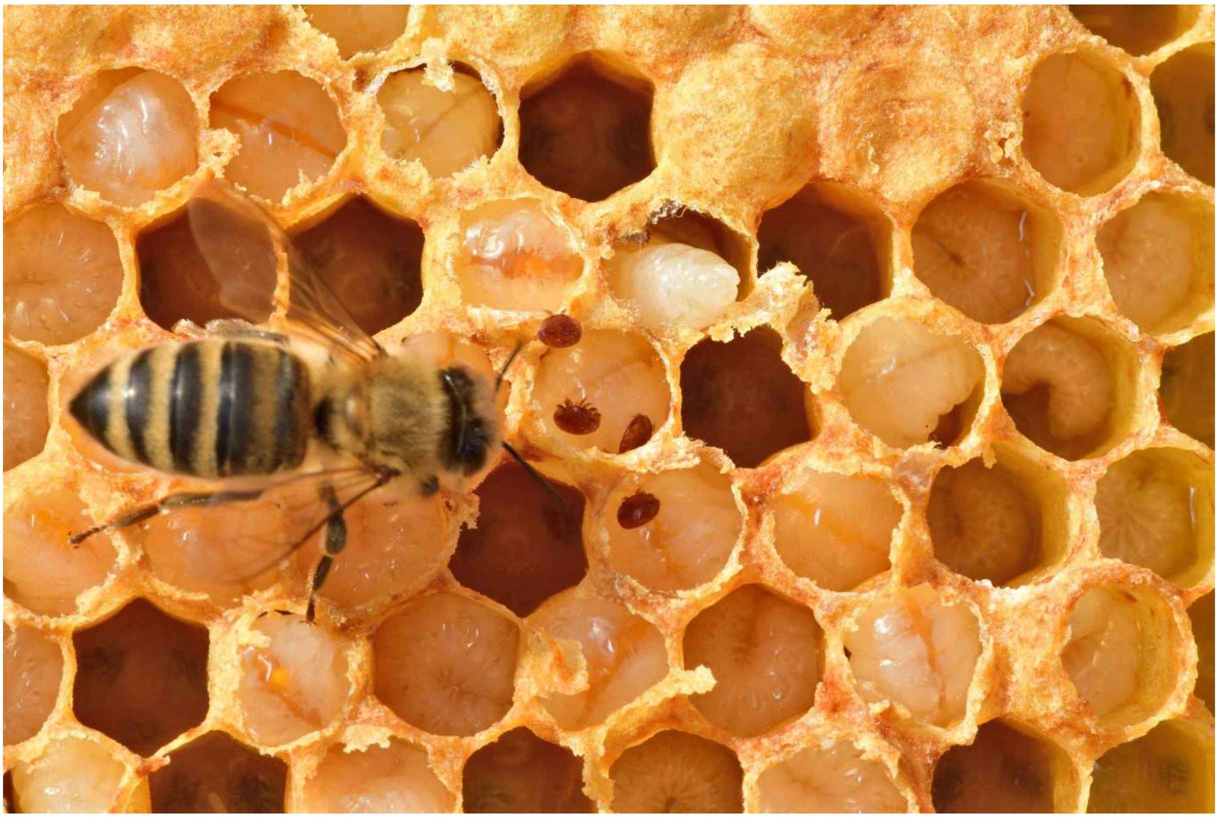
VKM

Vitenskapskomiteen for mat og miljø

Norwegian Scientific Committee for Food and Environment



VKM Report 2023: 6

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Cover photo: Photo of a varroa mite, *Varroa destructor*, infestation in a beehive from xiSerge downloaded from Pixabay

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Risk assessment of the predatory mite *Stratiolaelaps scimitus* for biological control of varroa mites in beehives

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the opinion. The project group consisted of three VKM members and a project manager from the VKM secretariat. Two referees commented on and reviewed the draft opinion. The VKM Panel on Biodiversity assessed and approved the final opinion.

Authors of the opinion

The authors have contributed to the opinion in a way that fulfils the authorship principles of VKM (VKM, 2019). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group and/or the VKM Panel on Biodiversity.

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Acknowledgement

VKM would like to thank the referees Paal Krokene, NIBIO and Mattias Jonsson, SLU for reviewing and commenting on the manuscript. VKM emphasises that the referees are not responsible for the content of the final opinion. In accordance with VKM's routines for approval of risk assessments (VKM, 2018), VKM received the referee comments before evaluation and approval by the Panel on Biodiversity, and before the opinion was finalised for publication.

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 regarding conflicts of interest apply to all work prepared by VKM.

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Summary

Key words: apiculture, biological control, Norwegian Environment Agency, Norwegian Scientific Committee for Food and Environment, predatory mites, risk assessment, varroa

Introduction

The Norwegian Environment Agency (NEA) have asked the Norwegian Scientific Committee for Food and Environment for an assessment of adverse impacts on biodiversity concerning import and release of the predatory mite *Stratiolaelaps scimitus* as measure against varroa mites (*Varroa destructor*) in apiaries.

