



Risk assessment of biodiversity impacts from release of biocontrol agents in livestock facilities in Norway

Brett K. Sandercock, Martin Malmstrøm, Eva B. Thorstad, Anders Nielsen, Paul R. Berg, Anders Bryn, Kjetil Hindar, Lars Robert Hole, Johanna Järnegren, Kyrre Kausrud, Lawrence R. Kirkendall, Erlend B. Nilsen and Gaute Velle

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

Short Abstract: VKM assessed the potential risks to biodiversity in Norway associated with the import and release of biocontrol agents for management of house flies and stable flies in poultry farms, pig or sheep barns, cattle feedlots, and horse stables. Effective control of filth flies requires repeated releases of up to one million mass-reared individuals, but recent permits have restricted releases to lower numbers. Risk assessments were completed for the dump fly *Hydrotaea aenescens*, the parasitoid wasps *Spalangia cameroni*, *S. endius*, *Nasonia vitripennis*, *Muscidifurax raptor*, *M. raptorellus* and *M. zaraptor*, and the hister beetle *Carcinops pumilio*. *Nasonia vitripennis* is a native species in Norway, *C. pumilio* is a non-native species that is widely established in Norway, and *S. cameroni* occurs on pig farms in southern Norway. *Hydrotaea aenescens* and *M. raptor* have been detected in low numbers, whereas *S. endius*, *M. raptorellus* and *M. zaraptor* have not been reported in Norway. The biological control agents are generalist predators and parasitoids that could affect native species through six impact mechanisms from the Environmental Impact Classification for Alien Taxa: competition, predation, hybridization, disease transmission, parasitism, and indirect effects. No impacts on native biodiversity have been documented where the non-native species occur in Norway or elsewhere. The potential for establishment and spread is low because the non-native species are associated with manmade habitats, have poor dispersal ability, and are warm-adapted species unlikely to cope with cold winters. Mitigation measures can reduce risks during import from commercial suppliers and releases in farms and stables, whereas surveillance programs could detect unexpected changes in insect communities. VKM concludes that the risks to native biodiversity in Norway are likely to be low from use of these biocontrol agents for management of pest flies in animal production facilities.

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Norwegian Scientific Committee for Food and Environment (VKM)

Postboks 222 Skøyen

0213 Oslo

Norway

Email: vkm@vkm.no

Web site: vkm.no

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Preparation of the opinion

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

Authors of the opinion

The authors have contributed to the opinion in a way that fulfils the authorship principles of VKM (VKM 2023). 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.

Members of the project group

Brett K. Sandercock – Member of the Panel on Biodiversity in VKM, and chair of the project group. Affiliations: 1) VKM; 2) Norwegian Institute for Nature Research (NINA)

Martin Malmstrøm – Project leader, VKM staff. Affiliation: VKM.

Eva B. Thorstad - Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Institute for Nature Research (NINA)

Anders Nielsen – Vice chair of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Institute of Bioeconomy Research (NIBIO)

Members of the Panel on Biodiversity

Paul Ragnar Berg – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Institute for Water Research (NIVA)

Anders Bryn – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Natural History Museum, University of Oslo; 3) Norwegian Institute of Bioeconomy Research (NIBIO)

Kjetil Hindar – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM

Lars Robert Hole – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Meteorological Institute (MET Norway)

Johanna Järnegren – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Institute for Nature Research (NINA)

Lawrence Kirkendall – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) University of Bergen (UiB)

Kyrre Kausrud – Member of the Panel on Biodiversity in VKM. Affiliations: 1) VKM; 2) Norwegian Veterinary Institute (NVI)

Erlend B. Nilsen – Member of the Panel on Biodiversity in VKM. Affiliation: 1) VKM; 2) Nord University

Gaute Velle – Chair of the Panel on Biodiversity in VKM. Affiliation: 1) VKM; 2) NORCE Norwegian Research Centre.

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The expertise of VKM experts

Individuals 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 provisions on impartiality in the Norwegian Public Administration Act apply to all work carried out by VKM.

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Summary

The Norwegian Environmental Agency asked VKM to conduct a risk assessment for non-native organisms that have been imported and released to control nuisance flies in animal production facilities. The project tasks included expert evaluation of a list of suitable species, the likelihood of establishment and adverse effects on native species, how the risks might be affected by the scale of the releases and climate change, development of mitigation measures that could be used to reduce potential risks, and an assessment of data gaps with future research directions.

Background

Three species of house flies (Diptera: Muscidae), including the common housefly (*Musca domestica*), the lesser house fly (*Fannia canicularis*), and the stable fly (*Stomoxys calcitrans*), are common pests in animal production facilities where high numbers can negatively impact animal welfare and human health. Chemical control has become less effective because pest flies have developed resistance to common insecticides. Commercial insectaries with specialized facilities for mass-rearing of biocontrol agents have been marketing biological products as organic solutions for pest control for over 50 years. The main species used for pest fly management in Europe and North America have been the black dump fly (*Hydrotaea aenescens*), six species of parasitoid wasps (*Spalangia* spp., *Nasonia vitripennis*, and *Muscidifurax* spp), and the hister beetle (*Carcinops pumilio*). Typical management interventions might include one-time or staggered releases of up to 100 000 or one million individuals in a season. The organisms target different life-stages of the pest flies: adult hister beetles eat fly eggs and small larvae, the predatory larvae of dump flies consume the larvae of other fly species, and the parasitoid wasps lay parasitic eggs that kill flies during the pupal stage. Import and release of biocontrol agents for management of pest flies was unregulated in Norway before 2015. Permits for pest management with non-native species have been required since enactment of national legislation for Regulations on Alien Species (FOR-2015-06-19-716, 19 Jun 2015). Six permit applications have been approved by the Norwegian Environmental Agency for three species in the past decade, initially for up to 12 million individuals but more recently with limits of 2 600 individuals.

Methods

VKM established a working group that used standardized search terms in Google Scholar and ISI Web of Science Core Collection to locate available information on the pest flies and biocontrol agents that was published as scientific articles in peer-reviewed journals. Supplementary information was compiled from three additional sources: an international database on parasitoid wasps maintained by the Universal Chalcidoidea Database (UCD Community 2023), product documentation prepared by commercial suppliers and information briefs prepared for producers by agricultural extension services, and a public database of past applications and permits posted by the Norwegian Environmental Agency.

The risk assessment was then based on a framework for Environmental Impact Classification for Alien Taxa (or 'EICAT') developed by the International Union for Conservation of Nature (IUCN) to identify possible impact mechanisms that non-native species might harm native biodiversity if they enter, become established, or spread into natural areas of Norway. A risk matrix comparing the

magnitude of potential impacts ('Minimal' to 'Massive') versus the overall likelihood of impacts ('Very unlikely' to 'Very likely') was used to characterize risk on a 4-point scale ('Low' to 'High'). The confidence of each assessment was then based on a confidence matrix that compared evaluations of data quality ('Low' to 'High') versus data consistency ('Inconsistent' to 'Consistent').

Results

The eight species of biocontrol agents differ in their species status in Norway. The parasitoid wasp *N. vitripennis* is a native species that naturally occurs as two ecotypes in Norway; the hister beetle *C. pumilio* is a non-native species that is widely established as far north as Trøndelag; and the parasitoid wasp *S. cameroni* is established on pig farms near Oslo. The dump fly *H. aenescens* and the parasitoid wasp *M. raptor* have been detected in low numbers and could be 'doorknockers' or possibly established as non-native species. The parasitoid wasps *S. endius*, *M. raptorellus* and *M. zaraptor* are non-native species with no occurrence records. Two species already occur in Norway and the potential for the other six species to become established and spread in natural areas appears to be low because they are typically restricted to manmade habitats, have poor dispersal ability, and are warm-adapted and unlikely to cope with cold winter conditions in Norway.

VKM identified six EICAT impact mechanisms that pose a risk of adverse effects to native biodiversity if populations of the non-native species become established in Norway.

- The native biodiversity of Norway includes a diverse community of predatory insects and parasitoids that share similar ecological niches but no congeneric species with the biocontrol agents. VKM assesses the **risks of adverse effects from competition, hybridization, and transmission of disease to be low with low to high confidence.**
- The dump fly *H. aenescens* and the hister beetle *C. pumilio* are generalist predators that feed on eggs and larvae of a wide range of prey species. However, no negative effects on native species have been documented for either species in Norway or elsewhere in their range. VKM assesses the **risk of adverse effects from predation from dump flies and hister beetles to be low with medium confidence.**
- The parasitoid wasps (*Spalangia* spp., *Nasonia vitripennis*, and *Muscidifurax* spp.) have a high potential for adverse effects because they attack an extensive range of suitable hosts that include dipteran species with important ecological roles in pollination and decomposition. *Spalangia* females will also switch to new hosts whereas *N. vitripennis* and *Muscidifurax* females are more likely to oviposit on the same species of hosts that they emerged from. However, parasitism rates are often strongly density-dependent and female wasps have difficulty locating suitable hosts at low densities. Introductions of parasitoid wasps elsewhere have not been documented to have major ecological effects or lead to extirpation of native hosts or other parasitoids. Thus, VKM assesses the **risk of adverse effects from parasitism from parasitoid wasps to be medium with medium confidence.**
- The different species of biocontrol agents are expected to have antagonistic interactions due to interference competition or intraguild predation and parasitism. VKM assesses **antagonistic interactions pose a low risk of negative effects with medium confidence.** Joint releases could lead to additive effects but are unlikely to be synergistic. Thus, VKM assesses the **risk of indirect effects of additive or synergistic interactions to be medium with low confidence.**

Mitigating measures

VKM identified seven mitigation measures that could be used to minimize impacts of predatory insects and parasitoid wasps on native biodiversity in Norway. Three mitigation measures are related to import from commercial suppliers: accurate product labelling, use of shipping materials and handling measures to avoid accidental escape, and product verification to ensure that only approved species are imported and released in Norway. Three measures related to release in animal production facilities include: use of products as directed, manure management to avoid transport of non-native species into natural areas, and applications as part of an integrated pest management program to minimize the total numbers released. A last measure involves national monitoring to detect unexpected arrivals of non-native species or sudden changes in the range or abundance of native species that can be used to reassess the status of species included on lists of approved biocontrol agents.

Uncertainties

VKM identified seven sources of uncertainty that reduce confidence in the characterizations of risk in the assessment. The biocontrol agents are difficult to identify: they are small-bodied species that can only be correctly identified to species by using fine details in morphology such as patterns of wing venation or by using genetic markers. The species are difficult to detect in the field, and available occurrence records may not accurately reflect the established range. The species composition of commercial biocontrol products are often poorly described by suppliers and often contain contamination of hitch-hiking species with similar functional biology. Demand for biocontrol agents appears to be low in Norway, which may be because other control methods are still effective. The terms of recent permits have been restricted to import and release of small numbers of biocontrol agents (ca. 2600 individuals) during a single production season (6–12 months) and the effects of repeated releases of up to 1 000 000 individuals has not been studied. Native species of flies, parasitoids and beetles are diverse communities, but their trophic interactions and disease ecology are poorly known so that it is difficult to assess the potential impacts of non-native species. The hister beetle *C. pumilio* is a warm-adapted species that is widespread in Norway, but it is uncertain whether the species occurs in warm microhabitats or if it could be more cold-tolerant than expected.

Conclusions

Predatory insects and parasitoid wasps are a targeted method for control of pest flies that can reduce applications of pesticides that affect native biodiversity. The conclusions of the risk assessment apply to the following eight species: the dump fly *Hydrotaea aenescens*, six species of parasitoid wasps *Spalangia cameroni* and *S. endius*, *Nasonia vitripennis*, *Muscidifurax raptor*, *M. raptorellus*, and *M. zarapator*, and the hister beetle *Carcinops pumilio*. The taxa include native and established species and only a subset do not yet occur in Norway but the potential for establishment and spread appear to be low. The agents include generalist predators and parasitoids that could affect a wide range of native species through several impact mechanisms, but no obvious impacts have been documented where the species occur elsewhere. **VKM concludes that the overall risk to native biodiversity in Norway is low from import and release of the dump fly and the hister beetle for management of pest flies in animal production facilities. For the six species of parasitoid wasps**

the risk from competition and parasitism is medium whereas the risk from hybridization and transmission of disease is low.

Data gaps and future research

VKM identified five data gaps where additional information would be helpful for assessing the potential impacts of biocontrol agents on native biodiversity in Norway. First, the biocontrol agents are small-bodied and cryptic insects where targeted field sampling would help to clarify the species status in Norway. Products available from commercial vendors often contain a mixture of species, including potential hitchhikers and product verification with controlled tests would help to minimize risks. The agents have poor dispersal and the pathways to establishment in nature remain poorly understood. Impacts of competition, predation and parasitism on natural biodiversity have not been evaluated but could be tested with different experimental protocols. The biocontrol agents are known to carry different pathogens but no information was available on disease transmission or risk to native biodiversity. Last, the efficacy of biocontrol agents for pest flies is not well known for animal production facilities in Norway and a wider range of field trials with different organisms would help to minimize potential risks from release of non-native species.

Sammendrag på norsk

VKM har på oppdrag fra Miljødirektoratet gjennomført en risikovurdering av fremmede organismer som kan importeres og settes ut for å bekjempe såkalte møkkfluer i anlegg for husdyrproduksjon. Oppdraget inkluderte å kartlegge hvilke arter som er aktuelle å importere, vurdere sannsynligheten for at de aktuelle artene kan etablere seg i norsk natur, samt hvilken risiko disse eventuelt måtte utgjøre for biodiversiteten i Norge. VKM ble også bedt om å vurdere hvordan risikoen påvirkes av omfanget av utsettinger, samt klimaendringer, og til slutt vurdere tiltak som kan redusere den potensielle risikoen.

Bakgrunn

Tre arter av fluer (Diptera: Muscidae), herunder husfluen (*Musca domestica*), liten husflue (*Fannia canicularis*) og stallflue (*Stomoxys calcitrans*), er vanlige problemarter i husdyrproduksjon. I stort antall har disse negativ innvirkning på både dyrenes helse og velferd, og kan også påvirke menneskers helse. Kjemisk bekjempelse har blitt mindre effektiv fordi fluene har blitt motstandsdyktige mot vanlige insektmidler.

Kommersielle anlegg for masseoppdrett av biologiske bekjempelsesorganismer har markedsført biologiske produkter for skadedyrbekjempelse i over 50 år. De viktigste artene har vært gylleflue (*Hydrotaea aenescens*), seks arter av snylteveps (*Spalangia* spp., *Nasonia vitripennis* og *Muscidifurax* spp.) og stumpbille (*Carcinops pumilio*). Typiske tiltak ved bruk av biologiske bekjempelsesorganismer kan innebære utsetting av 100 000 til 1 million individer i løpet av en sesong. Artene som brukes, angriper ulike livsstadier hos skadefluene: voksne stumpbiller spiser flueegg og små larver, larvene til gjødselfluene spiser larvene til andre fluearter, og snyltevepsene legger egg som klekker i fluene under puppestadiet og således dreper de.

Import og utsetting av biologiske organismer for bekjempelse av plagsomme fluer var uregulert i Norge frem til 2015. Tillatelse til skadedyrbekjempelse ved bruk av fremmede arter har vært påkrevd siden en forskrift om fremmede organismer trådte i kraft (FOR-2015-06-19-716, 19. juni 2015). Miljødirektoratet har i løpet av de siste ti årene godkjent seks søknader om tillatelse for tre arter, opprinnelig for opptil 12 millioner individer, men i nyere tid med grenser på 2 600 individer.

Metoder

Tilgjengelig informasjon om møkkfluene og de biologiske bekjempelsesorganismene i vitenskapelige artikler ble funnet gjennom søk i databasene Google Scholar og ISI Web of Science. I tillegg ble informasjon hentet fra en internasjonal database over snylteveps, produktdokumentasjon fra kommersielle leverandører og informasjonsmateriell utarbeidet for produsenter av landbruksrådgivningstjenester, samt en offentlig database over tidligere søknader og tillatelser fra Miljødirektoratet.

Risikovurderingen er basert på et internasjonalt klassifiseringssystem (EICAT eller «Environmental Impact Classification for Alien Taxa» utarbeidet av IUCN eller «International Union for Conservation of Nature») for å identifisere mulige påvirkningsmekanismer som kan føre til at fremmede arter skader stedegent biologisk mangfold dersom de kommer inn i, etablerer seg eller sprer seg til

naturområder i Norge. En risikomatrise som kobler alvorlighetsgraden av mulige effekter («Minimal» til «Massiv») med den samlede sannsynligheten for at effektene blir en realitet («Svært usannsynlig» til «Svært sannsynlig»), ble brukt til å karakterisere risikoen på en skala med fire nivå («Lav» til «Høy»). Sikkerheten i hver vurdering ble klassifisert basert på hvor godt datagrunnlaget var, herunder kvaliteten på dataene («Lav» til «Høy») og hvor konsistente de var («Inkonsekvent» til «Konsekvent»).

Resultater

De åtte artene av biologiske bekjempelsesorganismer som ble vurdert har ulik status i Norge. Snyltevepsen *N. vitripennis* er en stedege art som naturlig forekommer som to økomorfer, stumpbiller *C. pumilio* er en fremmed art som er vidt etablert så langt nord som Trøndelag, og snyltevepsen *S. cameroni* er etablert på svinegårder nær Oslo. Gyllefluen *H. aenescens* og snyltevepsen *M. raptor* er begge påvist i lave antall og kan enten være «dørstokkarter» eller muligens være etablert som fremmede arter. Snyltevepsene *S. endius*, *M. raptorellus* og *M. zaraptor* er tre fremmedarter uten registrerte forekomster i Norge. Potensialet for etablering og spredning av fremmedartene i norsk natur anslås å være lavt fordi de vanligvis er begrenset til menneskeskapte habitater, har begrenset spredningsevne, og er varmetilpassede arter som trolig har liten evne til å overleve de kalde vinterforholdene i Norge.

