år siden birøkteren velger å ikke vandre med biene, kanskje fordi utsiktene til god honningproduksjon er dårlige.
2. Hvordan er utviklingen av birøkt i Norge de siste 50 år?
    a. Antall birøktere (profesjonelle og amatører) Det finnes ikke en fullgod oversikt over antall birøktere. Som nevnt over er det ikke alle birøktere som har registrert bigårdsplassene sine, men vi har en høy organisasjonsgrad i Norge og vi antar at over 80% av birøkterne er medlemmer i Norges Birøkterlag. To ordninger gjør at vi har en rimelig grei oversikt over fordelingen av hobbybirøktere og næringsbirøktere. Siden 2009 har birøktere med mer enn 24 bifolk kunne søke om et produksjonstilskudd (per bifolk) gjennom

landbrukets tilskuddsordning. Tabellen viser produksjonstilskuddstatistikk for 2017-2023, hentet fra Landbruksdirektoratet. Det har vært endringer i ordningen i perioden, bl. a. at det gikk fra å være et tilskudd per bikube (med et bifolk på minimum 7 rammer) til at det ble et tilskudd per overvintringsdyktig bifolk. En del birøktere innvintrer 2 bifolk i en bikube, adskilt med en skillevegg. Dette forklarer en del av økningen (fra 2018 til 2019 hvis jeg husker riktig) I tillegg ble ordningen også endret slik at birøktere som mottar andre produksjonstilskudd kan søke produksjonstilskudd også om de har færre enn 24 bifolk. Husker ikke helt når dette ble gjennomført. Den reelle økningen i antall bifolk har derfor vært mindre enn det statistikken for produksjonstilskudd tilsier.

År	**Driftsenheter**	**Bifolk**
2023	1119	50214
2022	1098	48943
2021	1077	48335
2020	1037	46707
2019	965	44030
2018	829	37651
2017	730	33895
2016	722	31063
2015	654	29470
2014	600	28972
2013	539	26719
2012	506	29198
2011	513	29532
2010	553	33274
2009	529	36006

Generelt svinger antall birøktere etter hvor økonomisk lønnsomt det er å være birøkter, men antallet hobbybirøktere påvirkes også i stor grad av samfunnstrender. Som med andre «grønne bølger» opplevde vi i flere år en økning i antall birøktere fra 2012-2013, med noen års forsinkelse i forhold til Danmark og Sverige.
Jeg trenger litt mer tid hvis jeg skal grave fram medlemsstatistikk for enkeltår tilbake til 70-tallet.
I tillegg til ordningen med produksjonstilskudd gir ordningen med sukkeravgiftsrefusjon en oversikt over antall bifolk som holdes av birøktere med mer enn 5 bifolk. Sukker er avgiftsbelagt for å redusere humant konsum av sukker, men dersom sukkeret brukes som dyrefor kan dyreeieren, i dette tilfelle birøkteren søke om å få denne avgiften refundert dersom vedkommende har mer enn 5 bifolk. Ordningen administreres av Norges Birøkterlag på vegne Skatt Øst. I den seinere tid har det blitt mer populært blant birøktere å bruke ferdigfôr som kan kjøpes hos biredskapsforhandlere. Dette fôret er ikke avgiftsbelagt og birøkteren kan således ikke søke om

refusjon av sukkeravgift. Figuren nedenfor viser antall bifolk de er søkt om refusjon av sukkeravgift fra 1992 til 2023. Den store nedgangen fra 2022 til 2023 skyldes i hovedsak endring i dokumentasjonskrav og vi antar at det uten denne endringen ville vært søkt om refusjon for ca 40 000 bifolk.



b. Antall og tetthet av bikuber/bifolk. Ordningene nevnt ovenfor gir oss en relativt god oversikt over antall bifolk. Tettheten av bifolk over større områder som fylker kan lett beregnes, men tettheten varierer nok mye innenfor et fylke avhengig av hvilke områder birøkterne regner seg egnet for å drive birøkt (les: hvor de kan produsere skapelig med honning, eller utføre pollineringoppdrag for planteprodusenter).

c. Geografisk utstrekning Her gir Mattilsynets bigårdskart et rimelig greit bilde over utstrekning dersom man utelukker, opplagte feilregistrerte bigårdsplasser. Verdens nordligste bigård ligger i Lakselv, men vi antar at over 95% av bifolkene finnes sør for Steinkjer