The predatory mite is already in use in Norwegian greenhouses and polytunnels as a biological control agent against dark-winged fungus gnats in a various of plant cultures.

The NEA has received an application for a new type of use: to combat varroa mites in apiaries.

Background

Varroa destructor (the varroa mite) is a species of parasitic mite that feeds externally on honeybees; it is considered one of the major threats to beekeeping world-wide due to its parasitic behaviour and because it acts as a vector for several viral and bacterial bee pathogens. Beekeepers in North America have begun experimenting with introducing *Stratiolaelaps scimitus,* a commercially available predaceous mite originally used for biocontrol in greenhouses and polytunnels, to control varroa mites, and several studies on the use of the mite in this context have been published recently. The Norwegian Environment Agency has asked VKM to assess the risk to biological diversity in Norway associated with this new use of *S. scimitus*, and to assess the effects of climate change on any risks that are proposed.

Stratiolaelaps scimitus is a tiny (0.5 mm), soil-dwelling predaceous mite that in nature feeds on a wide variety of soil invertebrates, including fly larvae, nematodes, nymphs of thrips, potworms (oligochaetes), springtails, and other mites. For over three decades, *Stratiolaelaps scimitus* has been produced commercially and the species is now used globally for biological control. The mite is applied to control a wide variety of organisms harmful to food production or to the production of ornamental plants, but especially to combat infestations of fungus gnat larvae, spider mites, flower thrips, and certain plant-feeding nematodes. The species is already used as a biocontrol agent in Norway in greenhouses, open plastic polytunnels used for protecting crops, and in various indoor plantings and fungiculture.

Methods

VKM established a project group with expertise in entomology, invasion ecology, honeybee behaviour and ecology, and risk analysis of biological control agents. The group conducted systematic literature searches and scrutinized the relevant literature that was found. In the absence of Norwegian studies, VKM relied on literature from other countries.

Results and conclusions

This VKM assessment concludes with medium confidence that introducing *S. scimitus* for use in beehives would not significantly increase the probability of establishment and spread of *S. scimitus* above that of its current use. We point out that there is no evidence that continuous use of *S. scimitus* in Norway, over decades, has led to its establishment outside of enclosures, including open polytunnels. The optimal temperature for development and reproduction is far higher than what is normally observed in Norway (~28 °C). Although lethal temperature has been reported to be as low as –5.2 °C, we still conclude that *S. scimitus* would not be able to establish permanent populations in Norway, not even in the southern part of the country as such temperatures are expected to occur in some years throughout the country. Future climate change is not believed to alter this conclusion, since periods with lethally cold temperatures are expected to still occur in the future.

Sammendrag på norsk

Nøkkelord: Biologisk kontroll, birøkt, varroa, rovmidd, risikovurdering, Vitenskapskomiteen for mat og miljø, Miljødirektoratet

Innledning

Miljødirektoratet har bedt Vitenskapskomiteen for mat og miljø (VKM) om en vurdering av mulige negative effekter på biologisk mangfold ved innføring av rovmidden *Stratiolaelaps scimitus* for biologisk kontroll av varroamidd (*Varroa destructor*) i bikuber.

Rovmidden brukes allerede for bekjempelse av hærmygg (sørgemygg) i diverse plantekulturer i veksthus og plasttuneller i Norge. Miljødirektoratet har mottatt en søknad om en ny type bruk, nemlig bekjempelse av varroamidd i bikuber.

Bakgrunn

varroamidd er en parasittisk midd som lever på honningbier. Varroamidd er globalt ansett som en av de største truslene mot birøkt på grunn av dens parasittiske levesett, og fordi den kan bære med seg en rekke virus og bakterier som forårsaker biesykdommer. Birøktere i Nord-Amerika har satt i gang eksperimenter hvor de introduserer *Stratiolaelaps scimitus*, en kommersielt tilgjengelig rovmidd opprinnelig til bruk som plantevernmiddel i veksthus og plasttuneller, for å bekjempe varroamidd. Det er nylig publisert en rekke studier som har sett på denne nye bruken. Miljødirektoratet har bedt VKM å vurdere risikoen for norsk biologisk mangfold ved bruk av *S. scimitus* overfor varroamidd, og å vurdere hvordan fremtidige klimaendringer vil kunne påvirke eventuell risiko.

Stratiolaelaps scimitus er en liten (0.5 mm) jordlevende rovmidd som i naturen lever av et mangfold av evertebrater, som for eksempel fluelarver, rundormer, nymfer av trips, fåbørstemark, spretthaler og andre midd. Siden 1990-tallet har *S. scimitus* blitt produsert kommersielt, og arten er i dag brukt i plantevern over hele verden. Midden brukes til bekjempelse av en rekke organismer som er skadegjørere i matproduksjon og prydplanter, særlig soppmygg, edderkoppmidd, blomstertrips og enkelte plantespisende rundormer. Arten er allerede i bruk for biologisk kontroll i diverse matplantekulturer i drivhus og åpne plasttuneller, men også i prydplantesammenheng og i produksjon av sopp.