VKM identifiserte seks EICAT-påvirkningsmekanismer som innebærer risiko for negative effekter på biologisk mangfold dersom bestander av de fremmede artene etablerer seg i Norge.

- Det stedege biologiske mangfoldet i Norge omfatter et mangfoldig samfunn av insektpredatorer og parasitoider som deler tilsvarende økologiske nisjer, men ingen arter i samme slekt som de biologiske bekjempelsesorganismene. VKM vurderer **risikoen for negative effekter som følge av konkurranse, hybridisering og overføring av sykdom til å være lav, med lav til høy konfidens.**
- Gjødselfluen *H. aenescens* og stumpbiller *C. pumilio* er generalister, det vil si predatorer som lever av egg og larver fra et bredt spekter av byttedyrarter. Det er imidlertid ikke dokumentert negative effekter på stedege arter for noen av artene, verken i Norge eller andre steder innenfor deres utbredelsesområde. VKM vurderer **risikoen for negative effekter som følge av predasjon fra gjødselfluer og stumpbiller til å være lav, med middels konfidens.**
- Snyltevepsene (*Spalangia* spp., *Nasonia vitripennis* og *Muscidifurax* spp.) har et stort potensial for negative effekter fordi de angriper et omfattende spekter av egnede vertsarter, inkludert tovinger som har viktige økologiske roller innen pollinering og nedbrytning. Hunner av *Spalangia* vil også skifte til nye verter, mens hunner av *N. vitripennis* og *Muscidifurax* i større grad forventes å legge egg på de samme vertsartene som de selv har kommet ut fra. Parasittismegraden er imidlertid ofte sterkt tetthetsavhengig, og hunnene har vanskeligheter med å finne egnede verter ved lave tettheter. Introduksjoner av snylteveps andre steder er ikke dokumentert å ha hatt store økologiske effekter eller ført til utryddelse av stedege verter eller andre parasitoider. VKM vurderer derfor **risikoen for negative effekter som følge av parasittisme fra snylteveps til å kunne være medium, men med middels konfidens.**

- De ulike artene av biologiske bekjempelsesorganismer forventes å ha antagonistiske interaksjoner som konkurranse, predasjon og parasittisme som kan redusere deres potensielle påvirkninger på stedegne arter. Samtidige utsettinger kan føre til additive effekter der kombinasjonen av arter har en større innvirkning på stedegne arter. Effektene bør ikke være synergistiske fordi det er usannsynlig at de fremmede artene skaper nye ressurser for hverandre. VKM vurderer derfor **risikoen for antagonistiske interaksjoner til å være lav, med middels konfidens**. Imidlertid kan etableringen av flere snyltevepsarter samtidig potensielt ha **additive eller synergistiske effekter, og VKM konkluderer med at risikoen i så fall kan kategoriseres som medium, men med lav konfidens**.

Avbøtende tiltak

VKM identifiserte syv avbøtende tiltak som kan iverksettes for å minimere den potensielle risikoen knyttet til utsetting av predatoriske insekter og snylteveps på stedegent biologisk mangfold i Norge. Tre tiltak er knyttet til import fra kommersielle leverandører, herunder korrekt produktmerking, bruk av emballasje- og håndteringstiltak for å unngå utilsiktet rømming, samt produktverifisering for å sikre at bare godkjente arter importeres og settes ut i Norge. Tre andre tiltak er knyttet til utsetting i husdyrproduksjonsanlegg og omfattet bruk av produktene i henhold til bruksanvisningen, håndtering av husdyrgjødsel for å unngå transport av fremmede arter til naturområder, samt bruk som en del av et integrert skadedyrbekjempelsesprogram for å minimere det totale antallet individer som settes ut. Det siste tiltaket omfatter nasjonal overvåking for å oppdage uventede forekomster av fremmede arter eller plutselige endringer i utbredelsen eller mengden av stedegne arter.

Usikkerheter

VKM påpeker syv kilder til usikkerhet som påvirker hvor sikre ekspertene er på karakteriseringene av de potensielle risikoene. De biologiske bekjempelsesorganismene er små arter som kan identifiseres ut fra morfologi av spesialister eller ved hjelp av genetiske markører, men som lett kan overses som kryptiske arter. Artene er vanskelige å påvise i felt, og tilgjengelige forekomstdata gjenspeiler derfor ikke nødvendigvis den faktiske etablerte utbredelsen. Produktene fra kommersielle leverandører er ofte mangelfullt beskrevet med hensyn til artssammensetning og vil sannsynligvis inneholde forurensning i form av arter som følger med som blindpassasjerer.

Etterspørselen etter biologiske bekjempelsesorganismer ser ut til å være lav i Norge, noe som kan skyldes at andre bekjempelsesmetoder fortsatt er effektive. Vilklårene i nyere tillatelser har vært begrenset til import i én produksjonssesong (6–12 måneder) og små utsettinger av biologiske bekjempelsesorganismer (omtrent 2600 individer), noe som ikke synes å samsvare med anbefalte retningslinjer for bruk i felt. Stedegne arter av fluer, parasitoider og biller utgjør mangfoldige samfunn, men deres trofiske interaksjoner og sykdomsøkologi er lite kjent, slik at det er vanskelig å vurdere de mulige effektene av fremmede arter. Stumpbillen *C. pumilio* er en varmetilpasset art som likevel er vidt utbredt i Norge, og det er usikkert om arten forekommer i varme mikrohabitat eller om den kan være mer kuldetolerant enn forventet.

Konklusjoner

Predatoriske insekter og snylteveps er en målrettet metode for bekjempelse av møkkfluer. Bruken av disse kan redusere bruken av plantevernmidler som har en negativ effekt på stedegent biologisk mangfold. Konklusjonene fra risikovurderingen gjelder følgende åtte arter: gyllefluen *Hydrotæa aenescens*, seks arter av snylteveps – *Spalangia cameroni* og *S. endius*, *Nasonia vitripennis*, *Muscidifurax raptor*, *M. raptorellus* og *M. zaraptor* – samt stumpbillen *Carcinops pumilio*. Disse omfatter stedegne og etablerte arter, og bare et utvalg av dem forekommer ennå ikke i Norge, men potensialet for etablering og spredning vurderes til å være lavt.

Organismene omfatter generalistiske predatorer og parasitoider som kan påvirke et bredt spekter av stedegne arter gjennom flere påvirkningsmekanismer, men det er ikke dokumentert åpenbare effekter der artene forekommer andre steder.

VKM konkluderer med at den samlede risikoen for stedegent biologisk mangfold i Norge sannsynligvis er lav ved import av gylleflue og stumpbille for bekjempelse av skadefluer i husdyrproduksjonsanlegg. For seks arter av snylteveps er risikoen for negative effekter på biomangfold i Norge medium for konkurranse og parasittisme mens risikoen for hybridisering og overføring av sykdommer er lav.

Kunnskapshull

VKM påpeker fem kunnskapshull der ytterligere informasjon ville være nyttig for å vurdere de mulige effektene av biologiske bekjempelsesorganismer på stedegent biologisk mangfold i Norge. For det første er de biologiske bekjempelsesorganismene små og kryptiske insekter, og målrettet feltprøvetaking ville bidra til å avklare artenes status i Norge. Produkter som er tilgjengelige fra kommersielle leverandører inneholder ofte en blanding av arter, inkludert mulige blindpassasjerer, og produktverifisering gjennom kontrollerte tester ville bidra til å avdekke om det er behov for ytterligere risikovurdering. Organismene vi har vurdert har begrenset spredningsevne, og spredningsveiene som kan føre til etablering i naturen er fortsatt dårlig forstått. Effektene av konkurranse, predasjon og parasittisme på naturlig biologisk mangfold er sjelden blitt evaluert, men kan undersøkes ved hjelp av ulike eksperimentelle metoder. Til slutt er effekten av biologiske bekjempelsesorganismer mot møkkfluer ikke godt dokumentert i husdyrproduksjonsanlegg i Norge, og et bredere spekter av feltforsøk med ulike organismer ville bidra til å oppklare hvilken gevinst slik bruk eventuelt har.

Background as provided by the Norwegian Environment Agency

Various types of insects, such as parasitic wasps and dung flies (Muscidae), are used for biological pest control in agriculture to control nuisance insects in stables and barns. The Norwegian Environment Agency has received applications under the Alien Organisms Regulation for the importation of, among others, the dung fly *Hydrotaea aenescens* and the parasitic wasps *Spalangia cameroni* and *Nasonia vitripennis*, for use in controlling insects that bother animals in stables and barns. Under the regulations, the use of an organism will be considered as a release if the risk of escape is not excluded. This can occur when used in facilities where organisms can escape on their own or through human error. When processing an application, the Norwegian Environment Agency shall assess whether the organisms applied for may pose a risk of adverse effects for biodiversity, cf. Regulations on Alien Organisms Section 6.

We lack the necessary knowledge about the ability of such insects to establish themselves in Norway, and what adverse effects for biodiversity the introduction and use of these species may entail. This is especially true in a longer perspective given climate change, and the introduction and release of large numbers of individuals in one place. VKM's assessment of establishment ability and possible risk of adverse effects for biodiversity will form part of the knowledge base the Environment Agency uses in its decision on whether the species can be allowed to be introduced, whether the species should be exempted from the permit requirement or should be prohibited under regulations on alien organisms.

Terms of reference as provided by the Norwegian Environment Agency

The Norwegian Environment Agency requests VKM to:

1. Create a compilation of species within different orders of insects that are used for biological control of pests that plague animals in stables and barns.
2. Assess the likelihood of establishment today, and in the future, by introducing insects for use as biological control in stables and barns that do not guarantee against escape. The probability of establishment should include a description of uncertainty.
3. Assess the risk of adverse effects for biodiversity in Norway, when insects used for biological control in stables and barns escape into the wild. Such risks should be assessed for both scenarios where the insects do not establish themselves and scenarios where they do, as well as include a description of uncertainty for both scenarios.
4. Assessment of both the probability of establishment and the risk of adverse effects should be made from the perspective of individual cases of introduction, repeated cases of introduction and the introduction of large numbers of individuals in one place.
5. Furthermore, both the assessment of the likelihood of establishment and the risk of adverse effects for biodiversity shall include an assessment of how future climate change may affect the risk of adverse consequences. The assessments shall be made in a 10-year perspective, and beyond in a long-term climate perspective.
6. Identify and describe possible risk-reducing measures and assess the effect of these.

1 Introduction

1.1 Purpose and scope

The aim of the current report is to identify and conduct a risk assessment of predatory and parasitoid insects used as biological control agents against house and stable flies that can be a nuisance or severe pests in animal production facilities, including poultry houses, sheep and pig farms, cattle feedlots, and horse stables. A wide range of species are available for use as biocontrol agents but inclusion in the risk assessment was based on three different criteria. First, the insect species should have a history of use in other countries including information from experimental trials and also be available for purchase from commercial producers. Many of the biocontrol agents have been mass-produced for decades and are commonly sold as an organic alternative to control with pesticides. Second, the assessment did not consider insect species that are used for biocontrol of plant pests commonly found in greenhouses or growth tunnels, because those organisms are regulated by The Norwegian Food Safety Authority. Last, it was beyond the scope of the assessment to evaluate risks from the full range of substrates or unintended hitchhiking organisms associated with transport and release of the biocontrol agents. In total, the assessment covered a core list of eight species of predatory and parasitoid insects.

The opinion was prepared as a response to a request from the Norwegian Environment Agency and the area of coverage for the risk assessment is Norway. The relevant national legislation is the Regulations on Alien Organisms (FOR-2015-06-19-716, 19 Jun 2015). Under Sections 6 and 10 of the regulations, permits are required for the import and release of alien organisms into Norway.

1.2 Need for biological control agents

Agricultural pests pose a serious threat to domestic animals in animal production facilities. For many years, toxic chemicals were the primary solution for pest control (Davies et al. 2007), and broad-spectrum insecticides dominated the industry up until the 1990s (Angon et al. 2023). Routine applications of agricultural chemicals have caused environmental damage and led to evolution of host resistance so that pyrethroid-based insecticides and other commonly used products are now less effective for pest control. Since then, massive efforts have been invested in new technologies and strategies to control insect pests. Current management includes a variety of approaches, including chemical control (use of different insecticides), cultural practices (sanitation procedures), mechanical traps (light traps, glue traps), eco-friendly approaches (botanical use and microbe-mediated control), genetic pest management (CRISPR and RNAi-mediated management) and biological control agents (entomopathogenic fungi and nematodes, mites, insect predators and parasitoids). The EU Directive on the Sustainable Use of Pesticides (2009/128/EC) legally mandates that all professional agricultural and forestry users implement Integrated Pest Management (IPM) based on a combination of measures (EU Directive 2009). The directive was adopted by the EU in 2014 and by Norway in 2015.

Biological control agents are now widely used as alternatives to chemical pest control (Geden et al. 2021, Ullah et al. 2025) and the applications of predatory insects and parasitoid wasps have become increasingly popular because of their efficiency in targeting pest insects. Biocontrol agents have several advantages: they target specific pest species, reduce the need for chemical pesticides, and

reduce the risks of pests evolving resistance to control measures. However, import and release of non-native species of predatory insects and parasitoids can also pose a potential risk to native biodiversity (Kenis et al. 2008, Ferguson et al. 2024). In fact, several authorities have argued that generalist species of biological control agents require special risk assessments due to a higher risk of nontarget effects (van Lenteren et al. 2006, Loomans 2021). In Norway, a total of 34 species of nematodes and arthropods have been approved for import and use as biocontrol agents for agricultural pests (Mattilsynet Plantvernmidler 2026). The approved list contains a variety of predatory mites, bugs, beetles, moths and gall midges, as well as parasitic nematodes and wasps (Appendix 1). Several of these organisms have been evaluated in previous risk assessments from VKM, including the nematode *Heterorhabditis bacteriophora* (Källqvist et al. 2014a), the green lacewing *Chrysoperla carnea* (Källqvist et al. 2014b), and the parasitoid wasp *Anagyrus vladmiri* (Stenberg et al. 2025).

1.3 The need for biological control agents in animal production facilities

Three species of house flies (Diptera: Muscidae), including the common housefly (*Musca domestica*), the lesser house fly (*Fannia canicularis*) and the stable or barn fly (*Stomoxys calcitrans*) are common pests in animal production facilities in Norway. The common and lesser house flies are opportunistic scavengers that feed on waste, carcasses and decaying matter (Malik et al. 2007, Geden et al. 2021), whereas stable flies occur in similar habitats but are a biting insect that primarily feed on the blood of mammals, including livestock, pets, and humans (Cook 2020, Rochon et al. 2021, González et al. 2024). The three species are examples of ‘filth flies’, collectively defined as species of dipteran flies in two families (Muscidae and Calliphoridae) that use compost or excrement for nutrition and oviposition, are often associated with humans, and known to transmit pathogens that affect the health of domestic animals and humans (Machtinger et al. 2015b, Onwugamba et al. 2018).

Filth flies are global pests that cause reductions in animal welfare and economic losses in animal production. At high densities, filth flies cause four types of problems for chickens, pigs, cattle, and sheep in animal production facilities, and horses in barns or stables (Skovgård and Jespersen 2000, Geden and Hogsette 2006, Meerburg et al. 2007, Birkemoe et al. 2009). First, the activity of filth flies in general can be a source of irritation and stress for confined animals. Animal welfare can be negatively affected if animals must spend time swishing the tail and ears, or stamping feet to dislodge the flies (González et al. 2024). Second, stable flies are a biting insect that feed on blood meals and may therefore also cause anemia in addition to irritating and painful wounds in some cases. Studies have shown that weight gains and feeding efficiency are reduced in the presence of 20–50 stable flies per animal (Campbell et al. 1977, Cook 2020). Third, the feeding behavior of filth flies can transport microbes and other pathogens that contaminate animal feed and water, resulting in digestive problems and internal infections which cause reduced meat quality and lower animal welfare (Geden et al. 2021, Rochon et al. 2021). Last, reduced body condition or presence of skin lesions can facilitate disease transmission. Filth flies function as mechanical vectors for different types of pathogens including avian influenza in poultry, porcine reproductive and respiratory syndrome (PRRS) virus in pigs, *Cryptosporidium*, *Giardia* and other bacteria in dairy cows, and nematode parasites (*Habronema* and *Draschia* spp.) in horses (Pugh et al. 2014, Geden et al. 2021). Disease transmission can also have implications for human health because filth flies may transport and transmit *Salmonella* and other pathogens (Wang et al. 2011), including antibiotic resistant strains that are difficult to treat effectively.

Biological control agents are valuable alternatives to chemical treatments, intensive use of mechanical or odor-based traps, and manure management for control of filth flies (Skovgård & Nachman 2004). Applications of biocontrol agents can be effective when used alone (Morgan et al. 1975, Geden & Hogsette 2006) but have greater impact if used in combination with other management interventions in an integrated pest management program (Geden et al. 1992, Crespo et al. 1998, González et al. 2024). Different types of animal production facilities with alternative procedures for animal housing and sanitation can present unique challenges for successful implementation of biocontrol agents. Releases of predatory insects or parasitoid wasps may be more successful in a poultry facility with confined animals in a stable environment (Morgan et al. 1975, 1981) versus a cattle feedlot with large open areas that are also exposed to ambient climate conditions (Geden et al. 2021).