d. Hvilke raser brukes hvor (geografisk fordeling) I Norge brukes det i dag 3 hovedtyper, de to rasene *A. mellifera carnica* (krainerbier) og *A. m. mellifera* (brunbier) hvorav den førstnevnte stammer fra import av dronninger fra Østerrike på 1970-tallet og den sistnevnte er den hjemmehørende rasen i Nord-Europa og som trolig har vært viltlevende også i Norge i de mer klimatisk gunstige tidsperiodene. I tillegg brukes en krysningsbie ofte kalt buckfast som inneholder genetikk fra en rekke bieraser fra Europa, Midtøsten og Afrika. Honningbienes paringsbiologi hvor dronningene parer seg oppe i lufta med 10-20 hannbier (droner) gjør at det er vanskelig å holde birasene rene. I enkelte områder er birøkterne blitt enige om å holde kun en bestemt rase og Norges Birøkterlag kan søke (LMD) om å få godkjent området som et reinavlsområde. Her kan man opprettholde rimelig reine raser selv om de fleste bidronninger fripares i egen bigård. I andre områder er man avhengig av å bruke isolerte parestasjoner eller instrumentell inseminering for å holde rasene reine. I avlsarbeidet hvor man selekterer for bestemte egenskaper brukes lovbeskyttede geografisk isolerte parestasjoner. Grovt sett kan vi si at flest birøktere bruker krainerbier, fulgt av buckfastbier, mens brunbia er den minst vanlige. Geografisk kan vi si at brunbier i hovedsak finnes fra Telemark til Sogn, men også i østre deler av Hedmark. Krainerbier og buckfast brukes over det meste av landet

e. Honningproduksjon vs. Pollineringsbirøkt. De fleste birøktere har hovedfokus på honningproduksjon. I områder med frukt- og bærproduksjon er det også vanlig at spesielt litt større driftsenheter leier ut bifolk til pollineringsformål. For enkelte birøktere er pollineringsbirøkt en viktigere inntektskilde enn honningproduksjon. I seinere tid har også noen birøktere utvidet produktsortimentet til også inkludere pollen og propolis, mens knapt noen birøktere høster produkter som apitoxin, dronninggele og droneyngel for humant konsum.

3. Hvordan er sykdomsbildet (inkludert parasitter, som f.eks. varroa)? Norske honningbier har gjennomgående en god helsestatus sammenlignet med helsestatus for honningbier i de fleste andre land. De to meldepliktige bakteriesykdommene åpen og lukket yngelråte er svært sjeldne og bekjempes som andre meldepliktige dyresykdommer med tøffe virkemidler. Varroamidden som sammen med medfølgende virusinfeksjoner utgjør den største trusselen for honningbier globalt, men også i Norge, ble første gang påvist i Norge i 1993. Ut i fra utbredelsen den da hadde antas det at varroamidden ble introdusert til Norge i 1991. Ettersom næringa har innført selvpålagte flytterestriskjoner for å hindre spredning av varroamidd er Møre og Romsdal. Tidligere Sogn og Fjordane fylke, nordre del av Trøndelag, Nordland, Troms og Finnmark fremdeles uten varroa. Av øvrige sjukdommer er trakemidd (Acarapis woodi) så langt bare påvist i tidligere Sogn og Fjordane fylke. Mikrosporidiene *Vairimorpha apis* og *V. ceranae* er allment utbredt, men vi har ikke oppdatert kunnskap om deres innbyrdes fordeling. Kalkyngel (*Ascophaera apis*) er også allment utbredt, men utgjør normalt ikke noe problem for de fleste birøktere. Vi har så langt ikke oversikt over forekomst av trypanosomer (*Lotmaria passim* og *Chritidia mellifica*) men arbeider med å få gjennomført en screening for disse tarmparasittene. Av virussykdommer finner vi stort sett de samme virus som ellers i verden, men prevalens har vært lavere for de fleste i de undersøkelser som er gjennomført. Ellers ser vi den samme utviklingen i Norge som ellers at virussituasjonen endrer seg dramatisk med introduksjon av varroa, bl.a. med mer virulente virusvarianter.

a. I ulike regioner i Norge? Per i dag er det ikke påvist varroamidd i Møre og Romsdal samt tidligere Sogn og Fjordane fylke. I tillegg er Finnmark, Troms, Nordland og nordre del av Trøndelag fylke varroafrie

b. I Norge over de siste 50 år (mer/mindre?). Bakteriesykdommer har blitt sjeldnere enn tidligere, men introduksjon og spredning av varroa har gitt en forverring for flere typer virus hvor varroamidden fungerer både som en mekanisk og biologisk vektor