Metoder

VKM opprettet en prosjektgruppe med ekspertise i entomologi, invasjonsbiologi, honningbieatferd, økologi og risikovurdering av organismer til bruk i biologisk kontroll. Gruppen utførte et systematisk litteratursøk og gransket litteraturen som ble funnet. I mangel av studier fra Norge, måtte gruppen bygge sine konklusjoner på studier fra andre land.

Resultater og konklusjon

VKM konkluderer, med middels sikkerhet, at introduksjon av *S. scimitus* for bruk i bikuber, ikke vil øke sannsynligheten signifikant for at arten etablerer seg eller sprer seg, ut over den sannsynligheten som følger av dagens bruk. Vi poengterer at det ikke finnes noe som tyder på at kontinuerlig bruk av *S. scimitus* i Norge har resultert i at arten har etablert seg utenfor arealer hvor de har blitt introdusert, inkludert åpne plasttuneller.

Optimal temperatur for utvikling og reproduksjon er vesentlig høyere enn hva som normalt observeres i Norge (~28 °C). Gitt at laveste overlevelsestemperatur har blitt rapportert å være –5.2 °C, konkluderer vi med at *S. scimitus* ikke vil være i stand til å etablere permanente populasjoner, ettersom det er forventet at vi år om annet vil ha så lave temperaturer i fremtiden også, selv i de varmeste delene av landet. Vi vurderer at fremtidige klimaendringer ikke vil påvirke konklusjonen.

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

The Norwegian Environment Agency refers to the collaboration agreement signed between the Norwegian Environment Agency and VKM January 31st, 2019, as well as the mandate for assignments to VKM in 2019, and requests VKM to perform a scientific assessment of adverse impacts on biodiversity concerning import and release of the predatory mite *Stratiolaelaps scimitus* (synonym: *Hypoaspis miles*) as measure against varroa mites (*Varroa destructor*) in apiaries.

Background

The predatory mite *Stratiolaelaps scimitus* is used to combat dark-winged fungus gnats (*Sciaridae sp*.) in all plant cultures that are grown in organic growth medium. In Norway, preparations with *S. scimitus* are used in greenhouses, plastic tunnels and indoor plantings, especially in *Poinsettia sp.* and mushroom cultivation where dark-winged fungus gnats are often a problem. The species is exempt from the obligation to apply for a permit in accordance with the regulation on alien organisms §11.e. However, the Agency assumes that the exemption applies to use as a pesticide in greenhouses and cultivation tunnels.

The Agency has received an application for a new type of use: to combat varroa mites in apiaries.

The report will be used to decide whether permission is granted for the importation and release of the species in apiaries as a biological control agent against varroa mites.

Assignment

1. The Norwegian Environment Agency asks VKM to assess the risk to biological diversity associated with the new use of the predatory mite *Stratiolaelaps scimitus* to combat varroa mites in apiaries.
2. Assess the effect of changing climate on any impacts described above.

Methodology and Data

1.1 Data collection and literature search

Literature searches were performed in ISI Web of Science, CABI and PubMed. These databases were chosen to ensure comprehensive study retrieval. "*Stratiolaelaps scimitus*" was used as a search term for this study (see figure 1). The literature search was performed October 15, 2022.

The main searches resulted in a total of 50 records after duplicates were removed, both automatically and during primary screening of the bibliography. Screening and quality assessment of papers were performed independently by each member of the project group.

For the purpose of this report, all articles retrieved were considered important and read as full text articles.

To strengthen the knowledge basis of the opinion, additional manual searches for papers and relevant grey literature were also performed. Manual searches included "snowballing", i.e., checking articles that were referred to in papers found in the main literature, as well as searches via Google, Google Scholar and the reference manager EndNote.