1.4 Relevant species for control of filth flies

As outlined in the Terms of Reference (ToR), six permit applications for three species have been approved for import and release of predatory or parasitic insects for control of house and stable flies in Norway in the past decade (Miljøvedtaksregisteret 2026). The decisions provide background information on the commercial suppliers of the biocontrol agent, rationale for approval or decline, numbers permitted for import, and terms of use (2016/10870, 2021/5303, 2022/11905, 2025/11922, 2025/13919, 2026/5369). The three approved species of biocontrol agents are (Order: Family):

- The black dump fly *Hydrotaea aenescens* (Diptera: Muscidae)
- The parasitoid wasp *Spalangia cameroni* (Hymenoptera: Spalangiidae)
- The jewel wasp *Nasonia vitripennis* (Hymenoptera: Pteromalidae)

In addition, the project group identified five other insect species that matched the criteria outlined in the purpose and scope (section 1.1). The additional taxa include four species of parasitic wasps in two families and one beetle species:

- The parasitoid wasp *Spanglia endius* (Hymenoptera: Spalangiidae)
- The parasitoid wasps *Muscidifurax raptor*, *M. raptorellus* and *M. zaraptor* (Hymenoptera: Pteromalidae)
- The hister beetle *Carcinops pumilio* (Coleoptera: Histeridea).

The project group identified two other groups of organisms that have been proposed as biocontrol agents for filth flies, but these were not assessed because they did not match one or more of the project criteria (section 1.1). First, predatory macrochelid mites (Mesostigmata: Macrochelidae) have been proposed as a biocontrol agent for filth flies based on lab studies of predation rates (Abo-Taka et al. 2014, de Azevedo et al. 2015, 2018). Results from available field trials suggest that mites can be effective in poultry houses (Rodriguez et al. 1970) but are otherwise ineffective at controlling filth flies in barns or stables (Wicht & Rodriguez 1970, Cook 2020), unless parasitoid wasps are also present (Axtell 1963). Macrochelid mites are produced commercially but were not evaluated because the products are mainly recommended for biocontrol in commercial crops and horticultural applications (Knapp et al. 2018). Second, *Trichomalopsis sarcophagae* (Hymenoptera: Pteromalidae) is another parasitoid wasp that has also been proposed as a biocontrol agent and tested in field trials against house flies (Dobesh et al. 1994, Floate et al. 1999, Lysyk 1998, Floate 2003). We did not

evaluate *T. sarcophagae* because we were unable to identify a commercial vendor currently producing the species for sale (Hale 2010, LeBeck & Leppla 2023, White & Johnson 2026).

1.5 Mode of use for predatory insects and parasitoids

The three different groups of biocontrol agents target different life-stages of house and stable flies. The two species of predatory insects feed on early life-stages of the filth flies: the predatory larvae of dump flies *Hydrotaea aenescens* kill the growing larvae of other fly species whereas adult hister beetles *Carcinops pumilio* feed mainly on eggs and small larvae. In contrast, parasitoid wasps in the genera *Spalangia*, *Nasonia* and *Muscidifurax* lay parasitic eggs on the pupae of filth flies once the larval stage has been completed.

Dump flies are applied as pupae that hatch after 2–5 days (Hogsette & Washington 1995). The adult flies are ready to reproduce immediately and lay their eggs in available animal manure. For *H. aenescens* in Norway, it is recommended to release the flies in March/April and releases are repeated in batches every two weeks for about two months and then once a month after the first year of application. In the subsequent years, it is recommended with applications every 13th week. Commercial producers of *H. aenescens* include Miljøfluen in Denmark, Koppert in the Netherlands and Rincon-Vitova in the USA.

The different species of parasitoid wasps that are used as biocontrol agents have similar life histories. Females locate the pupal stage of house or stable flies, drill through the outer puparium to deposit one (solitary) or multiple eggs (gregarious) on the surface of the host larva, and then the parasitoid larvae emerge and consume the host. Parasitoid wasps are mass-reared on pupae of the filth flies that are a target for biological control and have been sold commercially for at least 40 years (Cranshaw et al. 1996, Floate et al. 2000). The parasitoids are transported as immatures within the pupae of the host target and packed in sawdust, vermiculite or other storage media. Favorable environmental conditions under mass rearing can be used to induce female-biased sex ratios in the emerging parasitoids (Heimpel & Lundgren 2000). The species are marketed in packages of 5000 to 25 000 individuals (Appendix 2), either as single species (Morgan et al. 1975, Floate et al. 2000, Skovgård & Nachman 2004), or as a mixture of multiple species (Kaufman et al. 2001, Geden & Hogsette 2006, González et al. 2024). The emerging parasites are distributed near potential sources of fly pupae and covered with damp soil to avoid desiccation and at sites that are protected from trampling or removal of manure (Greene et al. 1998). The parasitoids are applied as repeated releases of new batches of wasps every 1–4 weeks depending on the type of facilities and livestock (Legner & Brydon 1966, Geden et al. 1992, Floate et al. 2000, Skovgård & Nachman 2004, Birkemoe et al. 2009). ‘Inundative’ releases consisting of overwhelming numbers of mass-produced parasitoid wasps can be effective at reducing populations of filth flies in animal production facilities and stables (Morgan et al. 1975, Crespo et al. 1998, Skovgård & Nachman 2004, Geden et al. 2021). Commercial producers of the parasitoid wasps include Miljøfluen in Denmark, Koppert in the Netherlands and a variety of suppliers in Canada and the USA.

Carcinops pumilio are small predatory beetles that have been released for biological control of filth flies in poultry facilities. Larvae and adults live in manure, and they are regarded as effective biological control agents because of their high predation rates on fly eggs and maggots. Poultry houses with newly cleaned manure pits can benefit from releases of wild-captured beetles that will disperse throughout the facility (Kaufman et al. 2000). *Carcinops pumilio* appears difficult to mass-

rear at sufficient scale for commercial production, because high-density rearing leads to aggressive interactions and predation among adults and larvae. Reproduction is highly sensitive to nutrition and habitat conditions, and the species performs best in semi-natural manure systems rather than dense laboratory cultures (Geden & Stoffolano 1987, Moore & Kaufman 2023). We identified two commercial producers located in the United States, but found no evidence of commercial production elsewhere, including Europe. The U.S. producers supply reproductive adults that begin laying eggs after introduction into manure (Arbico-Organics 2026).

1.6 Species assessments, general assessments, and risk assessments

In the following sections, we review the literature to compile information on the key ecological and biological traits of the selected species of biocontrol agents. We summarize the systematics and taxonomy of each species, including any challenges for species identification, and discuss the biology of each species as potential species for biocontrol of filth flies. We also consider the status of the species in Norway, the potential for establishment and spread, along with potential impact on native biodiversity or human health. Some of the species have been subject of other risk assessments and we summarize the findings from previous evaluations.

General assessments across all taxa included a review of the species status in Norway, an overview of the magnitude and frequency of past imports and releases, the potential for releases to result in establishment or negative impacts on native biodiversity, and the potential for introduction of hitchhiking organisms.

We outline the methodology that VKM uses for risk assessments based on evaluation of impact mechanisms from the EICAT classification system, followed by descriptions of the hazard identification and classification, and then the likelihood, risk, and confidence of the assessments. The standardized approach for risk assessment was then applied separately to the three groups of predatory and parasitoid insects and to their potential for cumulative effects. We considered the parasitoid wasps as a single group because the six species share similar life-history strategies and functional ecology.

2 Literature search

The primary sources of scientific literature were identified using search tools in Google Scholar and ISI Web of Science Core Collection using search terms based on the scientific names of the different species of filth flies '*Musca domestica*', '*Fannia canicularis*' and '*Stomoxys calcitrans*' and the generic names of the eight biocontrol agents: '*Hydrotaea*', '*Spalangia*', '*Nasonia*', '*Muscidifurax*' and '*Carcinops*'. We used citation chasing to locate additional references with relevant information by reviewing the citation lists of relevant articles to find foundational publications, and by checking for subsequent citations of key articles to locate recent articles. We relied primarily on information published in the peer-reviewed literature where the original articles could be obtained from the publisher or by request to the author. Second, we used species accounts in the Global Biodiversity Information Framework to compile information on taxonomy and global data on occurrence records for the different species (**Figure 1**, GBIF 2026a-e). Third, comprehensive life-history data on parasitoid wasps has been compiled in individual species accounts in an international database maintained by Universal Chalcidoidea Database (UCD Community 2023). We used the existing information to compile a current overview of the range of insect species that are known to serve as host for the different taxa of parasitoid wasps (Appendices 3 and 4). Fourth, our literature search also located some unpublished reports with information targeted to applications by producers and other stakeholder groups. We included examples of reports produced by agricultural extension services supported by the US Department of Agriculture and guidelines for applications of biocontrol agents that were developed by different commercial suppliers. The documents provided practical information on how the biocontrol agents might be applied in field settings to help estimate the magnitude and frequency of releases. Last, we consulted the applications and permits approved by the Norwegian Environmental Agency during 2016–2026 for background information on the commercial suppliers of the biocontrol agent, rationale for approval or decline of previous applications, and the numbers permitted for import and terms of use for the releases (Miljøvedtaksregisteret 2026).

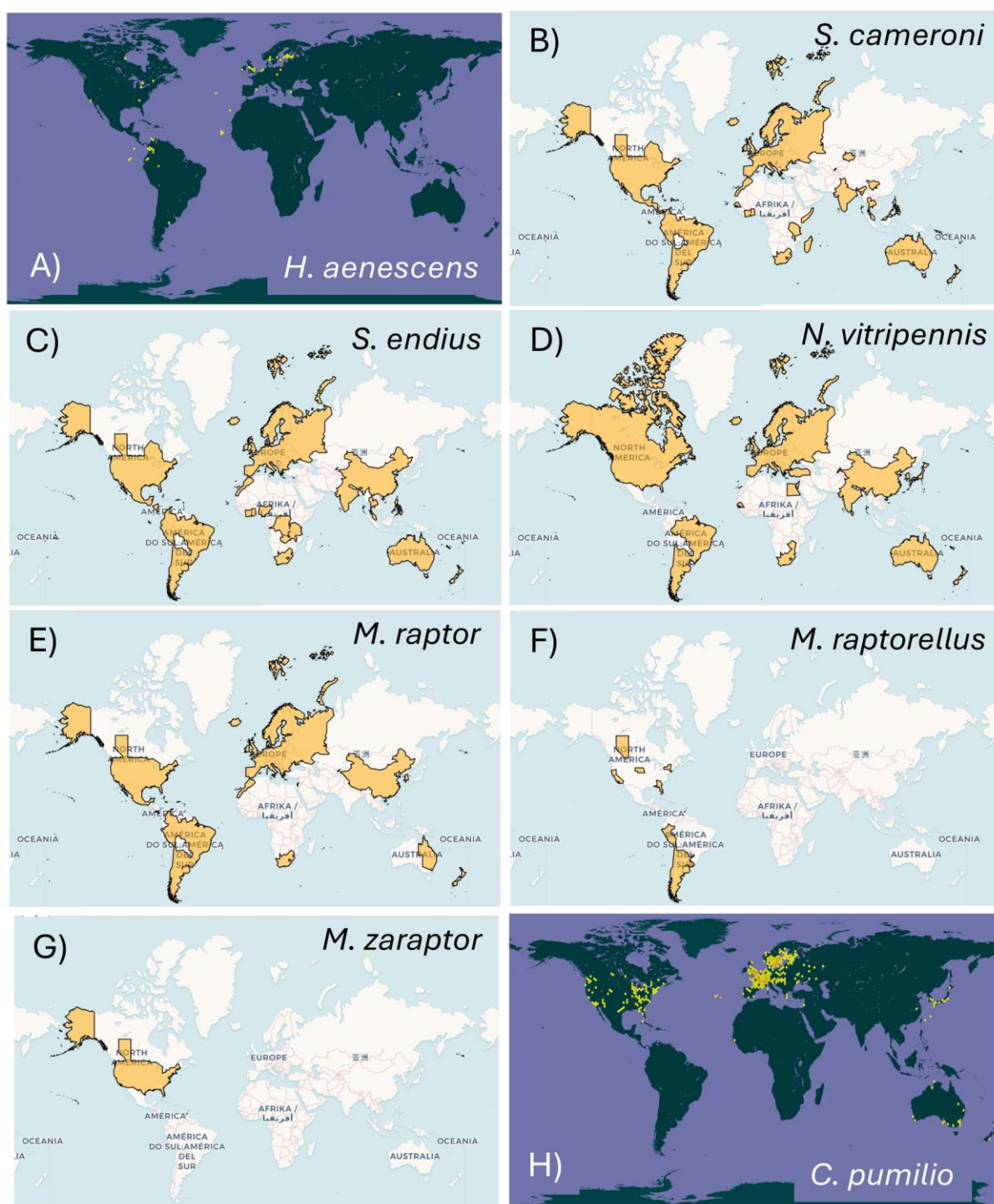


Figure 1: Global distribution of occurrence records for (A) the dump fly *Hydrotaea aenescens*, (B-G) six species of parasitoid wasps in the genera *Spalangia*, *Nasonia*, and *Muscidifurax*, and (H) the hister beetle *Carcinops pumilio*. Sources: A and H: GBIF (2026a, 2026e) and B-G: UCD Community (2023).

3 Species assessments

3.1 *Hydrotaea aenescens* (black dump fly)

3.1.1 Taxonomy and common names

- Kingdom Animalia
- Phylum Arthropoda
- Class Insecta
- Order Diptera
- Family Muscidae
- Genus *Hydrotaea* Robineau-Desvoidy, 1830
- Species *Hydrotaea aenescens* Wiedemann, 1830

Junior synonyms

- *Anthomya aenescens* Wiedemann, 1830
- *Anthomyia aenescens* Wiedemann, 1830
- *Anthomyia setia* Walker, 1849
- *Crossopalpus aenescens* Wiedemann, 1830
- *Ophyra argentina* Bigot, 1885
- *Ophyra aenescens* (Wiedemann 1830)
- *Ophyra carbonaria* Shannon & Del Ponte, 1926
- *Ophyra trochanterata* Malloch, 1932
- *Ophyra virescens* Macquart, 1844

Several recent studies refer to the species as *Ophyra aenescens* (Wiedemann 1830), particularly in the applied literature (Lefebvre & Pasquerault 2004, Cortinhas et al. 2016), but the genus *Ophyra* has now been transferred into the genus *Hydrotaea* (Grzywacz et al. 2017).

Common names: “Gylleflue” (in Norwegian), Black dump fly, Black garbage fly, Dump fly.

3.1.2 Biology of the species

Hydrotaea aenescens lays its eggs in animal dung, garbage dumps and carcasses where the larvae begin their life on a saprophagous diet; they shift to a zoophagous diet at a later stage (Burgio et al. 2025). At this later stage they feed on other animals, including fly larvae, living in the same substrate (Gammelmo et al. 2023). Optimum conditions for development are 26.7°C and 60% relative humidity (Hogsette & Jacobs 2003). Under these conditions, eggs hatch after 18–24 hours and the time required from egg to adults is about 14 days (Hogsette & Jacobs 2003). Under lab conditions, females have an average lifespan of 20 days (range: 5 to 50) and produce an average of 258 eggs per female (range: 196 to 372, Ribeiro et al. 2000). According to commercial producers, the flies are ineffective as biocontrol agents at temperatures below 15°C, presumably due to temperature-sensitive development and levels of activity (Koppert Canada 2026).

3.1.3 Occurrence and distribution in Norway and globally

Hydrotaea aenescens has its native distribution in North and Central America, in the Nearctic and Neotropical biogeographic regions (**Figure 1**). The species has been introduced to Europe, most likely through commerce in the 1960s (Hogsette & Washington 1995), and is now established throughout South and Central Europe, including Great Britain and Ireland (Pont et al. 2007 and references therein), Sweden and Finland (GBIF 2026a). *Hydrotaea aenescens* is likely to be already established in Norway. In Norway, the species has been imported over the last 20 years as a biological control agent to kill other fly species in poultry, pig and cattle farms. The species has been registered from two localities in southern Norway including Fadum, Vestfold County (1994, 2 flies) and northeast of Oslo (2022, 56 DNA reads, Artskart 2026). Based on the distribution of farms with relevant animal production in Norway, the current distribution likely includes the counties of Østfold, Vestfold, Oslo, Akershus, Agder and Rogaland. The Muscidae family have been poorly studied in Norway, and there are only a few records of *H. aenescens* in the Global Biodiversity Information Facility (GBIF 2026a). Twelve other species of *Hydrotaea* have been recorded in the national insect monitoring program in Norway but not *H. aenescens*: GBIF 2026f). The current distribution of *H. aenescens* is therefore uncertain (Gammelmo et al. 2023). Applications to import and release *H. aenescens* have been approved by the Norwegian Environment Agency for unrestricted numbers (2016/18070) and up to 12M flies (2021/5303) in the first two applications, but then more recently with permit terms restricted to a limit of 2,600 flies (2022/11905, 2025/1922, 2026/5369, 2026/5369, Miljøvedtakregisteret 2026).

3.1.4 Potential for entry, establishment, and spread

Hydrotaea aenescens has been recorded in Norwegian nature, but it is unclear whether the species is established in natural areas outside of animal production facilities. Kiritani (2012) reported that the minimum viable temperature for *H. aenescens* to fulfill its life cycle is 12.8°C. Anton et al. (2011) found no infestation of *H. aenescens* in pig carcasses during periods with temperatures below 10°C. The species depends on larvae substrates found indoors on farms, but it has been suggested that adults can fly more than 6 km (Stein et al. 1977, Hogsette & Jacobs 1999, 2003) with dispersal movements induced by food shortages (Geden et al. 1987). *Hydrotaea aenescens* could potentially spread to other farmhouses during summer despite low winter survival outdoors under Norwegian winter conditions. *Hydrotaea aenescens* has been recorded in Norway in very low numbers but the species appears to require manmade habitats and warm growing conditions so that it is unlikely to become established or spread in Norwegian nature.