c. I forhold til andre land (Verden, Europa, Norden)? Vesentlig bedre med tanke på bakteriesykdommer, og fremdeles områder uten etablerte populasjoner av varroamidd. For øvrige sykdommer og parasitter har vi ikke god nok kunnskap om utbredelse og prevalens til å sammenligne situasjonen i Norge med øvrige områder. Vi har en mindre populasjon av buckfastbier som klarer seg uten kjemisk bekjempelse av varroamidd, og Norges Birøkterlag arbeider med å selektere for bier som håndterer varroamidden med mindre/uten kjemisk varroabekjempelse.
d. Hvordan er sykdomsbildet hos ulike tambieraser? Vi har ikke grunnlag for å si at det er forskjeller mellom de ulike rasene av honningbier med tanke på deres mottakelighet for sjukdommer og parasitter.
e. Hva er omfanget av destruering av bikuber med sykdom (varroa, annet)? Dersom det påvises smitte av noen av de 2 meldepliktige bakteriesjukdommene vil Mattilsynet fatte saneringsvedtak som medfører destruksjon av samtlige bifolk i driftsenheten og sanering av materiell og lokaler. Foruten et større utbrudd av åpen yngelråte i 2010-2011 med Aust-Agder som arnested og hvor i overkant av 4500 bifolk ble destruert er antallet bifolk som destrueres som følge av disse sykdommene normalt under 100 bifolk årlig. Varroa er en liste 3 sjukdom (Mattilsynets klassifisering) og bekjempes ikke med tanke på utryddelse. Næringa har selv pålagt seg flytterestriksjoner for å hindre spredning av parasitten til nye områder, men spredning medfører ikke pålegg om destruksjon.
f. Hvordan foregår samarbeidet mellom offentlig sykdomsforvaltning hos bier (Mattilsynet) og Norges birøkterlag når det gjelder sykdomskontroll hos honningbier? Det er et svært godt samarbeid mellom Mattilsynet og Norges Birøkterlag når det gjelder sykdomskontroll. I tillegg er det et godt samarbeid med referanselaboratoriet for bisjukdommer ved NMBU. Dette samarbeidet omfatter kartlegging av meldepliktige sykdommer og tett samarbeid med forskrifter som omfatter sjukdommer og parasitter hos honningbier. Det har blant annet vært et tett samarbeid mellom Mattilsynet og Norges birøkterlag for å kunne unngå import og vandrebirøkt inn i Norge til tross for at EU's regelverk om åpne grenser i utgangspunktet også gjelder for honningbier. Norges Birøkterlag har en ganske omfattende FoU virksomhet med pågående prosjekter med finansiering fra NFR og EUs forskningsprogrammer. For å flytte bifolk eller eller utstyr mellom bigårdsplasser og ved salg av bifolk kreves det at bigården er sertifisert (gjennomgått en kontroll for kliniske symptom på meldepliktige sjukdommer og parasitter) Birøktere som har gjennomført kurs og bestått eksamen kan gjennomføre denne kontrollen på egne bier. Alternativt kan kontrollen gjennomføres av Mattilsynet.
g. Smittsom og eventuell arvelig svakhet hos honningbier har ofte historisk blitt spredt med importmateriale. I hvilken utstrekning importeres det bier og avlsmateriale til Norge? Import av honningbier til Norge skjer forhåpentligvis utelukkende i form av avlsmateriale. Vi frykter at arbeidsinnvandring kan

medføre ulovlig import av bifolk ved at birøktere, kanskje spesielt fra Øst-Europa hvor birøkt er svært vanlig, tar med seg bifolk til Norge framfor å kjøpe inn (langt dyrere) bifolk og utstyr i Norge. Norges Birøkterlag fraråder generelt import av avlsmateriale og vi tror at omfanget er svært begrenset. Norges Birøkterlag importerer av og til (kanskje hvert 4. år) avlsmateriale som kan inngå i det nasjonale avlsarbeidet til Norges Birøkterlag. I disse tilfellene settes det i verk omfattende tiltak for å hindre at det også importeres sykdommer og parasitter. Disse tiltakene er kostbare og vil normalt ikke gjøres av privatpersoner som importerer. Noe import av dronninger kan også skje i regi av Norges Birøkterlag i forbindelse med internasjonale forskningsprosjekter. I slike tilfeller gjennomfører vi omfattende tiltak for å hindre import av sykdommer og parasitter og noen planlagte importer har blitt avlyst som følge av dette. Vi gjennomfører nå en genetisk undersøkelse av varroamidden i Norge med tanke på å eventuelt sterkt sannsynliggjøre at varroamidden har blitt introdusert til Norge kun en gang. Dersom vi kan sannsynliggjøre dette tyder det på at landegrensene har vært en effektiv barriere for sykdommer og parasitter på honningbier i Norge.

h. Hvilke tiltak har Norges Birøkterlag iverksatt for å holde sykdomspresset nede og bevare de ulike tambierasene i Norge? Fraråder import. Før import gjøres det analyser av bifolkene i utlandet for å påvise eventuelt smitte. Norge har et særlig ansvar for å ta vare på den brune bia A.m.m. siden Norge er blant de få land som fremdeles har rasereine brunbier. Norges Birøkterlag driver et nasjonalt avlsarbeid for å avle fram brunbier (og krainerbier) som er attraktive blant birøkterne (conservation through utilization). Norges Birøkterlag initierte opprettelsen av Norsk Brunbielag i 2013 og har etter ønske fra birøktere søkt LMD om opprettelse av reinavlsområder og parestasjoner for både brunbier og krainerbier