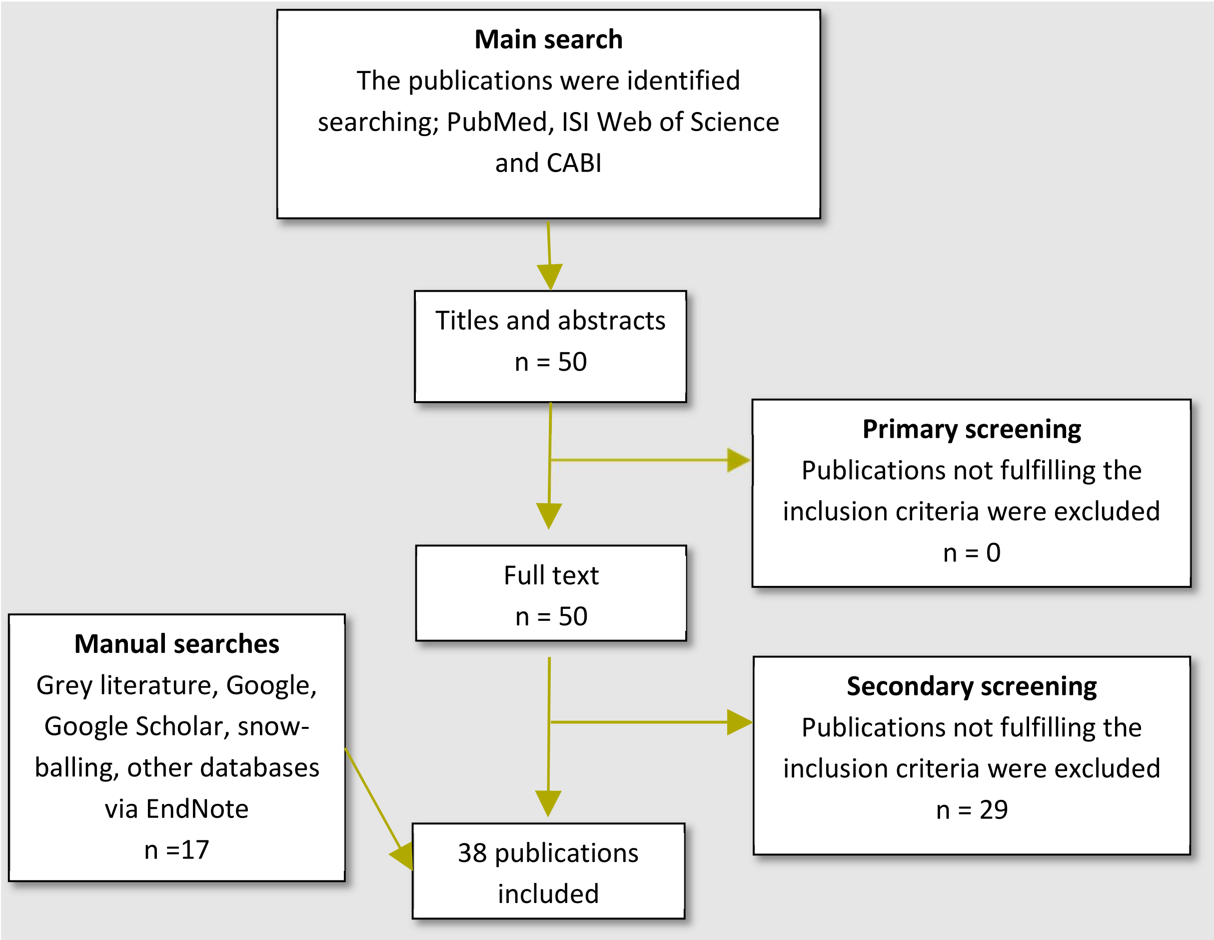

Figure 1. Flowchart for the literature search on *Stratiolaelaps scimitus*

1.2 Assessment of impact on biodiversity

Under "Likelihood" we assess how likely it is that the characterized hazard occurs. Likelihood intervals range from "Very unlikely" to "Very likely" (Table 1).

Table 1. Likelihood that a characterized hazard will occur.

Rating	Descriptor
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 %

Furthermore, assessment of confidence is characterized as either "Low", "Medium" or "High" and further described in table 2.

Table 2. Assessment of confidence in the conclusions made.

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

Assessment

2 Introduction

2.1 Purpose and scope

This document presents a scientific opinion prepared by the Panel on Biodiversity, in response to a request from the Norwegian Environment Agency. The opinion is an assessment of the risk posed to biodiversity from introduced specimens of *Stratiolaelaps scimitus* (Womersley, 1956) for use against varroa mites in beehivesof domestic honeybees. The assessment area for this opinion is Norway.

2.2 Product and trade names

Stratiolaelaps scimitus has been commercially available for biological control for at least three decades. Many companies sell these predatory mites, including several in Norway. The product is usually advertised and labeled with both the current scientific name *Stratiolaelaps scimitus* and the older designation for what used to be assumed to be the same species, *Hypoaspis miles* (Berlese, 1892). Trade names for the product are usually simply one or both of the species' scientific names: Nature's Good Guys, "*Hypoaspis miles– Stratiolaelaps scimitus*"; Growers' House "*Stratiolaelaps scimitus (Hypoaspis miles*)"; Applied Bio-nomics "*Stratiolaelaps";* Mat & Hage, *Hypoaspis miles*" (but the tubes containing the mites are labelled with *Stratiolaelaps scimitus*). A few companies use trade names but have a scientific name on the label (which can usually be read from the image on the website): BioProduction calls their product "Biomil"; Koppert, "Entomite-M".

2.2.1 Taxonomy

Stratiolaelaps scimitus and *H. miles* are not synonyms: *H. miles* is not an old name for (i.e., a junior synonym of) *S. scimitus* (Walter and Campbell, 2003). Both are currently recognized as good species in the genus *Stratiolaelaps* and belong to two different species complexes (Walter and Campbell, 2003). Walter and Campbell (2003) used morphology and DNA barcoding data (cytochrome oxidase I sequences) to address this taxonomic confusion. The samples they analyzed were all sold for biological control under the name *S. scimitus*, but they caution that it is possible that more than one species of *Stratiolaelaps* are bred and sold commercially. Cabrera et al. (2005a) confirmed that North American cultures used for biological control were *S. scimitus.* The recently published catalogue for the family Laelapidae (Moraes et al., 2022) also agrees with the taxonomic conclusions of Walter and Campbell (2003). The current taxonomic status is, then, that the older name *H. miles* was incorrectly used for what is now called *S. scimitus,* but the former species does belong in the same genus and is a good (separate) species.