3.1.5 Potential effects on biodiversity

The larvae of *Hydrotaea aenescens* can compete with and prey upon (the sole purpose of importing the species) larvae of other flies and organisms living in the same substrates. For predation and competition to have negative effect on Norwegian biodiversity, the species must be able to colonize dung and carcasses from wild animals to an extent that the species can negatively affect populations of native detritivores. We have found no reports of negative effects of the species on native biodiversity in Norway or elsewhere neither from predation, competition nor from transmission of disease.

3.1.6 Human health issues

Hydrotaea aenescens has been shown to be a mechanical vector of *Campylobacter* spp., *Escherichia coli* O157:H7, but also the eggs of the human botfly (*Dermatobia hominis*), since adults can be attracted to human excrement (Cortinhas et al. 2016). The human botfly has a tropical distribution and will most likely not be able to establish in Norway, but a full risk assessment of botflies as a commensal species is beyond the scope of this report.

3.1.7 Other risk assessments of the species

The Norwegian Biodiversity Information Centre has assessed *Hydrotaea aenescens* on their alien species lists in 2018 and 2023 to have **Low risk (LO)** to biodiversity in Norway due to a lack of known ecological effects (Artsdatabanken 2020; 2023).

3.2 *Spalangia cameroni* and *S. endius* (parasitoid wasps)

3.2.1 Taxonomy and common names

- Kingdom Animalia
- Phylum Arthropoda
- Class Insecta
- Order Hymenoptera
- Superfamily Chalcidoidea
- Family Spalangiidae Haliday, 1833
- Genus *Spalangia* Latreille, 1805
- Species *Spalangia cameroni* Perkins, 1910
- Species *Spalangia endius* Walker, 1839

The genus *Spalangia* is a diverse group of parasitoid wasps with at least 31 species (Taylor et al. 2006, Gibson 2009). The genus was originally placed in the family Pteromalidae but was later transferred to the family Spalangiidae by Burks et al. (2022). Alternative scientific names and the nomenclatural history for *S. cameroni* and *S. endius* are listed in species accounts at Global Biodiversity Information Framework (GBIF 2026b) and at the Universal Chalcidoidea Database (UCD Community 2023). The different species can be identified by morphology (Gibson 2009, Shimbori et al. 2020) or by molecular methods based on DNA barcoding and the ribosomal genetic markers (Taylor et al. 2006, Avila-Rodríguez et al. 2018).

Common names: The different species in the genus *Spalangia* do not have common names and are collectively referred to as ‘fly parasitoids’ or ‘Spalangia wasps, or ‘snylteveps’ in Norwegian.

3.2.2 Biology of the species

Parasitic wasps in the genus *Spalangia* are typically primary parasitoids of cyclorrhaphous dipteran flies, including houseflies, blowflies and fruit flies. More rarely, *Spalangia* wasps are hyperparasitoids of Diptera and Hymenoptera parasitoids associated with dipteran primary hosts such as tephritid fruit flies (Appendix 4). All species in the genus are solitary parasitoids except *S. dozieri*, which has several unusual features (Gibson & Reigada 2009). The two species *S. cameroni* and *S. endius* are generalist parasitoid wasps that have been reported from a total of 66 species of primary hosts (Appendix 3) and six species of parasitoid hosts (Appendix 4). The 39 primary hosts of *S. cameroni* include six species of root-maggot flies in Anthomyiidae (but not *Hydrotaea aenescens*), the domestic silkworm (*Bombyx mori*), 21 species of house flies in Muscidae including *Musca domestica* and three species of *Stomoxys*, and three species of fruit flies in Tephritidae. The 50 primary hosts of *S. endius* include four species of root-maggot flies in Anthomyiidae, including *Hydrotaea australia*, eight species of blow flies in Calliphoridae, 18 species of house flies in Muscidae including two species each of *Musca* and *Stomoxys*, and 12 species of fruit flies in Tephritidae including the Mediterranean fruit fly (*Ceratitis capitata*), which is an important agricultural pest. The two species of *Spalangia* wasps are also hyperparasites of other parasitoid insects including three species of flesh flies in Sarcophagidae and three species of bristle flies in Tachinidae.

Laboratory and field trials have tested the performance of *S. cameroni* alone and in combination with other parasitoid wasps. *Spalangia* spp. require warm environmental conditions for successful development and no parasitoids survived at constant exposure to temperatures of 15°C (Geden 1997). Developmental times are usually 20–27 days at optimal temperatures of 25–30°C (Gerling & Legner 1968, Birkemoe et al. 2012). Adult *S. cameroni* feed on juices of the host larvae or nectar from flowers if available, which prolongs their lifespan (Taylor et al. 2022). On the other hand, infections with microsporidian parasites can potentially reduce longevity and performance of female *Spalangia* (Dry et al. 1999). In single species trials, *S. cameroni* has higher rates of parasitism of house flies compared with *M. zaraptor* (D’Arco et al. 2024). In competition, *S. cameroni* and *S. endius* had higher search efficiency and greater attack rates than *M. raptor* but parasitoid efficiency can be reduced by intraspecific competition for house flies as hosts (Legner 1967, Ables & Shepard 1974). *Spalangia cameroni* was more effective than *S. endius* or *M. raptor* at locating and parasitizing fly pupae that were buried at depths of 1–2 cm in manure (Geden 2002). Releases of *Spalangia* spp. alone or in combination with other parasitoids have been effective for control of filth flies in poultry facilities (Morgan et al. 1975, 1981) and pig and dairy farms (Skovgård & Nachman 2004) but have often been less successful in cattle feedlots (Petersen et al. 1983, Greene & Cilek 1993, Andress & Campbell 1994).

3.2.3 Occurrence and distribution in Norway and globally

The parasitoid wasps *Spalangia cameroni* and *S. endius* are cosmopolitan species that have been recorded from six different biogeographic regions (**Figure 1**). The native range of the two species is thought to be North and Middle America (GBIF 2026b), and both species have been collected widely in the Western Hemisphere (Gibson 2009). The first specimens of *S. cameroni* were collected and described from localities in the Hawaiian Islands whereas the holotype of *S. endius* was described from Chile. *Spalangia cameroni* is considered nonnative in Europe where the first specimen was reported in 1969 (EASIN 2026). In Sweden, *S. cameroni* has been reported from the faunistic provinces of Skåne, Öland, and Närke, whereas *S. endius* has been reported once from Skåne in 1972 (Hedqvist 2003, T. Birkemoe, pers. comm.). More recent records of the species in Sweden have been compiled by the SLU Artdatabanken (2026a). Neither species has occurrence records for Norway (Artskart 2026, GBIF 2026b), including surveys of the national insect monitoring program (Åström et al. 2025, GBIF 2026f).

Faunal records likely underestimate species ranges of *Spalangia* wasps in the Nordic countries. *Spalangia* is one of the most important genera used in biological control of house and stable flies and is mass-reared commercially for this purpose (Geden & Hogsette 2006). Surveys of pig and cattle farms in Denmark in 1996–1997 recovered seven species of parasitoid wasps where *S. cameroni* was the most common species from indoor facilities (70% of 3780 parasitoids, Skovgård & Jespersen 1999). Three other species of *Spalangia* were recorded in lower numbers, including *S. nigripes*, *S. subpunctata*, and *S. nigra*. Field surveys of pig farms in Vestfold, Norway in 2002 found that *S. cameroni* was the most common parasitoid of house and stable flies (95% of 445 parasitoids), along with a few specimens of *S. nigripes* (Birkemoe et al. 2004a). Biweekly experimental mass releases of *S. cameroni* were conducted on pig farms in Akershus, Norway, in 2004–2005 (Birkemoe et al. 2009, Birkemoe & Øyrehagen 2010). Four shipments of import and release of *S. cameroni* have been

approved by the Norwegian Environment Agency in the past six years (2021/5303, 2022/11905, 2025/1922, 2026/5369, Miljøvedtaksregisteret 2026).

3.2.4 Potential for entry, establishment, and spread

The two species of *Spalangia* wasps may already be established in Norway following previous releases for biocontrol. *Spalangia cameroni* have been recorded as present in Norway, Sweden and Denmark, but at a small number of localized sites and usually with targeted sampling at animal production facilities. *Spalangia endius* has not yet been detected in Norway. Faunal records are presumably rare because the wasps are small and cryptic insects with a low probability of detection in natural areas of Norway. *Spalangia* spp. have higher rates of detection in targeted sampling for parasitoid wasps in barns and stables. The potential for spread of *Spalangia* spp. is likely to be low because the parasitoid wasps have limited dispersal ability and are poorly adapted to cold northern climates. Female *S. cameroni* rarely disperse more than 3–5 m after emergence (Skovgård 2002, Machtinger et al. 2015a). *Spalangia cameroni* may be unlikely to disperse through natural areas because the species has an apparent preference for indoor habitats (Rueda & Axtell 1985 cited in Birkemoe et al. 2004a). Different populations of *S. cameroni* vary in growth rates and sex ratios (Birkemoe et al. 2012), and translocated populations could be less likely to be well adapted to local environmental conditions. Experimental trials have shown that the pupal stages of *S. cameroni* cannot survive a 6-month overwintering period in in Denmark and Canada (Floate & Skovgård 2004).

3.2.5 Potential effects on biodiversity

Spalangia spp. are generalist parasitoid wasps that attack the larval stages of a wide range of flies and other insects living together in manure and other substrates. Together, *S. cameroni* and *S. endius* have been recovered from at least 72 species of primary and parasitoid hosts. Female *S. cameroni* raised on one host will readily switch and parasitize other hosts (Beitia et al. 2016, Tormos et al. 2018). The practical value of host-switching for management applications is that the parasitoids can be raised on one host type but then be released as a control agent against another pest species. Host-switching behavior also implies that *Spalangia* wasps could pose a potential risk to native species of suitable hosts. *Spalangia cameroni* is known to parasitize a wide range of muscid flies (Appendix 3), and higher rates of parasitism could disrupt trophic interactions in natural ecosystems because muscid flies play an important role in plant pollination in arctic and alpine habitats (Pont 1993, Díaz-Calafat et al. 2026) and in decomposition of dung and animal carcasses (Anton et al. 2021).

3.2.6 Human health issues

Parasitoid wasps in the genus *Spalangia* are small-bodied insects that are not harmful to livestock, domestic pets, or humans. Human health can benefit from the activity of parasitoid Hymenoptera in controlling native and invasive pest species, which reduces the spread of disease pathogens and the need for applications of insecticides for chemical control of flies in livestock production.

3.2.7 Other risk assessments of these species

Spalangia cameroni and *S. endius* have been approved for use as biocontrol agents under EC 1107/2009 in 27 EU Member States or under Mutual Recognition of Authorisation or national regulations in Norway and Iceland (BPDB 2026). *Spalangia cameroni* is included as a nonnative species in the database of the European Alien Species Information Network, with a first introduction in 1969, but no risk assessments have been completed (EASIN 2026). Parasitic wasps in the genus *Spalangia* were not assessed in the 2018 and 2023 risk assessments for nonnative species for Norway (Artsdatabanken 2020, 2023). *Spalangia cameroni* and *S. endius* are included on the Red List for Sweden but their conservation status has not yet been assessed (SLU Artdatabanken 2026c). The first application to import *S. cameroni* to Norway was rejected by the Norwegian Environment Agency due to insufficient information on possible impacts (2016/10870); subsequently, a permit was granted that allowed import of up to 12 million wasps (2021/5303), but three recent permits have limited imports to a total of 2,600 wasps (2022/11905, 2025/1922, 2026/5369, Miljøvedtaksregisteret 2026).

3.3 *Nasonia vitripennis* (jewel wasp)

3.3.1 Taxonomy and common names

- Kingdom Animalia
- Phylum Arthropoda
- Class Insecta
- Order Hymenoptera
- Superfamily Chalcidoidea
- Family Pteromalidae Dalman, 1820
- Genus *Nasonia* Ashmead, 1904
- Species *Nasonia vitripennis* (Walker, 1836)

Nasonia spp. are a small group of four species of pteromalid parasitoid wasps that lay eggs in the pupae of various species of host flies. *Nasonia vitripennis* was originally assigned to the genus *Pteromalus* and more recent junior synonyms include *Mormoniella brevicornis*, *Nasonia brevicornis* and *Mormoniella vitripennis* (Whiting 1967). The species can be identified by morphology (Whiting 1967), cuticular hydrocarbons (Carlson et al. 1999), and by genetics (Lynch 2015).

Common name: *N. vitripennis* does not have a standardized common name but is sometimes called a ‘jewel wasp’, ‘chalcidoid wasp’ or ‘parasitoid wasp’. Parasitoid wasps are collectively described as ‘snylteveps’ in Norwegian.

3.3.2 Biology of the species

Wasps in the genus *Nasonia* are model organisms that are easy to rear in the lab, have short generation times, and high fecundity with cross-fertile species. Haplodiploidy provides advantages for genetic studies because mutations are visible in the haploid males and studies of hybridization can see how genes move among species (Lynch 2015). Four species of *Nasonia* including *N. vitripennis* were the second group of Hymenoptera to have fully sequenced genomes after the domestic honeybee *Apis mellifera* (Nasonia Genome Working Group 2010). *N. vitripennis* occurs as two sympatric ecotypes in Europe: one ecotype that parasitizes fly pupae in bird nests including parasitic flies on live nestlings and carrion flies feeding on dead nestlings, and a second ecotype that parasitizes carrion flies associated with animal carcasses (Malec et al. 2021). The different ecotypes have been investigated as a model system for understanding speciation events. *Nasonia* wasps have also been a study system for two bacterial symbionts that affect reproductive compatibility (*Wolbachia*) and adult sex ratios in different populations (*Arsenophonus* or the ‘son-killer’ microbe, Dittmer et al. 2016, Nadal-Jimenez et al. 2023). *N. vitripennis* can also be affected by microsporidian parasites that reduce the performance of female wasps (Dry et al. 1999).

N. vitripennis has good potential as a biocontrol agent because it is a gregarious parasitoid where up to 25 adults can be produced from a single parasitized house fly pupa (Wylie 1966). *N. vitripennis* is a generalist parasitoid that has been reported from a wide range of hosts (Whiting 1967). *N. vitripennis* has been recorded from 97 primary hosts (Appendix 3) and 18 parasitoid hosts (Appendix 4), which is 2–3 times greater than the number of hosts reported for the other *Spalangia* and

Muscidifurax spp. considered in our risk assessment. Families of species that are commonly used as primary hosts include Calliphoridae (42 spp), Muscidae (14 spp), Sarcophagidae (9 spp), and Tachinidae (3 spp, Appendix 3). In addition, *N. vitripennis* has also been reported using domestic honeybees *Apis mellifera* as a primary host. The preferred hosts of *N. vitripennis* are sarcophagid blow flies in nests of cavity-nesting birds (Molbo & Parker 1996, Peters 2010, Paolucci et al. 2013). Female wasps prefer to deposit on the same species of dipteran fly that served as their larval host, but host-switching occurs depending on the availability of alternative hosts (Cornell & Pimental 1978, Smith & Cornell 1979). Parasitism rates may vary among different host species due to variation in the size, shape, and surface structures of host pupae (Peters 2010). Developmental times from oviposition to adult emergence range from 11–44 days at temperatures of 15–30°C (Grassberger & Frank 2003). *N. vitripennis* had more rapid developmental times, higher production of parasitoids and larger body sizes when sarcophagid species were used as a host instead of house flies (Rivers & Denlinger 1995).

In mixed species trials, *N. vitripennis* is not an effective competitor with *Spalangia* and *Muscidifurax* species (Kaufman et al. 2001). Moreover, field trials based on experimental releases of *N. vitripennis* suggest that the species is less successful than other parasitoids at reducing numbers of house flies (Birkemoe et al. 2009, Geden et al. 2021). McKay & Galloway (1999) found that releasing > 3 500 000 individuals of *N. vitripennis* did not result in substantial parasitism of either naturally occurring or sentinel pupae of filth flies. Birkemoe et al. (2004a,b) concluded that *N. vitripennis* was an unsuitable species for biocontrol in Norway because few wasps were recovered after releases. Similar results were obtained in at least two other field trials described by McKay & Galloway (1999). Different strains of *N. vitripennis* vary in growth and parasitism rates (Fried et al. 1990), and releases could have failed if source populations were not adapted to local conditions. Overall, *Nasonia vitripennis* and the related *N. nigroaenea* appear to be less effective than other biocontrol agents for controlling filth flies in poultry, dairy, and swine facilities, or in cattle feedlots (Meyer et al. 1990, Andress & Campbell 1994, McKay & Galloway 1999, Kaufman et al. 2001, Geden et al. 2021).