4. Hvor ofte forviller tamme honningbier seg i Norge? Hvordan er overvintringsevnen til tamme honningbier om de forviller seg i Norge? Og hvordan skiller dette seg fra forvillingsraten og overlevelsesevnen i resten av Europa? Et bifolk kan ses på som en superorganisme som formerer seg ved 2-deling gjennom sverming. Sverming er altså en naturlig prosess for et bifolk, men birøkterne gjennomfører tiltak for å redusere sverming til et minimum. Dette gjøres dels fordi sverming gir redusert honningutbytte, samt at svermer i tettbygde strøk kan oppleves negativt av befolkingen og svermer som etablerer seg i bygninger kan være kostbare å fjerne dersom de har kommet seg inn i konstruksjonen. Svermehindrende tiltak omfatter grovt sett å bruke avlsmateriale som er svermetregt, riktig utvidelse av plass ettersom bifolket vokser, oppdeling/svekkelse av bifolk som viser svermetrang. Vi har ingen god oversikt over hvor mange bifolk som svermer, men det varierer mellom år ettersom bifolkenes utvikling påvirkes av værforhold og tilgang på nektar og pollen. Birøkterne varierer også hvor dyktige de er til å hindre sverming. En halvkvalifisert gjetning er at mellom 5 og 10% av bifolkene svermer i løpet av sesongen. De aller fleste svermer går til grunne etter kort tid. Dette skyldes dels mangel på egnede bolplasser som følge av et svært intensivt drevet skogsbruk og dels at de må rekke å

samle inn et tilstrekkelig forråd av honning for å klare seg gjennom vinteren. For de få bifolkene som klarer seg til påfølgende vår vil normalt varroamidden og virusinfeksjoner ta knekken på bifolket på seinsommer/høst. Når det er sagt har vi lite data til å underbygge at svært få svermer overlever. Å måle overlevelsen til forvillede bifolk er relativt langt oppe på lista over prosjektideer som Norges Birøkterlag ønsker å arbeide videre med, men tilgang på prosjektmidler setter sine begrensinger. Hvorvidt overlevelsesraten er forskjellig fra resten av Europa er det vanskelig å si noe om. Mangel på egnede bolplasser og usikker mattilgang taler for dårlig overlevelse, mens en vinterperiode uten yngelproduksjon gir dårligere forhold for varroamidden noe som taler for bedre overlevelse enn lenger sør i Europa. En kald vinter er i seg selv ikke noe problem så sant bifolket er tilstrekkelig sterkt (nok unge bier), lageret av honning ved inngangen til høsten er tilstrekkelig (>15kg) og bifolket har etablert seg på et egnet sted.

5. Hvordan følger Norges birøkterlag opp sin policy vedrørende honningbier og ville pollinerende insekter? (I forbindelse med birøkterkurs o.l.) Norges Birøkterlag gjennomfører nå et NFR finansiert prosjekt (https://prosjektbanken.forskningsradet.no/project/FORISS/331662?Kilde=FORISS&distribution=Ar&chart=bar&calcType=funding&Sprak=no&sortBy=date&sortOrder=desc&resultCount=30&offset=0&Organisasjon.3=NORGES+BIR%C3%98KTERLAG) hvor vi målet er å bede kunnskapen vår om hvorvidt og under hvilke forhold honningbier kan forventes å ha en negativ effekt på ville pollinerende insekter. Et viktig element utover dette er å bruke birøkterne som ambassadører for ville pollinerende insekter siden mange av faktorene som påvirker honningbier og ville pollinerende insekter negativt ofte er sammenfallende (https://doi.org/10.3389/frbee.2024.1305679). Norges Birøkterlag har også en Erasmus+ søknad inne hvor målet er å etablere en standard for pollineringstjenester utført av honningbier sammen med partnere fra Danmark og Sverige. Blant temaene som vil inngå i kursopplegget som vil lages er hvordan eventuelle negative effekter på ville pollinerende insekter kan minimeres. Nybegynnerkurset vårt inneholder per i dag ikke så mye om dette temaet, men kurset oppdateres jevnlig og det er da naturlig at vi inkluderer temaet, trolig legges det inn i bolken om økologisk birøkt.

Appendix II

Documentation of literature search provided by the library for the healthcare administration.

Literature search for literature review, see section 2.1

HONNINGBIERS PÅVERKNAD PÅ POLLINERANDE INSEKT

Kontaktperson:	Jo Skeie Hermansen
Søk:	Ragnhild Agathe Tornes
Kommentar:	Gruppa ynskja eit søk tilnærma likt det som vart brukt i desse to systematiske oversiktane: Mallinger RE, Gaines-Day HR, Gratton C. Do managed bees have negative effects on wild bees?: A systematic review of the literature. PLoS One. 2017 Dec 8;12(12):e0189268. doi: 10.1371/journal.pone.0189268. PMID: 29220412; PMCID: PMC5722319. Iwasaki JM, Hogendoorn K. Mounting evidence that managed and introduced bees have negative impacts on wild bees: an updated review. Curr Res Insect Sci. 2022 Jul 22;2:100043. doi: 10.1016/j.cris.2022.100043. PMID: 36003276; PMCID: PMC9387436. Sistnemnde vart fullført i august 2021, og difor har vårt hovudsøk tidsavgrensing tilbake til då.