2.2.2 Associated organisms

Stratiolaelaps scimitus is usually shipped in vermiculite or peat moss with small numbers of *Tyrophagus putrescentiae* (Acaridae) as prey (e.g., Moshkin and Brygadyrenko, 2022; Rondeau et al., 2019, https://www.plantevernleksikonet.no/l/oppslag/126/). The latter is a cosmopolitan mite known as mould mite, cheese mite, or bran mite in English and *kopramidd* in Norwegian; it feeds on fungi growing on organic matter. We were able to ascertain that both Nyttedyr.no and Bondekompaniet import *S. scimitus* with this prey organism.

2.2.3 Natural distribution

The work of Walter and Campbell (2003) indicate that *S. scimitus* and its nearest relatives are endemic to the rainforests of Australia where they live in the soil. *Stratiolaelaps scimitus* has never been found in the wild in Norway, but the search effort is unknown and probably very limited (https://www.plantevernleksikonet.no/l/oppslag/126/).

2.3 Properties relevant to its use as a biological protection product

2.3.1 Development and reproduction of *Stratiolaelaps scimitus*

Stratiolaelaps scimitus (under the name *Hypoaspis miles* in much of the literature) is a tiny (0.5 mm) brown mite that preys on a wide variety of soil-dwelling organisms, including fly larvae, nematodes, thrips nymphs, potworms (oligochaetes), springtails, and other mites (Cabrera et al., 2005a; Chambers et al., 1993; Walter and Campbell, 2003).

Reproduction and survival have been studied in laboratories around the world, often with respect to the mite's ability to control current or potential target pest organisms. Of environmental variables, only temperature has been studied experimentally. As is the case for all invertebrates, development and reproduction in these mites are temperature dependent. Wright and Chambers (1994) reported that the threshold temperature for the mite to complete its life cycle was between 10 and 12 °C. At 10 °C, eggs did not hatch, nor did females lay eggs, but at 12 °C females could both feed and lay eggs. Moshkin and Brygadyrenko (2022) conducted laboratory experiments measuring how fast the mites move at various temperatures, to better understand the dispersal of mites released into biocontrol situations. They found that the mites were nearly inactive at the lowest temperature (14 °C) and moved most rapidly at 25–33 °C (see also section 2.2.2). Ydergaard et al. (1997) reported that juvenile mortality was 100 % at ≤10 °C, though inactive adults may survive at temperatures closer to freezing. Kjellström (2019) found that lethal temperature (LT50) for adult mites is -5.2 °C. Inactive adults of a related species, *Geolaelaps aculeifer* (Canestrini), can survive for over a month at 0 °C (Kevan and Sharma, 1964). Wright and Chambers (1994) found that at 28 °C the species could develop from egg to adult in as few as 9 days, but that development could take 34 days at 15 °C. They found that few eggs were laid at 32 °C and those suffered high mortality. Similarly, Ydergaard et al. (1997) found that reproduction is highest at 25–30 °C but begins to decrease at 30 °C. They estimated that fecundity would peak at 26 °C. Cabrera et al. (2005a) studied development of the mites at 22 °C, with several food sources. Fed on either fly larvae or potworms, juvenile development took 13 days; females then oviposited for 16 days (potworms) or 22 days (fly larvae) during which they laid 27 eggs on average. At slightly higher temperatures (25 °C) development was faster: 10 days for females and 8 days for males, and females laid an average of 28 eggs over 19 days (Park et al., 2021b). In contrast to the findings cited above about poor reproduction at temperatures above 30 °C, Lesna et al. (2012) found no temperature-induced negative effects when using *S. scimitus* for red mite control on caged hens at temperatures as high as 33 °C.

Gobbi et al. (2020) investigated the effects on *S. scimitus* populations of large variation in soil temperature by exposing experimental cultures to one of five temperatures ranging from 12 to 37 °C for up to four hours. The cultures were otherwise kept at 25 °C. Temperatures up to 31 °C had no effect on survival, but exposure for four hours to 37 °C led to over 60% mortality. Oviposition following the temperature treatments was significantly changed (compared to 25 °C) for some combinations of exposure time and temperature, but the responses are difficult to summarize. The strongest significant effect was for 37 °C for four hours, a treatment that reduced oviposition by about two thirds compared with four-hour exposures to 25 or 31 °C. However, Lesna et al. (2012) found that daytime temperatures as high as 33 °C (and 25 °C nighttime) did not negatively affect control of poultry red mites by *S. scimitus*, and in fact, control was greatest at the highest temperatures.

Stratiolaelaps scimitus feed on a wide variety of types and sizes of soil invertebrates (Wright and Chambers, 1994). Individual mites consumed, for example, eight first instar fly larvae per day but only 0.6 fourth instar larvae per day (prey items that were seven times larger than the mites). Though females oviposit for only 2–3 weeks at warmer temperatures, fed adults lived on average more than two months (Park et al., 2021a; Wright and Chambers, 1994). Starved juveniles or adults can survive for up to several weeks (Wright and Chambers, 1994).