3.3.3 Occurrence and distribution in Norway and globally

N. vitripennis has a widespread global distribution and is a native species to Norway and western Europe (**Figure 1**). In Europe, specimens have been collected from nest boxes of cavity-nesting birds (Abraham 1985, Peters 2010, Paolucci et al. 2013, Nadal-Jimenez et al. 2023) and from field experiments on decomposition of animal carcasses (Grassberger & Frank 2004). In Denmark, *N. vitripennis* was third most common of parasitoid recovered from larvae of house and stable flies at pig and cattle farms (Skovgård & Jespersen 1999). In Sweden, *N. vitripennis* has been reported from eight faunistic provinces including Skåne, Blekinge, Småland, Östergötland, Närke, Södermanland, Uppland and Lycksele (Hedqvist 2003). The species has at least 34 occurrence records in GBIF for Sweden but none for Norway (GBIF 2026c, Artskart 2026), including the national insect monitoring program (Åström et al. 2025, GBIF 2026f). However, the species may be less likely to be encountered with Malaise traps because it is a small-bodied insect with short dispersal movements. Field trials with release of *N. vitripennis* have been conducted in Vestfold but the species had low parasitism rates and did not establish viable populations at pig farms (Birkemoe et al. 2004b). Targeted field sampling for parasitoid wasps from parasitized pupae of house and stable flies recovered 19 individuals of *N. vitripennis* from three different pig farms in Vestfold, Norway in 2002 (Birkemoe et al. 2004a). At least two shipments for import and release of *N. vitripennis* have been approved by

the Norwegian Environment Agency in the past six years (2016/10870, 2021/5303, Miljøvedtakregisteret 2026).

3.3.4 Potential for entry, establishment, and spread

N. vitripennis is a native species that is widely distributed in western Europe and has been reported from several natural habitats in Fennoscandia. In Norway, *N. vitripennis* has been recovered from predaceous larva of long-legged flies (*Medetera* sp.) associated with the larvae of bark beetles (Pettersen 1976). In Sweden and Finland, *N. vitripennis* has been collected from the host pupae of blow flies (*Calliphora* and *Protocalliphora*), ectoparasites found in nests of cavity-nesting birds (Molbo & Parker 1996, Paolucci et al. 2013). Elsewhere, it has been recovered from sampling of insects associated with animal carcasses (Grassberger & Frank 2003, Malec et al. 2021). The species has not been included in national or international databases as an alien species. Releases of different stocks of *N. vitripennis* for biocontrol would likely be restricted to animal production facilities with manure and filth flies that provide resources needed to complete their life-cycle. Previous applications of mass-reared *N. vitripennis* for biocontrol of filth flies in Norway did not lead to establishment in animal production facilities and were considered unsuccessful because few wasps were recovered after mass releases (Birkemoe et al. 2004a,b).

3.3.5 Potential effects on biodiversity

N. vitripennis has been recovered from a wide range of hosts and could potentially pose a risk to biodiversity if it comes in contact with new or naïve hosts. The species is already widely distributed in western Europe and are less likely to switch hosts because females are more likely to parasitize the same species of host that they emerged from, and they have lower performance when parasitizing non-preferred host species. *N. vitripennis* occurs in two separate habitats including bird nests and animal production facilities but appears to be the least effective parasitoid for control of house and stable flies. Differences among strains have been reported (Fried et al. 1990) so that imports and release of *N. vitripennis* from other regions could potentially affect native populations adapted to local environmental conditions. *N. vitripennis* was the only one of the six parasitoid wasps in the current risk assessment listed as using domestic honeybees *Apis mellifera* as a primary host (Appendix 3). Domestic honeybees are a non-native species but are commercially important for crop pollination and honey and beeswax products (Nielsen et al. 2024). However, the host association was based on a lab study of the efficacy of venom of *N. vitripennis* on honeybees and other hosts (Rivers et al. 1993), and parasitism might not occur under natural conditions.

3.3.6 Human health issues

Jewel wasps in family Pteromalidae are small-bodied insects that are ca. 2–3 mm in length and are harmless to livestock, pets and humans (Whiting 1967). Use of chalcid wasps for biocontrol can reduce harmful effects of filth flies on human health and decrease reliance on insecticides for chemical control of filth flies.

3.3.7 Other risk assessments of this species

The status of *N. vitripennis* is unusual because the parasitoid wasp is a native species in western Europe, but it has still been included in risk assessments and permits have sometimes been required for import and release of the species. *Nasonia vitripennis* is not included in international databases for organisms approved for use as biocontrol agents in Europe (BPDB 2026). The species is not included as a nonnative species in the database of European Alien Species Information Network (EASIN 2026). Parasitic wasps in the genus *Nasonia* were listed as not evaluated in the 2018 risk assessment and were not included in the 2023 risk assessments for alien species for Norway (Artsdatabanken 2020; 2023). Similarly, the species was listed but not assessed in Sweden (SLU Artdatabanken 2026b). Two applications were approved by the Norwegian Environment Agency for import and release of *Nasonia vitripennis* for applications of 2000 wasps per 100 m² (2016/10870) or up to 12 million wasps (2021/5303, Miljøvedtaksregisteret 2026).

3.4 *Muscidifurax raptor*, *M. raptorellus* and *M. zaraptor* (filth fly parasitoids)

3.4.1 Taxonomy and common names

- Kingdom Animalia
- Phylum Arthropoda
- Class Insecta
- Order Hymenoptera
- Superfamily Chalcidoidea
- Family Pteromalidae Dalman, 1820
- Genus *Muscidifurax* Girault & Sanders, 1910
- Species *Muscidifurax raptor* Girault & Sanders, 1910
- Species *Muscidifurax raptorellus* Kogan & Legner, 1970
- Species *Muscidifurax zaraptor* Kogan & Legner, 1970

Common names: Species in the genus *Muscidifurax* do not have standardized common names. In commercial applications for agriculture or pest control, they have been referred to as ‘parasitic wasps’, ‘fly parasites’, or ‘filth fly parasitoids’. The genus *Muscidifurax* includes nine species of filth fly parasitoids (GBIF 2026d), including the three species evaluated in the current risk assessment. Alternative names for the taxa include *Smeagolia perplexa* Hedqvist, 1973 as a junior synonym for *Muscidifurax raptor* (Forshage et al. 2016). The different species of *Muscidifurax* can be identified by morphology (Kogan & Legner 1970), cuticular hydrocarbons (Geden et al. 1998, Carlson et al. 1999), or by genetic markers (Antolin et al. 1996, Taylor et al. 1997). Genome sequencing has been completed for *M. raptorellus* (Xiong et al. 2021).

3.4.2 Biology of the species

Muscidifurax raptor and *M. zaraptor* are solitary parasitoids where each female lays just a single egg on each parasitized pupa. *Muscidifurax raptorellus* wasps are gregarious parasitoids that lay multiple eggs on each parasitized pupa, and up to five wasps can emerge from a single pupa (Antolin et al. 1996, Lysyk 2004, Geden et al. 2014). Species of *Muscidifurax* have been recovered from fewer pupal hosts than have species of *Spalangia* or *Nasonia*: *M. raptor* from 19 primary hosts and 1 parasitoid host, and *M. zaraptor* and *M. raptorellus* from 5–7 primary hosts (appendices 3 and 4). *Muscidifurax raptorellus* has higher parasitism rates for muscid than tephritid hosts (de Pedro et al. 2020). *Muscidifurax* parasitoids also differ from *Spalangia* and *Nasonia* in that they have innate host preferences that do not change depending on the host species from which they emerged (Tormos et al. 2018, de Pedro et al. 2020). For example, *M. raptor* raised on the pupae of *M. domestica* or *F. canicularis* for 20+ generations retained an innate host preference for oviposition on *M. domestica* when given both species as possible hosts (Mandeville & Mullens 1990). Releases of *M. raptor*, *M. zaraptor* and *M. raptorellus* alone or together have successfully reduced house fly numbers in poultry (Crespo et al. 1998, Kaufman et al. 2001), dairy facilities (Meyer et al. 1990, Geden et al. 1992, Kaufman et al. 2012), and cattle feedlots (Petersen et al. 1992, Petersen & Cawthra 1995). Field trials sometimes fail to reduce fly numbers, which could be attributed to low emergence rates for parasitoids in the commercial products, the total number of parasitoids released, or exposure to high temperatures or other unsuitable environmental conditions (Andress & Campbell 1994, Geden

1997, Greene et al. 1998, Kaufman et al. 2001). Commercial insectaries that produce *M. raptor* can have high rates of infections with a microsporidian pathogen (*Nosema muscidifuracis*) that reduces the lifespan and fertility of female wasps (Geden et al. 1995).

Muscidifurax species are often used in combination with other species of parasitoid wasps, and species interactions may affect their performance. Developmental times from oviposition to adult emergence are typically 12–33 days at 20–30°C for *M. raptor* and *M. zaraptor* (Lysyk 2000, 2001a), but slower for *M. raptorellus* at the same temperatures (Lysyk 2001b). *Muscidifurax raptor* also had faster developmental times than *S. cameroni* when raised at the same temperatures (Geden 1997). The parasitoid *M. raptor* has a competitive advantage over *M. raptorellus* and produced more progeny, especially when hosts were limited in experimental parasitism trials (Geden et al. 2014). *Muscidifurax raptor* and *M. zaraptor* had a lower search efficiency that resulted in lower rates of parasitism than *S. cameroni* (Legner 1967, D’Arco et al. 2024). Moreover, *M. raptor* spends more time searching for hosts at the manure surface whereas *S. cameroni* and *S. endius* can be more efficient at locating buried hosts (Legner 1977, King 1997, Geden 1997). *Muscidifurax zaraptor* can discriminate among suitable pupae and prefers to oviposit on unparasitized hosts or hosts parasitized by non-conspecific parasitoids (Wylie 1971). Intraspecific competition among the genera of parasitoids can reduce performance at high densities (Ables & Shepard 1974). Nevertheless, the actions of the different species could be complementary such that joint releases of *Muscidifurax* species in combination with species of *Spalangia* or *Nasonia* might be more effective at fly control (Geden & Hogsette 2006).

3.4.3 Occurrence and distribution in Norway and globally

The first collections and descriptions of *Muscidifurax* species were from the Western Hemisphere with *M. raptor* from Illinois, *M. zaraptor* from the southwest USA, and *M. raptorellus* from Chile (Kogan & Legner 1970). However, the species have a strong host preference for parasitism of house flies, a species thought to have originated in the Middle East. Thus, *Muscidifurax* spp. could have a Palearctic origin and been introduced together with their host, or they could be a Holarctic species, which has secondarily adapted to a novel host (Kogan & Legner 1970). Antolin et al. (1996) showed that the three species are highly divergent and thus likely have a Holarctic origin. The three species of *Muscidifurax* are widely distributed but are found in fewer regions than *Spalangia* or *Nasonia* wasps (Figure 1).

Muscidifurax raptor was one of the most common parasitoids recovered from sampling of fly puparia collected on pig and cattle farms in Denmark, especially at outdoor sites (2832 parasitoids or 82% of the sample, Skovgård & Jespersen 1999). In Sweden, *M. raptor* has been reported from two faunistic provinces including Öland and Uppland in the southeast (Hedqvist 2003), but *M. raptorellus* and *M. zaraptor* have not yet been reported in Sweden (SLU Artdatabanken 2026). None of the species have been reported in occurrence records for Norway (Artskart 2026, GBIF 2026d), including the national insect monitoring program (Åström et al. 2025, GBIF 2026f) but two specimens of *M. raptor* were recovered from targeted field sampling of naturally occurring parasitoid wasps at pig farms in Vestfold, Norway in 2002 (Birkemoe et al. 2004a). No applications for import and release of *Muscidifurax* spp. have been made in Norway (Miljøvedtaksregisteret 2026).

3.4.4 Potential for entry, establishment, and spread

M. raptor has been reported in low numbers and might already be established in Norway whereas *M. raptorellus* and *M. zaraptor* have not yet been reported in Norway. Large numbers of wasps have been released during past biocontrol applications in Norway, but only a few individuals of *Muscidifurax* have been recorded and are typically associated with barns and stables. The potential for establishment is uncertain. Lysyk (2001b) reared *M. raptorellus* in the lab under different experimental conditions and concluded there were no climatic barriers for inundative releases of the nonnative species for fly control in Alberta, Canada. However, few overwintering parasitoids were recovered from experimental releases of *M. raptorellus* in southern Alberta, suggesting that the species is unlikely to survive cold winter conditions (Floate et al. 2000). Overwinter survival rates of *M. zaraptor* were low in silage used for animal feed in Nebraska, especially if buried at depths >6 cm (Guzman & Petersen 1986). The potential for spread seems low because *Muscidifurax* wasps have poor dispersal ability. Dispersal distances measured in field trials of releases of *Muscidifurax* species are typically <20–100 m (Petersen & Cawthra 1995, Tobin & Pitts 1999, Floate et al. 2000). Parasitism by *M. raptorellus* increases during weeks when releases are made but then declines rapidly (Floate et al. 2000, Kaufman et al. 2012). Rapid post-release declines suggested that introduced populations of *M. raptorellus* were competitively disadvantaged relative to *M. raptor* as a native species in North America (Geden et al. 2014).

3.4.5 Potential effects on biodiversity

Muscidifurax species appear to have relatively strong host preferences and female parasitoids raised on house flies prefer to oviposit on the same host species (Mandeville & Mullens 1990). A narrow range of preferred hosts and an absence of host switching suggests that the potential risks to native insects could be low for *Muscidifurax* wasps.

3.4.6 Human health issues

Parasitoid wasps in the genus *Muscidifurax* are small-bodied insects ca. 2–3 mm in length and are harmless to livestock, domestic pets and humans (Wise & Kaufman 2023). Successful biocontrol of house and stable flies can improve human health by reducing exposure to pathogens that cause illness and disease and can reduce applications of insecticides needed for pest control.

3.4.7 Other risk assessments of these species

Muscidifurax raptor and *M. raptorellus* have been approved for use as biocontrol agents under EC 1107/2009 in 27 EU Member States or under Mutual Recognition of Authorisation and/or national regulations in Norway and Iceland (BPDB 2026). *Muscidifurax raptor* is included as a non-native species in the database of the European Alien Species Information Network based on a first introduction from 1954, but a risk assessment has not been completed (EASIN 2026). Parasitic wasps in the genus *Muscidifurax* were not included in the 2018 or 2020 risk assessments for alien species for Norway (Artsdatabanken 2020; 2023) and are listed but not assessed in Sweden (SLU Artdatabanken 2026c). The Norwegian Environment Agency has no records of applications for import of *Muscidifurax* spp. in their permit database (Miljøvedtaksregisteret 2026).

3.5 *Carcinops pumilio* (hister beetle)

3.5.1 Taxonomy and common names

- Kingdom Animalia
- Phylum Arthropoda
- Class Insecta
- Order Coleoptera
- Family Histeridae Gyllenhal, 1808
- Genus *Carcinops* Marseul, 1855
- Species *Carcinops pumilio* (Erichson, 1834)

Junior synonyms

- *Paromalus pumilio* Erichson, 1834
- *Carcinops quatuordecimstriata* (Stephens, 1835)
- *Carcinops 14-striata* (Stephens, 1835)
- *Carcinops quatuordecemstriata*
- *Carcinops quatuordecimstriata* (Stephens, 1835)
- *Dendrophilus 14-striatus* Stephens, 1835
- *Dendrophilus pumilio* Dejean, 1833
- *Dendrophilus quatuordecimstriatus* Stephens, 1835
- *Epierus krujanensis* Mader, 1921
- *Hister nanus* J.E. LeConte, 1845

Common names: The species does not have an official Norwegian name but belongs to the family of beetles called *stumpbiller*. The species is called hister beetle, clown beetle, dwarf clown beetle, or carcinops beetle, but none of these names are unique to the species, because they refer to the family or genus level. Some sources call the species a poultry house pill beetle, but this is a misnomer because the species is not a true pill beetle which belong to a separate family Byrrhidae.

3.5.2 Biology of the species

Carcinops pumilio lay their eggs in manure with a moisture content of ca. 50% and have two larval instar stages (Achiano & Giliomee 2005, Moore & Kaufman 2023). Total development from egg to adult is temperature dependent, averaging 17 days at 32.5°C, 21 days at 30°C and reported up to an average of 42 days (Achiano & Giliomee 2005, Moore & Kaufman 2023 and references therein). The adult beetle has a total length of 1.6–2.7 mm and can live for up to two to three years (Moore & Kaufman 2023). Embryo development within the eggs is completed within an average of 6.2 days, the larval stage lasts for an average of 15.5 days, whereas the pupal stage lasts for an average of 17.5 days (Morgan et al. 1983 referred to in Moore & Kaufman 2023). *Carcinops pumilio* are predators of *Musca domestica* eggs and larvae, other Diptera, mites to some extent (reviewed by Watson et al. 2001, Moore & Kaufman 2023 and references therein), and perhaps other insects and arthropods. All life stages of *C. pumilio* can be found in poultry manure with moisture content between 55% and 80% (Achiano & Giliomee 2005, Moore & Kaufman 2023). First instar larvae are more common in manure with a 55% to 60% moisture content, whereas second instars and adult

beetles are more common in manure with moisture contents between 70% and 75% (Achiano & Giliomee 2005, Moore & Kaufman 2023). *Carcinops pumilio* is commonly encountered in manure pits between 21°C and 27°C (Moore & Kaufman (2023). Achiano & Giliomee (2005) found all stages of *C. pumilio* at a wide range of temperatures, from 12 to 30 °C, but they found few individuals below 21°C and above 27°C. Maximum development rates for eggs and larvae are at 32.5°C (tested at 17.5–35°C, Fletcher et al. 1991).