Kva spørsmål skal litteratursøket svara på?
• hold av honningbiers påvirkning på ville pollinerende insekter • mulige risikoreduserende tiltak for å bidra til å forhindre/redusere risikoen på ville pollinatorer ved hold avhonningbier
Kjende relevante studier
Alaux, C., Y. Le Conte, and A. Decourtye. 2019. Pitting Wild Bees Against Managed Honey Bees in Their Native Range, a Losing Strategy for the Conservation of Honey Bee Biodiversity. Frontiers in Ecology and Evolution 7.
Cane, J. H., & Tepedino, V. J. (2017). Gauging the effect of honey bee pollen collection on native bee communities. Conservation Letters, 10(2), 205-210.
Forup, M. L., and J. Memmott. 2005. The relationship between the abundances of bumblebees and honeybees in a native habitat. Ecological Entomology 30:47-57.
Fürst, M. A., McMahon, D. P., Osborne, J. L., Paxton, R. J., & Brown, M. J. F. (2014). Disease associations between honeybees and bumblebees as a threat to wild pollinators. Nature, 506(7488), 364-366.
Geldmann, J., and J. P. González-Varo. 2018. Conserving honey bees does not help wildlife. Science 359:392-393.
Goras, G., C. Tananaki, M. Dimou, T. Tscheulin, T. Petanidou, and A. Thrasyvoulou. 2016. Impact of honey bee (Apis mellifera L.) density on wild bee foraging behaviour. Journal of Apicultural Science 60:49-61.
Goulson, D., and K. R. Sparrow. 2009. Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size. Journal of Insect Conservation:1-5.
Hansen, D. M., J. M. Olesen, and C. G. Jones. 2002. Trees, birds and bees in Mauritius: exploitative competition between introduced honey bees and endemic nectarivorous birds? Journal of Biogeography 29:721-734.
Herbertsson, L., S. A. M. Lindström, M. Rundlöf, R. Bommarco, and H. G. Smith. 2016. Competition between managed honeybees and wild bumblebees depends on landscape context. Basic and Applied Ecology 17:609-616.
Kato, M., A. Shibata, T. Yasui, and H. Nagamasu. 1999. Impact of introduced honeybees, Apis mellifera, upon native bee communities in the Bonin (Ogasawara) Islands. Researches on Population Ecology 41:217-228.
Garibaldi, L. A., Carvalheiro, L. G., Vaissière, B. E., Gemmill-Herren, B., Hipólito, J., Freitas, B. M., ... & Zhang, H. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. Science, 351(6271), 388-391.

Geslin, B., Gauzens, B., Baude, M., Dajoz, I., Fontaine, C., Henry, M., ... & Vereecken, N. J. (2017). Massively introduced managed species and their consequences for plant–pollinator interactions. In Advances in ecological research (Vol. 57, pp. 147-199). Academic Press.
González-Varo, J. P., & Vilà, M. (2017). Spillover of managed honeybees from mass-flowering crops into natural habitats. Biological Conservation, 212, 376-382.
Magrach, A., González-Varo, J. P., Boiffier, M., Vilà, M., & Bartomeus, I. (2017). Honeybee spillover reshuffles pollinator diets and affects plant reproductive success. Nat Ecol Evol 1: 1299–1307.
Mallinger, R. E., Gaines-Day, H. R., & Gratton, C. (2017). Do managed bees have negative effects on wild bees?: A systematic review of the literature. *PloS one*, *12*(12), e0189268.
Minckley, R. L., J. H. Cane, L. Kervin, and D. Yanega. 2003. Biological impediments to measures of competition among introduced honey bees and desert bees (Hymenoptera : Apiformes). Journal of the Kansas Entomological Society 76:306-319.
Moritz, R. F. A., S. Härtel, and P. Neumann. 2005. Global invasions of the western honeybee (Apis mellifera) and the consequences for biodiversity. Ecoscience 12:289-301.
Nanetti, A.; Bortolotti, L.; Cilia, G. Pathogens Spillover from Honey Bees to Other Arthropods. Pathogens 2021, 10, 1044. https://doi.org/10.3390/ pathogens10081044
Paini, D. R. 2004. Impact of the introduced honey bee (Apis mellifera) (Hymenoptera: Apidae) on native bees: A review. Austral Ecology 29:399-407.
Paton, D. C. 1993. Honeybees in the Australian environment: Does Apis Mellifera disrupt or benefit the native biota? Bioscience 43 (2):95-103.
Piot, N., O. Schweiger, I. Meeus, O. Yanez, L. Straub, L. Villamar-Bouza, P. De la Rua, L. Jara, C. Ruiz, M. Malmstrom, S. Mustafa, A. Nielsen, M. Mand, R. Karise, I. Tlak-Gajger, E. Ozgor, N. Keskin, V. Dievart, A. Dalmon, A. Gajda, P. Neumann, G. Smagghe, P. Graystock, R. Radzeviciute, R. J. Paxton, and J. R. de Miranda. 2022. Honey bees and climate explain viral prevalence in wild bee communities on a continental scale. Scientific Reports 12.
Lindström, S. A., Herbertsson, L., Rundlöf, M., Bommarco, R., & Smith, H. G. (2016). Experimental evidence that honeybees depress wild insect densities in a flowering crop. Proceedings of the Royal Society B: Biological Sciences, 283(1843), 20161641.
Rasmussen, C., Dupont, Y. L., Madsen, H. B., Bogusch, P., Goulson, D., Herbertsson, L., ... & Kryger, P. (2021). Evaluating competition for forage plants between honey bees and wild bees in Denmark. Plos one, 16(4), e0250056.
Roubik, D. W. 1980. Foraging behavior of competing africanized honeybees and stingless bees Ecology 61:836-845.
Roubik, D. W., J. E. Moreno, C. Vergara, and D. Wittmann. 1986. Sporadic food competition with the african honey bee projected impact on neotropical social bees Journal of Tropical Ecology 2:97-111.
Schaffer, W. M., D. W. Zeh, S. L. Buchmann, S. Kleinhans, M. V. Schaffer, and J. Antrim. 1983. Competition for nectar between introduced honey bees and native north-american bees and ants. Ecology 64:564-577.
Steffan-Dewenter, I., and T. Tscharntke. 2000. Resource overlap and possible competition between honey bees and wild bees in central Europe. Oecologia 122:288-296.
Thomson, D. 2004. Competitive interactions between the invasive European honey bee and native bumble bees. Ecology 85:458-470.
Thomson, D. M. 2016. Local bumble bee decline linked to recovery of honey bees, drought effects on floral resources. Ecology Letters 19:1247-1255.
Torne-Noguera, A., Rodrigo, A., Osorio, S., & Bosch, J. (2016). Collateral effects of beekeeping: Impacts on pollen-nectar resources and wild bee communities. Basic and applied ecology, 17(3), 199-209.
Valido, A., Rodríguez-Rodríguez, M.C. & Jordano, P. Honeybees disrupt the structure and functionality of plant-pollinator networks. Sci Rep 9, 4711 (2019). https://doi.org/10.1038/s41598-019-41271-5
Wojcik, V. 2018. Floral Resource Competition Between Honey Bees and Wild Bees: Is There Clear Evidence and Can We Guide Management and Conservation? | Environmental Entomology | Oxford Academic (oup.com)
Walther-Hellwig, K., G. Fokul, R. Frankl, R. Buchler, K. Ekschmitt, and V. Wolters. 2006. Increased density of honeybee colonies affects foraging bumblebees. Apidologie 37:517-532.