2.3.2 Sensitivity to chemical and biological control

Stratiolaelaps scimitus is generally considered to be a beneficial species and is thus typically not the target of chemical or biological control. All published studies on the sensitivity of *S. scimitus* to chemical and biological products aimed to investigate if the mite is compatible with plant protection products used in broader integrated pest management (IPM) strategies targeting other invertebrate pests.

Three published articles describe experimental work regarding the sensitivity of *S. scimitus* to various chemical pesticides. Cabrera et al. (2004) showed that *S. scimitus* is very sensitive (as predicted) to the organochlorine acaricide dicofol. They also found that the organophosphate insecticide chlorpyrifos was highly toxic to the protonymphs, causing 100 % mortality after 48 h when applied at the highest recommended dose. Another insecticide, the insect growth regulator (a juvenile hormone mimic) pyriproxyfen, caused much lower mortality in the study of Cabrera et al. (2004). In a later study, Cabrera et al. (2005b) found that another insect growth regulator, novaluron, showed minimal negative effects on *S. scimitus.* Finally, Duarte et al. (2020) showed that the pyrethroid insecticide lambda-cyhalothrin is slightly harmful to *S. scimitus*, while several other pesticides (including spinetoran, abamecitin, azadirachtin, azaxystrobin, difenoconazole, iprodione, and thiamethoxam) were harmless.

In a study of the effects of biological control agents on *S. scimitus*, Saito and Brownbridge (2016) found no negative effects of the microbial biocontrol agents *Metarhizium brunneum* and *Beauveria bassiana* or the entomopathogenic nematode *Steinernema feltiae*. Later, Lin et al. (2017) and Sun et al. (2018) confirmed that *B. bassiana* is harmless to *S. scimitus.*

2.3.3 Target pest – distribution, life cycle and taxonomy

Varroa destructor is a parasitic mite that feeds externally on honeybees. It originates from Asia where it parasitises the eastern honeybee (*Apis cerana*). As western honeybees (*A. mellifera*) were introduced to eastern Russia and the Far East in the first half of the last century, the parasite spilled over to the introduced colonies and has since spread to all continents where honeybees are kept resulting in infested bees and hives (Goulson et al., 2015; Rosenkranz et al., 2010). The short evolutionary history without past interactions leaves *A. mellifera* with limited resistance to the parasite and *V. destructor* is seen as a major threat to beekeeping worldwide (Rosenkranz et al., 2010).

Varroa destructor completes its life cycle within the beehive. Female mites have two distinct life stages; a phoretic phase where they feed on fat body tissue and hemolymph of adult bees, and a reproductive phase that feed and reproduce within sealed bee brood cells (Ramsey et al., 2019). Males and nymphs are short-lived and are only found in brood cells. Phoretic mites are moved within the beehive or transported to other hives when the worker bees are swarming or foraging (Rosenkranz et al., 2010).

Varroa destructor was first described as a species in 2000 (Anderson and Trueman, 2000). Detailed taxonomic investigations revealed that *V. destructor* and *V. jacobsoni* are two distinct species and that only *V. destructor* infests *A. mellifera* hives. Three *V. destructor* haplotypes have been identified. The Korean type is found worldwide, while the Japanese/Thai type has a more limited distribution in Japan, Thailand and North- and South America. The Japanese/Thai haplotype is also less virulent. The third Chinese haplotype seems to be avirulent, and it is questionable whether it infests *A. mellifera* (Zhou et al., 2004). The native distribution of the Chinese haplotype is unknown, but most likely overlaps with the distribution of *A. cerana*. A more recent study identified seven haplotypes of *V. destructor* on *A. mellifera* in Asia (Navajas et al., 2010). The authors argue that the high diversity in Asia, compared to the extreme lack of polymorphism in other parts of the world, could be explained by genetic bottlenecks occurring as the mites shifted hosts from their original eastern to the western honeybees.

2.3.4 Efficiency as a biological protection product

It is unclear to what extent *Stratiolaelaps scimitus* is an effective predator on *Varroa destructor* in beehives. Rondeau et al. (2018 & 2019) showed that *S. scimitus* could feed on varroa mites under laboratory conditions, but that it also attacked all unprotected brood stages of the honeybee itself. These findings were confirmed by Rangel and Ward (2018) in similar experiments. Rondeau et al. (2019) found no effect of *S. scimitus* on reducing *Varroa* densities in beehives treated in autumn (September and November). The authors tested the recommended introduction rates from biocontrol producers (6,250 mites per hive) and also a double dosage (12,500 mites per hive). On the other hand, experienced beekeepers in Canada report that "experienced hives react very positively to the application of *S. scimitus* and "bathe in the piles [of mites] in order to distribute them" (pers. comm. Brian Spencer, 2 Dec. 2022, Applied Bio-nomics Ltd., Victoria, B.C. Canada). However, this information is interpreted with caution since it is not scientific.