3.5.3 Occurrence and distribution in Norway and globally

Carcinops pumilio was already known from indoor habitats in Denmark in the 19th century and is now established in all Fennoscandian countries and common especially in warm types of compost (Ødegaard 1999). The beetle was first recorded in Norway in 1932 in a compost heap near Oslo and is now an established species that is common in compost heaps and different types of animal waste in most areas of southern Norway (Ødegaard 1999, Ødegaard & Tømmerås 2000). The species is also found in association with poultry production (Olberg et al. 2023) and in bird nests (Ødegaard et al. 2018). At least 130 specimen records from Norway have been reported in Artskart (2026) and GBIF (GBIF 2026e), but the species has not yet been detected in the national insect monitoring program (GBIF 2026f). The known distribution includes Østfold, Oslo og Akershus, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Rogaland, Sogn og Fjordane, Møre og Romsdal, and Sør-Trøndelag. The assumed distribution includes Agder, Hordaland and Nord-Trøndelag, hence, the current distribution likely includes all of southern Norway and Trøndelag (Olberg et al. 2023). Ødegaard et al. (1999) suggested beetles can survive overwinter in large compost heaps that retain heat even if the species are warm-adapted and do not have temperature tolerances for a cold environment. No applications for import and release of *C. pumilio* appear to have been made or approved in Norway (Miljøvedtaksregisteret 2026).

The native range of *C. pumilio* remains uncertain but the species is now widely distributed globally (**Figure 1**), occurring in both animal production facilities but also natural habitats across multiple regions (Africa, Central America, Europe, North America, Oceania, and South America), spanning a wide range of climatic zones, including temperate, subtropical, and tropical environments (Moore & Kaufman 2023, Olberg et al. 2023).

3.5.4 Potential for entry, establishment, and spread

Carcinops pumilio is already well-established as a non-native species that is relatively common in compost heaps throughout southern Norway and also found in bird nests (Ødegaard et al. 2018). The species has a high capacity for both natural dispersal and human-mediated spread, but the species has probably nearly reached its current maximum distribution in Norway and already spread to most suitable habitats (Ødegaard et al. 2018). Over the next 50 years, a warmer climate could facilitate further spread of the species, with its range likely to expand northward into Nordland (Olberg et al. 2023). International publications report that *C. pumilio* occur in habitats with warm temperatures, with few individuals found in manure heaps below 21°C, although they are documented down to 12°C (Achiano & Giliomee 2005, Moore & Kaufman 2023). Very few studies have been conducted in climates comparable to that of Norway, and it therefore remains unclear whether the species could become established in natural habitats away from manure and compost heaps, where temperatures are likely to be warmer than ambient environmental conditions.

3.5.5 Potential effects on biodiversity

Potential effects of *Carcinops pumilio* on biodiversity may include competition with native beetles in family Histeridae or other groups, as well as predation on non-target fly egg and larvae, and other insects and arthropods. Although as many as 34 alien beetle species have invaded compost heaps in the Nordic countries during the 20th century, including *C. pumilio*, very few native species appear to have declined or disappeared (Ødegaard 1999). The lack of reported negative effects of *C. pumilio* on biodiversity in Norway and elsewhere suggests that there are few documented adverse effects. However, given the limited number of specific studies, potential impacts cannot be ruled out.

3.5.6 Human health issues

No direct human health issues related to *Carcinops pumilio* are known. The beetle can act as a reservoir and vector for *Salmonella enteritidis* in poultry facilities. *Carcinops pumilio* can carry the bacterium internally for up to 13 days and externally for up to 4 days after exposure in poultry manure environments, and feces were culture-positive for *S. enteritidis* for at least 14 days (Gray et al. 1999). Gray et al. (1999) therefore suggested its movement between poultry facilities should be carefully considered. Additional experiments in poultry houses also suggested that the beetles can be a reservoir for *Salmonella indiana*, but likely not for *Campylobacter* spp. (Skov et al. 2004).

3.5.7 Other risk assessments of this species

The Norwegian Biodiversity Information Centre has assessed *Carcinops pumilio* on their alien species lists in both 2018 and 2023 to have **Low risk (LO)** to biodiversity in Norway due to no known ecological effects, and a moderate invasion potential because the species has soon reached its maximum distribution in Norway (Ødegaard et al. 2018, Ohlberg et al. 2023). In the Swedish alien species list, *C. pumilio* is assessed to have a potential high risk, based on a high invasion potential and no known ecological effect (SLU Artsdatabanken 2025).

4 General assessments

4.1 Current status of the biocontrol agents within Norway

The different species of biocontrol agents could pose a risk to native biodiversity if they are imported and released in animal production facilities but then disperse and become established in natural areas. The risk depends on whether the biocontrol agents are already a native or established species or if they would be a new introduction. The population status of the biocontrol agents is challenging to assess because all the organisms are small-bodied insects that are unlikely to be encountered in standard insect sampling with pitfall traps, sweep nets or Malaise traps. Occurrence records require nonstandard sampling techniques, such as rearing emerging wasps from parasitized fly larvae or targeted sampling at manure or compost piles (Ødegaard 1999, Birkemoe et al. 2024). In addition, reliable species identification requires an understanding of subtle differences in morphology (Kogan & Legner 1970, Gibson 2009).

The species status within Norway differs among the eight biocontrol agents evaluated in our risk assessment. The parasitoid wasp *Nasonia vitripennis* is a native species in Norway and other countries in western Europe where it is routinely recovered as a parasite of flies associated with the nesting materials of cavity-nesting birds or animal carcasses (Molbo & Parker 1996, Peters 2010, Paolucci et al. 2013). The remaining seven species are non-native organisms. The hister beetle *C. pumilio* has been established in Norway for over 90 years and has been found in compost piles and bird nests from Agder to Trøndelag (Ødegaard 1999). Similarly, *Spalangia cameroni* is a common parasitoid that is routinely recovered in high numbers wherever targeted sampling has been conducted for parasitoid wasps at animal production facilities in Norway (Birkemoe et al. 2004a,b). The two species of *Spalangia* wasps are cosmopolitan species where the original native ranges are uncertain but thought to be in the Western Hemisphere. The black dump fly *H. aenescens* and the three species of *Muscidifurax* wasps are non-native species that have recently been introduced to Europe or Scandinavia. *Hydrotaea aenescens* has been reported from two locations in Vestfold and *M. raptor* has been detected in small numbers during targeted sampling for parasitoids in Norway. *Spalangia endius* has been reported from Skåne in southern Sweden but has not yet been detected in Norway. The total number of records and locations are likely limited by sampling effort and the actual distributions of these two species in Norway could be much broader. We also considered *Muscidifurax raptorellus* and *M. zaraptor* in our risk assessment but neither species has been previously reported in Norway.

4.2 Magnitude and frequency of imports of biocontrol agents

Import and release of biocontrol agents for control of filth flies in barns and stables were unregulated in Norway before 2015. Commercial suppliers of control agents have been available for decades in Europe and North America, but the magnitude of commercial imports and numbers of releases are unknown (Appendix 2). Field studies of the efficacy of biocontrol agents included experimental releases of the parasitoid wasps *Spalangia cameroni* (Birkemoe et al. 2009, Birkemoe & Øyrehagen 2010) and *Nasonia vitripennis* on pig farms in Vestfold near Oslo, Norway (Birkemoe et al. 2004b). Experimental releases of *S. cameroni* included import of 12–20 boxes per year over 1–2 years where each box contained about 10 000 juvenile and adult parasitoids cultured on the black dump fly *Hydrotaea aenescens* (Birkemoe et al. 2009, Birkemoe & Øyrehagen 2010). The total

releases of *S. cameroni* during 2004–2005 were ca. 440 000 parasitoids. Experimental releases of *N. vitripennis* included import of five boxes where the commercial supplier reported that each box contained about 10 000 parasitoids but the actual number was higher and estimated to be about 17 000 parasitoids per box (Birkemoe et al. 2004b). The total releases of *N. vitripennis* in 2002 were ca. 70 000 parasitoids.

National legislation was adopted in 2015 for Regulations on Alien Organisms (FOR-2015-06-19-716, 19 Jun 2015). Permits are required for the import and release of alien organisms into Norway under Sections 6 and 10 of the regulations. A total of six applications for import and release have been evaluated by the Norwegian Environmental Agency: 2016/10870, 2021/5303, 2022/1905, 2025/11922, 2025/13919, and 2026/5369 (Miljøvedtaksregisteret 2026). All six permits were for three species of biocontrol agents: the black dump fly *Hydrotaea aenescens* and the two parasitoid wasps *Spalangia cameroni* and *Nasonia vitripennis*. None of the permits included applications for import of the parasitoid wasp *Spanglia endius*, any of the three species of *Muscidifurax*, or the hister beetle *Carcinops pumilio*. Terms of the permits were typically for 6–12 months, which would cover a single production season.

Limits on the maximum number of insects have changed during the past decade. The first permit (2016/10870) allowed import of an unrestricted number of insects for releases based on guidelines from commercial suppliers for targets of 5000 flies per 100 m² for *H. aenescens* and 2000 wasps per 100 m² for *N. vitripennis*. Import of *S. cameroni* was initially declined pending submission of additional information. The second permit (2021/5303) allowed import of up to 12 million individuals for each of the three species based on estimates of 14 imports per year with shipments of 40 boxes each containing 20 000 insects per box. The remaining four permits (2022/11905, 2025/11922, 2025/13919, 2026/5369) reduced the numbers allowed with permit terms restricted to 2,600 individuals for *H. aenescens* and *S. cameroni*. In the case of permit 2025/13919, the applicant applied for permission to import up to 1000 kg of *H. aenescens* and the approved terms for import of 2600 individuals (ca. 270 g) were equivalent to about 0.03% of the original request.

4.3 Potential for releases to result in establishment or spread

Product descriptions from Rincon-Vitova Insectaries (2009) in the USA indicate that a typical unit for sale would contain 10 000 pupae of dump flies *H. aenescens* (1.0 kg or 2.3 lb) or hister beetles *C. pumilio* (0.5 kg or 1 lb), or 10 000 fly pupae infected with mixtures of the parasitoid wasps *S. cameroni*, *M. raptorellus* and *M. zaraptor* (0.2 kg or 0.04 lb). *Muscidifurax raptorellus* is gregarious and a host pupae can be parasitized multiple times, so that units containing 10 000 fly pupae are expected to produce at least 20 000 adult parasitoids. The recommended number of units for releases of dump flies and hister beetles is a one-time application of one unit per 93 m² (1 000 sq ft) of manure. An animal production facility with a manure storage facility that is 0.5 ha in area might require releases of up to 500 000 dump flies (25 kg) or 500 000 hister beetles (50 kg). The recommended number of units needed for parasitoid wasps is based on target numbers for parasitoids per domestic animal and varies among animal production facilities. Typical release schedules would include deployment of <1 unit per week for horses in stables (up to 30 horses), 1–5 units per week for poultry facilities (up to 10 000 birds), and 5–10 units per week for cattle in dairies and feedlots (100 to 1000 head). Releases of 10 units per week for six weeks would total about 1 200 000 parasitoids (12 kg). It is difficult to assess commercially available products for biocontrol agents in Europe because Miljøfluen in Denmark and Koppert in the Netherlands provide little information

on product specifications on their public websites (Appendix 2). Nevertheless, the numbers of predatory insects and parasitoid wasps needed for a typical management application (500 000 to 1 200 000) appear to be 2–3 orders of magnitude greater than the current terms allowing for import and release of 2600 insects in recent permits issued by the Norwegian Environmental Agency.

Import and release of predatory insects and parasitoids for control of house and stable flies would likely involve large numbers of insects but the probability of establishment in natural areas in Norway appears to be low for three reasons. First, the six species of parasitoid wasps have limited potential for dispersal and typically move only short distances <100 m from the release sites (Floate et al. 2000), and in some cases only distances of 3–5 m (Skovgård 2002, Machtinger et al. 2015b). The dump fly *H. aenescens* can disperse up to 6–10 km but is usually not successful at colonizing new sites (Hogsette & Jacobs 1999). Birkemoe et al. (2004a) released ca. 70 000 individuals of *N. vitripennis* at three farms in Norway but then detected no adult wasps at nearby farms without release. In contrast, the hister beetle *C. pumilio* has strong natural and human-mediated dispersal and has already spread to most suitable habitats in Norway (Ødegaard et al. 2018). Second, most of the species of biocontrol agents are strongly associated with anthropogenic habitats. The dump fly and several of the parasitoid wasps have been reported from Norway and neighbouring countries where they have almost always been detected in animal production facilities (Skovgård & Jespersen 1999, Birkemoe et al. 2004a). Similarly, the hister beetle *C. pumilio* has a wide distribution in southern Norway but is usually found in compost or manure piles. The one exception is the wasp *N. vitripennis*, which naturally occurs as a parasite of native flies associated with bird nests. Last, most of the species have optimal temperature ranges of 20 to 30°C and appear unlikely to cope with the cold winter conditions associated with natural areas in Norway. Studies using experimental releases of the parasitoid wasps *S. cameroni* and *M. raptorellus* in Alberta and Nebraska reported that overwintering survival rates were low (Guzman & Petersen 1986, Floate and Skovgård 2004). Floate et al. (2000) released over 1 300 000 million individuals of *M. raptorellus* over two years in southern Alberta (Canada) but recovered only 29 individuals in the following year. *Carcinops pumilio* is a warm-adapted species but have good overwinter survival in compost piles or other microhabitats where fermentation processes create a more stable and warmer thermal environment than ambient winter conditions (Ødegaard 1999). Alternatively, *C. pumilio* may have greater cold tolerance than expected and could exhibit range expansions with milder winter conditions. Regional warming associated with long-term climate change could improve overwinter survival rates but many of the biocontrol agents seem unlikely to be affected by future environmental change since they are synanthropic species associated with modified habitats created by human activities in their non-native range.

4.4 Potential for impacts of biocontrol agents on native biodiversity

The dump fly *H. aenescens* and the hister beetle *C. pumilio* are generalist predators of eggs and larvae, whereas the three genera of parasitoid wasps parasitize the pupae of a wide range of host species. It can be challenging to determine the potential range of a generalist predator or to assess host specificity of a new parasitoid, and both groups are often excluded *a priori* for consideration for import licences (van Lenteren et al. 2006, Loomans 2021). In Norway, *H. aenescens* and *C. pumilio* are already established but are typically found in modified habitats, such as manure or compost piles, where they may be less likely to come in contact with native species of invertebrates. On the other hand, processed manure is spread as fertilizer on crop fields and pastures in spring, providing a potential pathway for the introduction of non-native species into natural environments (Hansrud et

al. 2017). The dispersal pathway is unknown, but *C. pumilio* has also been collected from bird nests. Compost piles have been identified as a potential pathway by which non-native species of plants and insects could become established or spread in Norway (Sandercock et al. 2023). Two species of native beetles (*Atomaria* spp.) were formerly widespread in compost piles and are now listed as vulnerable in Norway, although it is unknown if their population declines were due to competition with non-native species (Ødegaard & Tømmerås 2000).

The parasitoid wasps vary in their range of primary hosts and can also be hyperparasitoids of other parasitoid insects but differ in their host specificity and ability to change to alternative hosts. *N. vitripennis* has the widest host range but is also a native species that is likely adapted to a wide range of native hosts, including blow flies commonly found in the nests of cavity-nesting birds. In addition, *N. vitripennis* was recorded as a parasitoid of the domestic honeybee *Apis mellifera* but the association was based on experimental trials in a laboratory study and may not occur under natural conditions (Rivers et al. 1993). The status of the *Spalangia* wasps is uncertain, but they are likely already established as non-native species. The two species have been recovered from fewer hosts than *N. vitripennis* but appear to switch hosts more readily, and *S. cameroni* is also a stronger competitor for pupal hosts compared to other parasitoid wasps. Taken together, the suit of traits suggests that *Spalangia* wasps could potentially impact native species of insects, including ecologically important groups of muscid flies. Nevertheless, the trophic interactions among parasitoids and hosts remain poorly known, and the potential impacts of non-native species on ecosystem functions are difficult to predict. The *Muscidifurax* wasps are non-native but seem unlikely to impact native insects because they have been recovered from a limited range of hosts and have strong host specificity. Several hundred species of parasitoid- and hyperparasitoid wasps have been reported from Norway and Sweden, including both generalist- and specialist species (Hedqvist 2003, Westrum et al. 2010, Elven & Sjøli 2021). The trophic ecology of the insect community is poorly known, and the potential interactions among native and non-native species are difficult to assess without better information on host specificity.

4.5 Potential for introduction of hitchhiking organisms or diseases

Import of biocontrol agents as single or mixtures of species can include species of uncertain taxonomy or additional species of parasitoids as hitchhiking organisms. For example, the biocontrol agents sold under the brand names “Fly Eliminator® Programs” by Arbico Organics or the “Standard Mix (Fly Parasites)” of Rincon-Vitova Insectaries do not specify which species of parasitoids are included as an active ingredient in the descriptions of the product materials (Appendix 2). The packing materials for shipment of wasps are usually inert, such as wood chips or vermiculite that are unlikely to contain non-native species. However, contamination is a well-documented problem because the commercial insectaries rearing multiple species of parasitic wasps often have difficulty maintaining pure colonies of the different parasitoids (Meyer et al. 1990, Andress & Campbell 1994, Greene et al. 1998). Previous imports of *S. cameroni* to Norway also included low numbers of *N. vitripennis* in more than half of packages (Birkemoe et al. 2009). The parasitoid wasps are usually cultured on house flies (Floate & Skovgård 2004) but can also be reared on the black dump fly *H. aenescens* (Birkemoe et al. 2009, Birkemoe & Øyrehaugen 2010). Imports of commercially reared species of flies, parasitoid wasps, and beetles are likely to include additional species of non-native organisms. Negative impacts may be unlikely if the hitchhikers are functionally similar to the target organisms that have been approved for import.

Mass-reared parasitoid wasps can carry a variety of viral, bacterial or protozoan pathogens that could impact native species of parasitoids or hosts (Dry et al. 1999, Dittmer et al. 2016, Strand et al. 2026). Concerns have been raised about release of *H. aenescens* because dump flies can transmit pathogens mechanically just like house and stable flies (Olsen & Hammack 2000, Geden et al. 2021). Diseases or other pathogens may be less likely if the biocontrol agents are reared in sterile or controlled conditions. For example, the hister beetles *C. pumilio* produced by Arbico Organics are lab-reared and product descriptions claim that the beetles are free of *Salmonella* bacteria.