Database: **Web of Science Core Collection**
- WOS.SCI: 1987 to 2023
- WOS.AHCI: 1987 to 2023
- WOS.ESCI: 2018 to 2023
- WOS.SSCI: 1987 to 2023

Dato: 19.10.23
Antall treff: 941 (hovudsøk) og 37 (forvaltningstiltak)

1	TS=("Apis mellifera" OR "honey bee$" or honeybee$)	Exact search	31680
2	TS=(competition OR disease$ OR pathogen$ OR (pollin* AND (exotic OR invasive)))	Exact search	5809779
3	TS=(((management OR mitigation OR "risk-reducing" OR conservation) NEAR/3 (measure$ OR action$)) OR (guidance$ NEAR/4 (beehive$ OR "wild bee$")))	Exact search	53392
4	#1 AND #2	Exact search	5261
5	#4 Timespan: 2021-08-01 to 2023-10-19	Exact search	954
6	#1 AND #2 AND #3	Exact search	37
7	#5 not #6	Exact search	941

Literature search for identification of risk reducing measures, see section 2.3

Database: **Web of Science Core Collection**

- WOS.SCI: 1987 to 2023
- WOS.AHCI: 1987 to 2023
- WOS.ESCI: 2018 to 2023
- WOS.SSCI: 1987 to 2023

Dato: 06.05.24
Antall treff: 13 (forvaltningstiltak)

7	#5 not #6	Exact search	1,021
6	#1 AND #2 AND #3	Exact search	13
5	#4	Exact search	1,034
4	#1 AND #2	Exact search	5,554
3	TS=(((management OR mitigation OR "risk-reducing" OR conservation) NEAR/3 (measure$ OR action$)) OR (guidance$ NEAR/4 (hive$ OR "wild bee$")))	Exact search	56,908
2	TS=(competition OR disease$ OR pathogen$ OR (pollin* AND (exotic OR invasive)))	Exact search	6,024,944
1	TS=("Apis mellifera" OR "honey bee$" or honeybee$)	Exact search	32,952

Database: CAB Abstracts <1973 to 2023 Week 43>
Dato: 02.11.23
Antall treff: 1460 (hovudsøk) og 41 (forvaltningstiltak)
Kommentar: Var ikkje mulighet til å avgrensa på publikasjonsmånad i Cab Abstracts. Er difor med treff frå jan-juli 2021, noko som ikkje er tilfelle for Web of Science-søket.
Etter dublettkontroll i Endnote (mot Web of Science-søket) og bibehold av bare fagfellevurderte artikler: 16 (forvaltningstiltak)

1	exp honey bees/ or exp Apis mellifera/ or ("Apis mellifera" or "honey bee?" or honeybee?).tw.	49550
2	(competition or disease? or pathogen? or (pollin* and (exotic or invasive))).tw.	3001248
3	(((management or mitigation or "risk-reducing" or conservation) adj4 (measure? or action?)) or (guidance? adj3 (beehive? or "wild bee?"))).tw.	33086
4	1 and 2	11373
5	limit 4 to yr="2021 -Current"	1471
6	1 and 2 and 3	41
7	5 not 6	1460

Database: CAB Abstracts <1973 to 2024 Week 18>
Dato: 06.05.24
Antall treff: 44 (forvaltningstiltak)