2.4 Regulatory status in Norway

2.4.1 *Stratiolaelaps scimitus*

In Norway, *S. s cimitus* is approved for use as a plant protection product in greenhouses, polytunnels and indoor plantings. According to "*plantevernleksikonet.no*" and the Norwegian Food Safety Authority (https://www.mattilsynet.no/plantevernmidler/bio.asp) three products from three producers are available in Norway (Hypoline from Bioline, Hypoaspis-system from Biobest, and Entomite-M from Koppert).

Furthermore, *S. scimitus* has been widely used and distributed in Europe since 1994 and is found on the list "Biological control agent (BCA) with no adverse effects or with acceptable adverse effects" by the European and Mediterranean Plant Protection Organization (EPPO, 2021).

3 Hazard identification

3.1 Current use, occurrence, and distribution in Norway

In Norway, *Statiolaelaps scimitus* is currently used for plant protection in greenhouses, polytunnels and indoor plantings. It is primarily used against dark-winged fungus gnats (Sciaridae), but also against fungus gnats (Mycetophilidae), shore flies (Ephydridae) and thrips (Thysanoptera). It mainly feeds on soil dwelling stages of its prey (eggs, larvae and pupa) (www.plantevernleksikonet.no/l/oppslag/126/).

The species has never been recorded in the wild in Norway. No reports on negative environmental effects of *S. scimitus* have been reported in Norway (or Europe) during the 30 years or so that the species has been used in biological control of greenhouse and polytunnel pests (EPPO, 2021).

3.2 Potential for spread, establishment and dispersal

3.2.1 Climatic limitations

Stratiolaelaps scimitus is reportedly native to Australian rainforests (Walter and Campbell, 2003) and has thus evolved under considerably warmer climatic conditions than in Norway. The fact that the mite is established and abundant in soils of Tunisian citrus orchards (Kort et al., 2020) shows that the species can spread into nature where temperature conditions allow.

The climatic limitations of the mite are not well studied, but the manipulative experimental studies that are available show that its lethal temperature (LT_{50}) is -5.2 °C, meaning that 50 % of a given *S. scimitus* population are expected to die within 24 hrs at this temperature (Kjellström, 2019). Most parts of Norway experience at least -5.2 °C during at least 24 h at least once during winters, and data from The Norwegian Centre for Climate Services (seklima.met.no) show that over the last 20 years even the warmest parts of the country (such as Lista fyr) have experienced minimum temperatures below -15 °C. Climate projections towards the year 2100, accessible from the same web service, shows that the increase in minimum temperature in most parts of the country (all parts south of Troms and Finmark County) is in the range of 2–4 °C, suggesting that *S. scimitus* will experience lethal temperatures also in the future.

Summer temperatures strongly affect the mite’s ability to reproduce and complete its life cycle. It takes nine days for *S. scimitus* to complete its life cycle at 28 °C, but this increases to 34 days at 15 °C (Wright and Chambers, 1994). The mite reportedly becomes inactive and hence cannot feed at temperatures below 12 °C (Wright and Chambers, 1994; Moshkin and Brygadyrenko, 2022). Only adults can survive for long without feeding (Wright and

Chambers, 1994). Even at 16 °C, survivorship of nymphs and immature adults is reduced by 40–50% (Wen et al. 2019). No special adaptions are known for surviving long periods of cold (no cold tolerance or diapause). Under future natural conditions in Norway, few if any *S. scimitus* could be expected to survive winters, and only occasionally would the species experience high activity or rapid reproduction.

Given the information about temperatures limits, we conclude it to be very unlikely that *S. scimitus* could establish permanent populations in Norway. Short-time establishment for one or a few mild years may be possible, but existing data suggest that the mites would not be able to build up populations that will survive over years. This is assessed with medium to high confidence.

3.2.2 Dispersal ability

Stratiolaelaps scimitus is usually described as a soil dwelling mite, and it disperses locally by walking. However, being only 0.5 mm in size, the mites do not walk far, and their movement behaviour is temperature dependent. In a recent study, Moshkin and Brygadyrenko (2022) found that adults only walked a few millimeters per 10 seconds when the temperature was below 19 °C, and they were almost immobile below 14 °C. However, mites in the family Laelapidae can often disperse over longer distances by hitchhiking with more mobile animals, like mammals, birds, and bees. *Stratiolaelaps scimitus* is used for biocontrol of red mites in poultry production and has been found in the nests of wild birds (Lesna et al., 2012), indicating that they can disperse very long distances, especially if they are attached to migrating birds. The species is also used for biocontrol of *Varroa destructor* mites in beehives in other parts of the world (Rangel and Ward, 2018; Rondeau et al., 2018; Rondeau et al., 2019), and it seems likely that also *S. scimitus* may be vectored by bees, although this should be further studied. As *S. scimitus* is used for biocontrol in plant production Sweden, Denmark, and most other European countries, one cannot exclude that natural dispersal into Norway can and does occur.

Honeybees are vectors of many diseases and can infect wild bees that they share host plants with (Piot et al., 2022). Likewise, *S. scimitus* mites that hitchhike with honeybees to flowers could probably “disembark” and potentially infect later visiting wild bees with infectious agents, or the mites might attach to the bees themselves. We can only speculate about the extent and importance of such dispersal.