5 Risk assessment methodology

For the questions outlined in the Terms of Reference (ToR), hazards were identified and assessed separately. VKM evaluated each potential hazard as a mechanism through which impacts may occur, following four standardized steps: hazard identification, hazard characterisation, likelihood assessment, and risk characterization. Details of each step are described below.

5.1.1 Description of possible mechanisms for impact

Each hazard was associated with an impact mechanism through which it could have an effect. VKM used the Environmental Impact Classification for Alien Taxa (or 'EICAT') classification system to first identify which impact mechanisms are relevant for the assessed species (IUCN 2020, 2021). The 12 impact mechanisms that are considered in the risk assessment are listed in **Table 1**.

Table 1. Key impact mechanisms through which a non-native organism can lead to harm on native biodiversity or natural ecosystems (IUCN 2020, 2021).

#	Impact mechanism	Description
1	Competition	The alien organism competes with native organisms for resources (e.g., food, water, space)
2	Predation	The alien organism preys on native organisms
3	Hybridisation	The alien organism hybridizes with native organisms
4	Transmission of disease	The alien organism transmits diseases to native organisms
5	Parasitism	The alien organism parasitizes native organisms
6	Poisoning/toxicity	The alien organism is toxic, or allergenic by ingestion, inhalation, or contact, or allelopathic to plants
7	Bio-fouling or other direct physical disturbance	The accumulation of individuals of the alien Organism on the surface of a native organism (i.e., bio-fouling), or other direct physical disturbances not involved in a trophic interaction (e.g., trampling, rubbing, etc.)
8	Grazing/herbivory/browsing	Grazing, herbivory or browsing by the alien organism
9	Chemical impact on ecosystem	The alien organism causes changes to the chemical characteristics of the native environment (e.g., pH; nutrient and/or water cycling)
10	Physical impact on ecosystem	The alien organism causes changes to the physical characteristics of the native environment (e.g., disturbance or light regimes)
11	Structural impact on ecosystem	The alien organism causes changes to the habitat structure (e.g., changes in architecture or complexity)
12	Indirect impact through interactions with other species	The alien organism interacts with other native or alien organisms (e.g., through any mechanism, including pollination, seed dispersal, apparent competition, mesopredator release), facilitating indirect deleterious impact

The last EICAT impact mechanism (no. 12) includes the possibility of species interactions among non-native species that co-occur in an introduced range. Velle et al. (2025) provided a theoretical framework for assessing the potential for cumulative impacts among multiple species of non-native organisms under a framework of antagonistic, additive, or synergistic interactions. Interference competition, intraguild predation or reciprocal parasitism are examples of **antagonistic** interactions that can reduce the joint impacts of multiple non-native species where they co-occur. Cumulative

impacts can also be **additive** if non-native species have neutral interactions, but each organism has different effects on native species. In a worst case scenario, non-native species may facilitate each other so that the overall negative effects are **synergistic** and greater than the individual species on their own.

5.1.2 Description of hazard identification

In the hazard identification section, we described the specific hazard, including the mechanisms that the hazard has effect through, and why each hazard is considered in the current assessment. The known effects of the hazard are presented and examples of the impacts from other countries are included, where known.

5.1.3 Description of hazard characterisation

In the hazard characterisation section, the specific potential effects of the hazards in question are evaluated in terms of their nature, intensity, and potential to cause harm under Norwegian conditions. Here, the potential magnitude of the specific hazards is ranked from “Minimal” to “Massive”, as described in **Table 2**. The characterisation assumed that at least one population has been established in Norway.

Table 2. Rating of the potential magnitude of impact on biodiversity in Norway

Rating	Impact descriptors
Minimal	Impact on biodiversity is limited to occasional deaths of individuals. No expected effects on the local-, regional-, or national population size.
Minor	Impact on biodiversity includes limited reductions in local abundance of one or a few species and these effects are temporally and spatially limited. No expected effects on the regional-, or national population size.
Moderate	Impact on biodiversity can result in moderately reduced abundance of one or more species, with potential implications on population viability at a regional level.
Major	Impact on biodiversity may cause severe reductions in the abundance of one or more species, including potential extinction of local or regional populations. Consequences may also affect ecosystem functions and services. The consequences are likely reversible if the assessed species can be successfully eradicated.
Massive	Impact on biodiversity may cause detrimental reductions in the abundance of more than one native species, including extinction of local populations and potentially threaten the survival of the national population. Consequences are likely to affect ecosystem functions and services and are likely irreversible.

5.1.4 Description of likelihood

In the likelihood section, we assess how likely it is that the characterized hazard occurs. Likelihood intervals range from 0–5% “Very unlikely” up to 75–100% “Very likely” (**Table 3**). In most cases and unless otherwise stated explicitly, the likelihood was based on subjective assessments (also referred to as expert judgement), rather than frequency-based likelihood or specific modelling that estimate the likelihood. The likelihood assumes that at least one population has been established in Norway.

We also present an approximation of the overall risk posed by the species by incorporating the potential impact of the hazard with the greatest magnitude and the likelihood of establishment.

Table 3. Rating of the likelihood of specific impacts in the assessment.

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

5.1.5 Description of risk characterisation

In the risk characterisation section, the risk to biodiversity in Norway, posed by the specific hazard, was ranked on a 4-point scale ranging from “**Low**”, “**Medium**”, “**Possibly high**” or “**High**”. The characterisation was based on the combination of the overall likelihood of the event occurring and then the magnitude of potential impact of a hazard given that an event occurs (**Figure 2**).

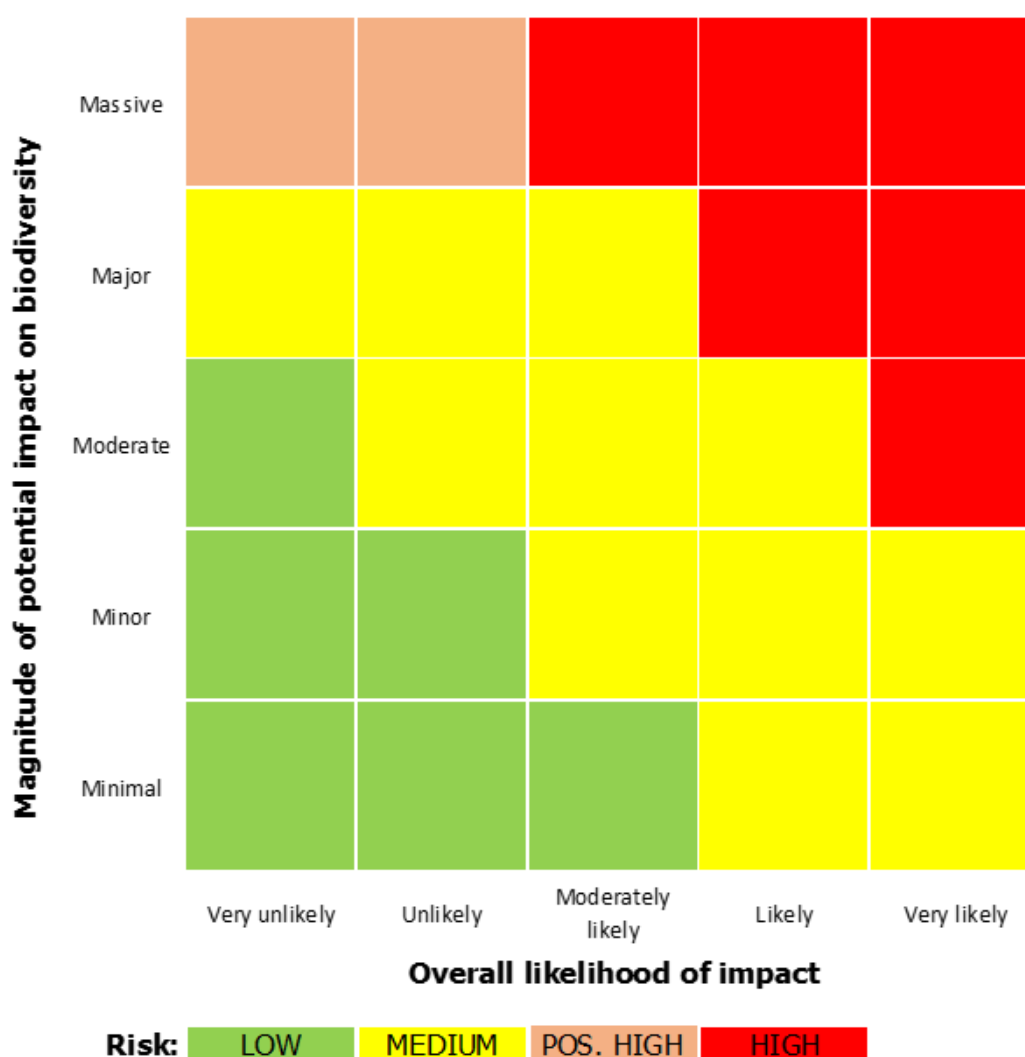


Figure 2: The risk matrix used to graphically illustrate the assessed risks.

5.1.6 Description of confidence assessments

For each assessment of potential impact (hazard characterisation) and likelihood, and eventually the risk, VKM described the level of confidence with which these assessments were made. Confidence was based on both the level of information available on each subject, the relevance and consistency of that information (**Table 4**).

Table 4. Qualitative scale used for describing the level of confidence in an assessment.

Rating	Confidence descriptors
Low	Low confidence is often the result of little or poor data, or if the data provided is inconsistent or partly inconsistent. This is often the case when there is limited information on the specific subject, in particular from comparable environmental settings. Subjective expert judgements may be introduced without supporting evidence. There is often also little peer reviewed literature available and there are limited to no empirical and quantitative data to support the assessment.
Medium	Relevant information on the specific subject is available, but only limited information from comparable environmental settings. Some subjective expert judgements are introduced. Both grey literature and peer reviewed literature are used and there are some empirical and quantitative data to support the assessment.
High	High confidence is appointed to assessments where there is high data quality of ample amounts and the findings are predominantly consistent. This means that there is extensive information on the specific subject, also from comparable environmental settings. Few or no subjective expert judgements are introduced. Peer-reviewed literature is used primarily and there are empirical and quantitative data to support the assessment.

The basis of the confidence of each assessment is presented graphically in a matrix where the data quality is assessed in relation to the data consistency (**Figure 3**).

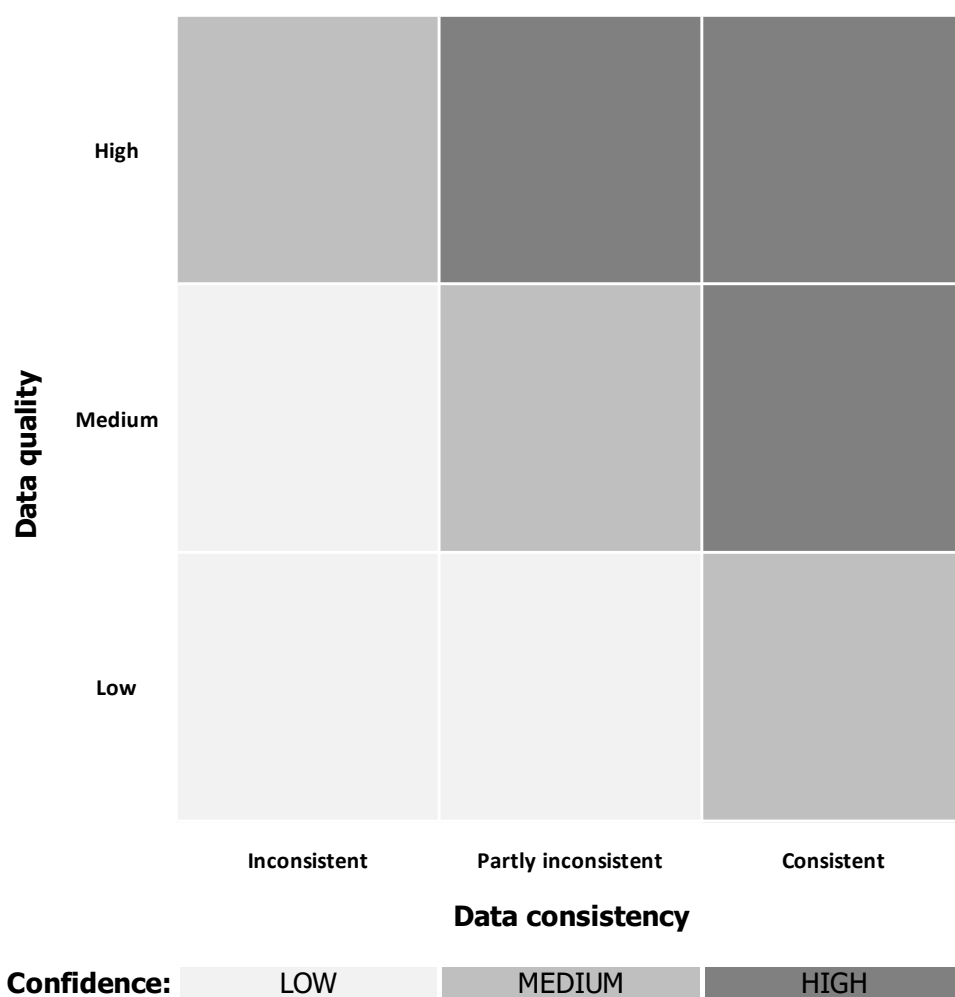


Figure 3: The confidence matrix used to graphically illustrate the confidence of the assessments.

6 Risk assessments

6.1 Relevant impact mechanisms

VKM finds that the eight taxa of biological control agents assessed here could potentially have a negative impact on native biodiversity through 6 of 12 EICAT impact mechanisms (**Figure 4**). The six relevant mechanisms include: competition (1), predation (2), hybridization (3), transmission of disease (4), parasitism, and (5) species interactions (12). We assessed the first five mechanisms separately for the dump fly *H. aenescens*, the six species of parasitoid wasps, and the hister beetle *C. pumilio* (sections 6.2–6.4). We then assessed the cumulative effects of species interactions, including the possibilities that joint introduction of non-native species could have antagonistic, additive or synergistic effects on native biodiversity (section 6.5).

No.	EICAT impact mechanisms	<i>Hydrotaea aenescens</i>	<i>Spalangia cameroni</i>	<i>Spalangia endius</i>	<i>Nasonia vitripennis</i>	<i>Muscidifurax raptor</i>	<i>Muscidifurax raptorellus</i>	<i>Muscidifurax zaraptor</i>	<i>Carcinops pumilio</i>
1	Competition								
2	Predation								
3	Hybridization or genetic impact								
4	Transmission of disease								
5	Parasitism								
6	Poisoning/toxicity								
7	Bio-fouling or other direct physical disturbance								
8	Grazing/herbivory/browsing								
9	Chemical impact on ecosystem								
10	Physical impact on ecosystem								
11	Structural impact on ecosystem								
12	Indirect impacts through interactions with other species								

Figure 4: EICAT impact mechanisms for potential negative impacts of each of the biocontrol agents on native biodiversity in Norway. Blue boxes indicate relevant mechanisms, and white boxes indicate mechanisms that are not relevant.

6.2 *Hydrotaea aenescens* (black dump fly)

VKM has assessed whether *H. aenescens* could potentially become a hazard through the four EICAT mechanisms competition, predation, hybridization and transmission of disease. The assessment considers that the Environment Agency previously approved applications for introduction and release of an unrestricted number of individuals in 2016 and for 12 million individuals in 2021 but that the species has still been recorded only once after 2021.

6.2.1 Hazard identification

a. Competition. *Hydrotaea aenescens* larvae can compete with native species with similar diets that are living in the same substrate of animal manure or carcasses and can therefore negatively impact populations of native fly species.

b. Predation. *Hydrotaea aenescens* is used for predation of larvae of other fly species that are living in the same substrate of animal manure and carcasses and can therefore negatively impact populations of native fly species.

c. Hybridization. We have found no records of *H. aenescens* hybridizing with related species.

d. Transmission of disease. *Hydrotaea aenescens* is a mechanical vector of *Campylobacter* spp. and *Escherichia coli* O157:H7, since adults can be attracted to human excrement (Cortinhas et al. 2016). We have found no records of *H. aenescens* being a vector for diseases relevant for Norwegian biodiversity.

6.2.2 Hazard characterisation

The current risk assessment relates to potential negative effects on biodiversity and aims to highlight potential negative effects if *H. aenescens* became established in natural habitats in Norway.

a. Competition. In large numbers, *H. aenescens* can compete with and have negative impacts on native species living in the same substrate. The degree to which *H. aenescens* can compete with native detritivorous flies is however unknown. Due to the scattered distribution of its substrate in nature and the limited probability of winter survival, the infestation of manure or carcasses will be from individuals escaping animal facilities. Thus, negative impacts on native biodiversity in natural areas due to competition are likely to be **minimal** (with medium confidence) with negligible reductions in local abundance of a few species with effects that are spatially and temporally restricted to local areas near animal production facilities where releases are conducted.

b. Predation. In large numbers, *H. aenescens* can predate on and have negative impact on native species living in the same substrate. Due to the scattered distribution of its substrate in nature and the limited probability of winter survival, the infestation of manure or carcasses will be from individuals escaping animal facilities. Thus, negative impacts on native biodiversity in natural areas due to predation are likely to be **minimal** (with medium confidence) with negligible reductions in local abundance of a few species with effects that are spatially and temporally restricted to local areas near animal production facilities where releases are conducted.

c. Hybridization. We have found no records of *H. aenescens* hybridizing with related species and Moon (2019) stated that there are no records of hybridization within the genus *Hydrotaea* genus. We therefore assess the negative impacts on native biodiversity due to hybridization to be **minimal** (with high confidence).

d. Transmission of disease. *Hydrotaea aenescens* can be a mechanical vector for pathogens of relevance for humans but disease transmission depends on the species being in contact with human excrement. We have found no records of the species being a vector of diseases relevant to native biodiversity in Norway or elsewhere. We therefore assess the negative impact on native biodiversity in natural areas due to transmission of disease to be **minimal** (with medium confidence).