1	exp honey bees/ or exp Apis mellifera/ or ("Apis mellifera" or "honey bee?" or honeybee?).tw.	50574
2	(competition or disease? or pathogen? or (pollin* and (exotic or invasive))).tw.	3096167
3	(((management or mitigation or "risk-reducing" or conservation) adj4 (measure? or action?)) or (guidance? adj3 (beehive? or "wild bee?"))).tw.	34686
4	1 and 2	11683
5	limit 4 to yr="2021 -2023"	1687
6	1 and 2 and 3	44
7	5 not 6	1673

Database: CAB Abstracts <1973 to 2024 Week 22>
Dato: 05.06.24
Antall treff: 44 (forvaltningstiltak)

1	exp honey bees/ or exp Apis mellifera/ or ("Apis mellifera" or "honey bee?" or honeybee?).tw.	50741
2	(competition or disease? or pathogen? or (pollin* and (exotic or invasive))).tw.	3108064
3	(((management or mitigation or "risk-reducing" or conservation) adj4 (measure? or action?)) or (guidance? adj3 (hive? or "wild bee?"))).tw.	34945
4	1 and 2	11726
5	limit 4 to yr="2021 -2023"	1696
6	1 and 2 and 3	44
7	5 not 6	1682

Database: CAB Abstracts <1973 to 2024 Week 22>
Dato: 05.06.24
Antall treff: 44 (forvaltningstiltak)

1	exp honey bees/ or exp Apis mellifera/ or ("Apis mellifera" or "honey bee?" or honeybee?).tw.	50741
2	(competition or disease? or pathogen? or (pollin* and (exotic or invasive))).tw.	3108064
3	(((management or mitigation or "risk-reducing" or conservation) adj4 (measure? or action?)) or (guidance? adj5 (hive? or "wild bee?"))).tw.	34946
4	1 and 2	11726
5	limit 4 to yr="2021 -2023"	1696
6	1 and 2 and 3	44
7	5 not 6	1682

Appendix III

Scoring of studies included after full text-screening, based on our search in the recent literature. See separate Excel document.

Appendix IV

Table summarising the conclusions of the risk assessment.

<u>Resource competition</u>

Risk from exploitative competition from managed honey bees on:

Wild pollinator group	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Oligolectic bees and bees with strong dietary overlap	Major	Medium	Unlikely	Low	Medium	Low

Wild pollinator group	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Bumble bees in homogeneous landscapes and/or landscapes with limited floral resources	Moderate	Medium	Unlikely	Medium	Medium	Medium

Wild pollinator group	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Bumble bees in heterogeneous landscapes and/or landscapes with abundant floral resources	Minor	Medium	Unlikely	Medium	Low	Medium

Wild pollinator group	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
All other wild pollinators	Minor	Low	Very unlikely	Low	Low	Low

Risk from interference competition from managed honey bees on:

Wild pollinator group	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
All wild pollinators	Minimal	Medium	Very unlikely	High	Low	Medium

Pathogen spillover

Risk of spillover of bacterial pathogens from managed honey bees to all wild pollinators

Pathogen	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
***Paenibacillus larvae*, the cause of American foulbrood**	Minimal	Low	Very unlikely	High	Low	High
***Melissococcus plutonius,* the cause of European foulbrood**	Minimal	Low	Very unlikely	High	Low	High

Risk of spillover of ascomycete fungal pathogens from managed honey bees to all wild pollinators

Risk to all wild pollinators

Pathogen	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
***Ascosphaera apis,* the cause of chalkbrood**	Minimal	Low	Unlikely	Medium	Low	Medium
***Aspergillus* pathogens, the cause stonebrood**	Minimal	Low	Very unlikely	Medium	Low	Medium

Risk of spillover of microsporidian fungal pathogens from managed honey bees to all wild pollinators

Risk to all wild pollinators

	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
***Vairimorpha* pathogens, the cause of nosematosis**	Minor	Medium	Unlikely	Medium	Low	Medium

Risk of spillover of RNA viruses from managed honey bees to all wild pollinators

Pathogen	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Sacbrood virus (SBV)	Minor	Low	Unlikely	Medium	Low	Medium
Deformed wing virus (DWV)	Minor	Medium	Unlikely	Medium	Low	Medium
Black queen cell virus (BQCV)	Minor	Medium	Very unlikely	Medium	Low	Medium

Parasite spillover

Risk of spillover of parasitic mites from managed honey bees to all wild pollinators

Parasitic mite	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
***Varroa destructor*, the cause of varroosis**	Minimal	High	Very unlikely	High	Low	High
***Acarapis woodi*, the cause of acarapisosis**	Minimal	High	Very unlikely	High	Low	High
Tropilaelaps *mercedesae*	Minimal	High	Very unlikely	High	Low	High

Risk of transmission of the small hive beetle (*Aethina tumida*) from managed honey bees to all wild pollinators

	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
***Aethina tumida* (Small hive beetle)**	Moderate	Medium	Very unlikely	Medium	Low	Medium

Altered plant communities and predation pressure

Risk to all wild pollinators from altered plant communities as a result of managed honey bee presence

	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Altered plant communities	Minimal	Low	Very unlikely	Low	Low	Low

Risk to all wild pollinators from altered predation pressures as a result of managed honey bee presence

	Impact	Confidence	Likelihood	Confidence	Risk	Confidence
Altered predation pressure	Minimal	High	Very unlikely	High	Low	High

Appendix V

Table listing the scientific, English, and Norwegian names of all organisms mentioned in the opinion.