3.3 Taxonomic challenges

In much of the earlier literature, the mite that is the subject of our report was referred to as *Hypoaspis miles* (e.g., Wright and Chamber 1994, Ydergaard et al. 1997). Commercially, this mite is sold as *Hypoaspis miles*, *Stratiolaelaps scimitus,* or under both names (e.g. https://bondekompaniet.no/hypoaspis-jordrovmidd-2-500stk-970201h550006. So, in both the literature and in commercial preparations, the names are used interchangeably. Unfortunately, *H. miles* is not simply an older name for *S. laelaps.* Walter and Campbell

(2003) found that *S. scimitus* and *S. miles* (transferred to *Stratiolaelaps* from the genus *Hypoaspis*) belong to their own cryptic species complexes, and hence are not two names for the same species. Their treatment has been supported by Cabrera et al. (2005a) and the recent world catalogue of Moraes et al. (2022) does treat *S. scimitus* and *S. miles* as separate. Carrillo et al. (2015) point out that each species in the complex could have different uses in biological control. The actual species that is sold by a given producer could be confidently identified by non-specialists using DNA barcoding (Walter and Campbell, 2003; Yan et al., 2022; Yan et al., 2021) or by taxonomical experts using identification keys (Cabrera et al., 2005a; Kort et al., 2020).We cannot be confident about the identity of *Stratiolaelaps* species studied in most published research and we do not know to what extent genetically similar species might differ in their ecology and behaviour and hence their appropriateness for specific biocontrol usages.

3.4 Effects on biodiversity

Stratiolaelaps scimitus is omnivorous. In addition to its main target pests, it feeds on other small arthropods, such as mites (e.g., *Varroa destructor*), nematodes (Carta et al., 2019; Yan et al., 2022), pollen (Xie et al., 2018) and honeybee eggs and larvae, at least under laboratory conditions (Rondeau et al., 2018). There are no reports of *S. scimitus* affecting other animal populations, although negative effects on prey populations are possible. As *S. scimitus* has been used in polytunnels for decades, in Norway as well as elsewhere in Europe (EPPO, 2021), any negative effects on native biodiversity would most likely already be known.

We conclude that it is very unlikely that the use of *S. scimitus* in beehives will have negative consequences for Norwegian biodiversity in addition to any negative effect from its use as biological control agent in greenhouses and polytunnels. Our conclusion is assessed with medium confidence.

4 Uncertainties

The native distribution of *S. scimitus* is uncertain and it is therefore unclear under what climatic conditions it has evolved. The species' minimum temperature requirements for survival, development and reproduction, and how these can be altered by acclimatization, have been studied in laboratory settings, but are not known in the wild. This generates uncertainty also with respect to how the conclusions in this risk assessment will be affected by future climate change. No information exists on whether the species has become established in Norwegian nature, as escapees from polytunnels and greenhouses, and whether these escapees have any negative effect on biodiversity. There are also uncertainties related to which organisms that might be affected by *S. scimitus*, due to its broad diet and the lack of information on potential prey in Norwegian nature.

5 Conclusions with answers to the terms of reference

5.1 The prevalence of *Stratiolaelaps scimitus* and whether it occurs naturally in Norway

The predatory mite *S. scimitus* has never been recorded in the wild in Norway, despite being used as a plant protection product in open polytunnels for decades. However, it is unclear to what extent any mite- or soil-related studies would have been able to discover this species if it had indeed managed to establish at least temporary populations in agricultural soils.

5.2 The potential for establishment and spread in Norway under the conditions specified for the use in beehives

It is possible that *S. scimitus* can survive temporarily in the mildest areas of Norway, but we see no increase in the probability of establishment and spread of *S. scimitus* if it is used also in beehives, given the fact that the species is already used in open polytunnels in the same area (south of Norway). This is assessed with medium confidence.

5.3 Ambiguities regarding taxonomy that hamper risk assessment

In the past, there has been confusion as to the correct name of the predatory mites that are mass-produced for biological control. However, based on the literature and from correspondence with producers, most if not all scientific studies are on the same species, which is now known as *S. scimitus* (see section 3.3). We see no major taxonomic problems that would affect this assessment.

5.4 Assessment of the product and the organism concerning possible risks for biodiversity

We conclude that there is low risk to Norwegian biodiversity by introducing *S. scimitus* for use in beehives. We emphasize that this risk assessment focus on the additional risk from this particular use and that Norwegian nature is already exposed to the mite from its use as biological control agent in polytunnels and greenhouses. This conclusion is assessed with medium confidence.

6 Data gaps

Generally, there is a need for new knowledge of the extent of negative effects on non-target prey species in the wild. Such information would help us to assess the risk more precisely for biodiversity.

Furthermore, there is a need for knowledge of the species occurrence and distribution in Norway today and the extent and distribution of its use in greenhouses and polytunnels in Norway. If this information together with knowledge of the species climate tolerance (winter survival) under Norwegian conditions would be available, we would be more able to precisely predict the outcome of an introduction and the prevalence of the species in different parts of Norway.

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