Scientific name	English common name	Norwegian common name
A cross between several subspecies of *A. mellifera*	Buckfast	Buckfastbier
Acarapis woodi	Tracheal mites	Trakémidd
Acer	Maple	Lønn
Aethina tumida	Small hive beetle	Liten kubebille
Alnus	Alder	Or
Andrena flavipes	Yellow-legged mining bee	Ingen norsk navn
Andrena fulvago	Hawks-beard mining bee	Kurvsandbie
Andrena fuscipes	Heather mining bee	Lyngsandbie
Andrena hattorfiana	Large scabious mining bee	Rødknappsandbie
Andrena nigrospina	Scarce black mining bee	Sotsandbie
Apis mellifera	Western honey bee	Honningbie
Apis mellifera carnica	Carniolan honey bee	Krainerbie
Apis mellifera mellifera	European dark bee	Brunbie
Barbarea vulgaris	Wintercress	Vinterkarse
Bombus distinguendus	Great yellow bumblebee	Kløverhumle
Bombus muscorum	Large carder bee	Kysthumle
Bombus ruderarius	Red-shanked carder bee	Gresshumle
Bombus subteranneus	Short-haired bumblebee	Slåttehumle
Bombus terrestris	Buff-tailed bumblebee	Mørk jordhumle
Brassica	Cabbages	Kålslekten
Bunias orientalis	Warty-cabbage	Russekål
Calluna vulgaris	Heather	Røsslyng
Campanulaceae	Bellflowers	Klokkefamilien
Chelostoma campanularum	Harebell carpenter bee	Klokketrebie
Colletes succinctus	Heather colletes	Lyngsilkebie
Corylus	Hazels	Hassel
Dasypoda hirtipes	Panataloon bee / Hairy-legged mining bee	Buksebie
Erica cinerea	Bell heather	Purpurlyng
Fabaceae	Legumes	Erteblomstfamilien
Knautia arvensis	Field scabious	Rødknapp
Lasioglossum nitidiusculum	Tufted furrow bee / Neat furrow bee	Kystjordbie
Lasioglossum zonulus	Bull-headed furrow bee	Båndjordbie
Lavandula x intermedia	Lavender flowers	Lavender
Megachile alpicola	No English common name	Småbladskjærerbie
Melipona beecheii	Social stingless bee	Ingen norsk navn
Melitta leporina	Clover blunthorn bee	Lusernbie
Melilotus sp.	Sweet clover	Steinkløver
Osmia bicornis	Red mason bee	Hornmurerbie
Osmia maritima	Maritime mason bee	Strandmurerbie
Philanthus triangulum	European beewolf	Biulv
Rubus fruticosus agg.	Bramble	Bjørnebær

Rubus ideaus	Raspberries	Bringebær
Salix	Willow	Vier, selje og pil
Taraxacum	Dandelions	Løvetannslekta
Tilia	Lindens	Lind
Trifolium	Clover	Kløverslekta
Tropilaelaps mercedesae	Tropilaelaps mites	Tropilaelaps-midd
Vaccinium myrtillus	Bilberry	Blåbær
Varroa destructor	Varroa mites	Varroamidd
Vespa crabro	European hornet	Geithams
Vespa mandarinia	Japanese hornet	Japansk kjempeveps
Vespa velutina	Yellow-legged hornet	Asiatisk geithams

English common name of disease or parasite	**Scientific name of pathogen**	**Norwegian common name of disease or parasite**
American foulbrood (AFB)	*Paenibacillus larvae* ssp. *larvae*	Lukket yngelråte
Black queen cell virus (BQCV)	Dicistroviridae: *Triatovirus nigereginacellulae*	
European foulbrood (EFB)	*Melissococcus plutonius*	Åpen yngelråte
Chalkbrood, ascosferosis	*Ascosphaera apis*	Kalkyngel
Deformed wing virus (DWV)	Iflaviridae: Iflavirus aladeformis	
Fire blight	*Erwinia amylovora*	Pærebrann
Israeli acute paralysis virus (IAPV)	Dicistroviridae: Aparavirus israelense	
Nosematosis	*Vairimorpha apis* (previously *Nosema apis*) *Vairimorpha ceranae* (previously *Nosema ceranae*)	Nosema
Sacbrood virus (SBV)	Iflaviridae: Morator aetatulas	
Stonebrood, aspergillosis	*Aspergillus flavus/fumigatus*	Steinyngel
Tracheal mite, acariosis	*Acarapis woodi*	Trakémiddinfeksjon
Tropilaelaps mite	*Tropilaelaps mercedesae*	Tropilaelaps-midd
Varroa mite, varroosis	*Varroa destructor*	Varroainfeksjon