6.2.3 Likelihood of impact

a. Competition. We find it **very unlikely** (with high confidence) that *H. aenescens* will have negative impacts on Norwegian biodiversity through competition with native insects. The assessment is based on the scattered distribution of substrates the species need to reproduce, the limited probability of winter survival outside of animal production facilities, and that the infestation of manure or carcasses will be only from individuals escaping animal facilities.

b. Predation. We find it **very unlikely** (with high confidence) that *H. aenescens* will have negative impacts on Norwegian biodiversity through predation upon native insects. The assessment is based on the scattered distribution of substrates the species need to reproduce, the limited probability of winter survival outside of animal production facilities, and that the infestation of manure or carcasses will be only from individuals escaping animal facilities.

c. Hybridization. We find it **very unlikely** (with high confidence) that *H. aenescens* will have negative impacts on Norwegian biodiversity through hybridization with native insects. Although there are at least 12 other species of *Hydrotaea* occurring in Norway, the assessment is based on the lack of documented hybridization events within the genus (Moon 2019).

d. Transmission of disease. We find it **very unlikely** (with medium confidence) that *H. aenescens* will have negative impact on Norwegian biodiversity through transmission of diseases to native insects. The assessment is based on the lack of studies documenting the species being a vector of relevant diseases. The medium confidence is based on the reports of the species being able to vector diseases relevant to humans.

6.2.4 Risk characterisation

In sum, VKM finds that potential negative effects caused by *H. aenescens* to biodiversity in Norway are characterized by the following risks:

- **Low risk with medium confidence** for competition.
- **Low risk with medium confidence** for predation.
- **Low risk with high confidence** for hybridization.
- **Low risk with medium confidence** for transmission of disease.

6.3 *Spalangia* spp., *Nasonia vitripennis*, and *Muscidifurax* spp. (parasitoid wasps)

6.3.1 Hazard identification

VKM finds that the six species of parasitoid wasps could potentially become a hazard through 4 of 12 possible EICAT impact mechanisms (**Table 1**), including competition, hybridization, disease transmission and parasitism. The other eight EICAT impact mechanisms were judged to be not relevant.

a. Competition. The native biodiversity of Norway and Sweden includes several hundred species of parasitoid wasps with a mixture of generalist and specialist species (Hedqvist 2003, Westrum et al. 2010, Elven & Sjøli 2021). The ecology and life-history of these species is poorly known, but releases of mass-reared parasitoid wasps could potentially negatively impact non-target species in natural habitats if the non-native wasps become competitors for larval hosts. Competitive interactions could be exploitative if the non-native species reduces densities of a host required by a native species or could be interference if host parasitism by the non-native species occurs earlier or is more effective than the native species (Parry 2009).

b. Hybridization. Parasitoid wasps in the genera *Spalangia* and *Muscidifurax* are presumed to be native to the Western Hemisphere, and no native species occur in Norway that would be at risk of hybridization. On the other hand, *Nasonia vitripennis* is a native species with two ecotypes that parasitize fly larvae associated with cavity-nesting birds or animal carcasses. Field studies have shown that different populations of *N. vitripennis* and other parasitoid wasps can diverge in their life-history traits (Fried et al. 1990, Birkemoe et al. 2012), and the two ecotypes have been investigated as a possible example of incipient speciation (Malec et al. 2021). Different populations also vary in infection rates of the bacterial symbionts *Wolbachia* and *Arsenophonus* that affect reproductive compatibility and create female-biased sex ratios (Kyei-Poku et al. 2006, Dittmer et al. 2016, Nadal-Jimenez et al. 2023). The Norwegian Environmental Agency has required import permits for *N. vitripennis* because the source populations for imports might be from different stocks than natural populations (2021/5303, Miljøvedtaksregisteret 2026). It is unknown if mass releases of imported wasps could potentially negatively affect naturally occurring ecotypes of the same species via genetic introgression.

c. Transmission of disease. Parasitoid wasps carry and transmit a wide variety of viral pathogens to host insects (Strand et al. 2026). The potential for virus acquisition and transmission is high because parasitoids are a diverse group, multiple parasitism of the same host by different parasitoids is common, and pathogens are introduced by the piercing ovipositor. Viruses can be reproductive parasites that kill both the host and parasitoid larvae, whereas others are beneficial symbionts that help the parasitoid wasps to immobilize the host larvae. Parasitoid wasps also carry bacterial symbionts that can cause reproductive incompatibility or female-biased sex ratios (Dittmer et al. 2016). Microsporidian parasites (Protozoa: Microspora) have been recovered from parasitoid wasps in the three genera *Spalangia*, *Nasonia*, and *Muscidifurax* (Dry et al. 1999), but some are host-specific, such as infections of *M. raptor* by *Nosema muscidifuracis* (Geden et al. 1995).

d. Parasitism. The life-history of the parasitoid wasps is based on obligate parasitism where they oviposit on host pupae and kill their insect hosts, or in the case of hyperparasitoids, the developing larvae of other parasitoid wasps. The different taxa vary in host specificity, but all attack a wide range of possible hosts: 72 species of primary and parasitoid hosts for the two species of *Spalangia*, 115 host species for *N. vitripennis*, and 5–20 host species for the three species of *Muscidifurax*. *Spalangia* wasps readily switch hosts whereas females of *N. vitripennis* and *Muscidifurax* spp. are more likely to oviposit on the same species of insect hosts that they emerged from. Common dipteran hosts include species that have important ecosystem functions, including root-maggot flies (Anthomyiidae) and house flies (Muscidae) that are often pollinators in natural systems, as well as blowflies (Calliphoridae) and flesh flies (Sarcophagidae) that play a role in decomposition of animal carcasses (Appendix 3).

6.3.2 Hazard characterisation

The current risk assessment relates to potential negative effects on Norwegian biodiversity and aims to highlight potential negative effects if the six species of parasitoid wasps become established in natural habitats in Norway.

a. Competition. Three species of parasitoid wasps are already present in Norway as native species or from previous releases as non-native species, but the three other species would potentially be novel parasites if released for biocontrol. No negative impacts of parasitoids on native biodiversity have been reported from previous releases, but intensity of sampling has not been adequate to test for possible changes in range or abundance. Releases of non-native parasitoids have had few documented effects in any ecosystem because pre-release data are rarely available and only major changes such as extirpation of a common host species can be detected (Kenis et al. 2008). Extirpation of a native parasitoid by competition with an introduced parasitoid has never been documented (Parry 2009). The risk of competition is potentially high in Norway because the community of native parasitoids is diverse and share many of the same hosts as the non-native species. Thus, the consequences for native biodiversity in natural areas are likely to be **minor** (with medium confidence) with limited reductions in local abundance of a few species with effects that are spatially and temporally restricted to local areas near animal production facilities where releases are conducted.

b. Hybridization. The potential impacts of hybridization can be rated as **minimal** (with high confidence) because parasitoid wasps in the genera *Spalangia* and *Muscidifurax* that do not naturally occur in Norway. The situation is more complex for *Nasonia vitripennis* because the species occurs as two ecotypes in the wild and different populations also vary in infection rates with the bacterial symbionts *Wolbachia* and *Arsenophonus* that affect reproductive compatibility and create female-biased sex ratios that determine mating opportunities. Import and release of mass-reared parasitoids from different stocks could have **minor** impacts (with medium confidence) on native populations of *N. vitripennis* with effects that are likely to be spatially and temporally restricted to local areas where releases are conducted.

c. Transmission of disease. Parasitoid wasps can carry infections of viruses, bacterial or protozoan pathogens. Many of the pathogens are host-specific including viruses and bacteria that function as beneficial symbionts and the microsporidian parasites. Screenings of parasitoids that were mass-

reared by commercial insectaries have reported both low (Dry et al. 1999) and high rates of infection with microsporidian parasites (Geden et al. 1995). Transmission of disease is likely to have **minimal** impacts on native biodiversity (with low confidence) because commercially reared parasitoids infected with harmful pathogens have lower fertility and longevity rates, which in turn reduce dispersal and possible establishment in natural habitats. Even if the parasitoids reach natural habitats, many of the pathogens are host-specific and are unlikely to infect native species of parasitoid wasps.

d. Parasitism. Parasitoid wasps require host larvae to complete their life cycle, implying that parasitism is the EICAT impact mechanism with the highest ranking for potential impacts. If a new species of parasitoid wasp became established in Norway, it could potentially attack the pupal stages in a wide range of native insects, some of which have important ecological functions in pollination and decomposition. Extirpation of a native host is unlikely to occur because parasitism rates are often density-dependent and parasitoid wasps have difficulty locating host larvae at low densities. Overall, negative impacts on native biodiversity appear to be uncommon for releases of parasitoid wasps used for biocontrol (Kenis et al. 2008, Parry 2009). Where spillover effects have occurred, they have been in island ecosystems where the introduced parasitoid parasitizes a range of hosts, and the target host co-occurs with non-target endemic species that can serve as hosts (Hennemann & Memmott 2001, Ferguson et al. 2024). Thus, the potential magnitude of impacts of parasitism by parasitoid wasps on native biodiversity are rated as **moderate** (with medium confidence) because abundance could be reduced for multiple host species within the introduced range of the parasitoid.

6.3.3 Likelihood of impact

a. Competition. The likelihood of interspecific competition is potentially high given the broad overlap in suitable hosts between native parasitoids and the parasitoid wasps used as biocontrol agents. However, the likelihood of competition is **moderately likely** (with medium confidence) because the parasitoid wasps used for biocontrol are unlikely to disperse and survive in natural areas outside of the animal production facilities where they have been released.

b. Hybridization. The likelihood of hybridization is **very unlikely** (with high confidence) for parasitoid wasps in the genera *Spalangia* and *Muscidifurax* because no congeneric species occur in Norway. In contrast, the likelihood of hybridization is **moderately likely** (with medium confidence) for *N. vitripennis* because two conspecific ecotypes occur in natural areas of Norway. Different populations would only come in contact if introduced wasps become established and spread in Norway but then it is unknown if the different forms can possibly interbreed or if crosses with introduced stocks would negatively affect the performance of the native ecotypes.

c. Transmission of disease. The likelihood of transmission of disease agents by parasitoid wasps is **unlikely** (with low confidence). The wasps are competent hosts for a range of viral, bacterial and protozoan pathogens and can acquire infections under mass-rearing conditions. Biocontrol agents are unlikely to be infected with *Salmonella* or other pathogens if they are reared in sterile conditions. Impacts from transmission of disease would require that the parasitoid wasps are infected with a harmful pathogen, can become established in Norwegian nature, can transmit the pathogen to the insect community and that the pathogen then has deleterious effects on native biodiversity.

d. Parasitism. The probability that mass-reared parasitoid wasps from commercial insectaries will become established in Norway is low because they are expected to be confined to animal production facilities, have poor dispersal ability and are unlikely to survive during winter. The likelihood of parasitism is assessed as **moderately likely** (with medium confidence) because the parasitoid wasps are obligate parasites that require host insects to complete their life-cycles, the parasitoid wasps can infect a wide range of host species, and several species can switch hosts from the insect host that the female emerged from.

6.3.4 Risk characterisation

In sum, VKM finds that potential negative effects caused by six species of parasitoid wasps to biodiversity in Norway are characterized by the following risks:

- **Medium risk** with **medium confidence** for competition.
- **Low risk** with **high confidence** for hybridization in *Spalangia* and *Muscidifurax* wasps.
- **Medium risk** with **medium confidence** for hybridization in *Nasonia vitripennis*.
- **Low risk** with **low confidence** for transmission of disease.
- **Medium risk** with **medium confidence** for parasitism.

6.4 *Carcinops pumilio* (hister beetle)

6.4.1 Hazard identification

VKM finds that *C. pumilio* could potentially become a hazard through the four EICAT mechanisms competition, predation, hybridization and transmission of disease.

a. Competition. Larvae and adults of *C. pumilio* are predators of eggs and larvae of house flies *Musca domestica* and other Diptera, mites to some extent, and perhaps other insects and arthropods. They may therefore compete for food with native beetles and other generalist predators that exploit the same prey in compost heaps.

b. Predation. *Carcinops pumilio* may potentially prey upon non-target fly eggs and larvae, mites and perhaps other insects and arthropods.

c. Hybridization. There is a potential risk that *C. pumilio* will hybridize with other species, but we have not found any records of such hybridization.

d. Transmission of disease. *Carcinops pumilio* can act as a reservoir and vector for *Salmonella*.

6.4.2 Hazard characterisation

The current risk assessment relates to potential negative effects on Norwegian biodiversity and aims to highlight potential negative effects of *C. pumilio* in Norway. It should be noted that *C. pumilio* is already introduced, well established, and common in compost heaps throughout southern Norway and also found in bird nests.

a. Competition. Since *C. pumilio* is already common in southern Norway, it may compete with native beetles and other predators in compost heaps that feed on eggs and larvae of house flies *M. domestica* and other Diptera, and possibly mites. However, very few native species inhabiting compost heaps appear to have declined or disappeared because of alien beetle species including *C. pumilio* (Ødegaard 1999). We found no reports of negative effects of *C. pumilio* on biodiversity in Norway and elsewhere, but the number of specific studies is limited, and potential impacts cannot be ruled out. VKM assesses that release of *C. pumilio* as biological control agents will have **minimal** impact (with medium confidence) on native biodiversity through competition.

b. Predation. *Carcinops pumilio* may potentially prey upon non-target fly eggs and larvae, mites and perhaps other insects and arthropods. However, very few native species inhabiting compost heaps appear to have declined or disappeared because of alien beetle species including *C. pumilio* (Ødegaard 1999). We found no reports of negative effects of *C. pumilio* on biodiversity in Norway and elsewhere, but the number of specific studies is limited, and potential impacts cannot be ruled out. VKM assesses that release of *C. pumilio* as biological control agents will have **minimal** impact (with medium confidence) on native biodiversity through predation on non-target prey.

c. Hybridization. We have not found any examples of hybridization between *C. pumilio* and other species, and no other congeneric species occur in Norway. VKM assesses that release of *C. pumilio* as

biological control agents will have **minimal** impact (with high confidence) on native biodiversity through hybridization.

d. Transmission of disease. *Carcinops pumilio* has been shown to act as a reservoir and vector for *Salmonella* in poultry houses in other countries (Gray et al. 1999, Skov et al. 2004), but there are few studies of this. VKM assesses that release of *C. pumilio* as biological control agents will have **minimal** impact (with low confidence) related to transmission of disease.

6.4.3 Likelihood of impact

a. Competition. We find it **unlikely** (with medium confidence) that *C. pumilio* will have negative impact on Norwegian biodiversity through competition with native insects. The assessment is based on the lack of reports of negative effects of *C. pumilio* on biodiversity in Norway and elsewhere. However, given the limited number of specific studies, potential impacts cannot be ruled out.

b. Predation. We find it **unlikely** (with medium confidence) that *C. pumilio* will have negative impact on Norwegian biodiversity through predation with native insects. The assessment is based on the lack of reports of negative effects of *C. pumilio* on biodiversity in Norway and elsewhere. However, given the limited number of specific studies, potential impacts cannot be ruled out.

c. Hybridization. We find it **very unlikely** (with high confidence) that *C. pumilio* will have negative impact on Norwegian biodiversity through hybridization with native insects. The assessment is based on the lack of studies documenting hybridization with other related species, and no other species of the genus occur in Norway.

d. Transmission of disease. We find it **unlikely** (with low confidence) that *C. pumilio* will have negative impact on Norwegian biodiversity through transmission of disease to native insects. The assessment is based on the lack of studies documenting the species being a vector of relevant diseases.

6.4.4 Risk characterisation

In sum, VKM finds that potential negative effects caused by *C. pumilio* to biodiversity in Norway are characterized by the following risks:

- **Low risk with medium confidence** for competition.
- **Low risk with medium confidence** for predation.
- **Low risk with high confidence** for hybridization.
- **Low risk with low confidence** for transmission of disease.

6.5 Assessment of cumulative effects

6.5.1 Hazard Identification

The different species of predatory insects and parasitoid wasps can be released as individual species but are often sold as commercial products that contain mixtures of organisms (Appendix 2). For example, 5 of 6 applications for import of biocontrol agents in Norway have been for mixtures of species, including different combinations of the dump fly *H. aenescens* together with *S. cameroni* (2022/1905, 2025/11922, 2026/5369), or with both *S. cameroni* and *N. vitripennis* (2016/10870, 2021/5303). Joint releases of multiple biocontrol agents have the potential to lead to unintended consequences if interactions among the species affect the probabilities of establishment and spread, or the impacts on native biodiversity.

6.5.2 Hazard characterization

In the case of integrated pest management, joint releases of multiple biocontrol agents might be desirable if they are more effective for control of filth flies. Species interactions could be **additive** because hister beetles *C. pumilio* feed mainly on eggs and small larvae, the predatory larvae of dump flies *H. aenescens* feed on the larvae of other fly species, whereas the parasitoid wasps will target any filth flies that have survived up until the pupal stage. Field trials have also shown that species interactions can be facilitative so that the net effects of multiple agents on pest insects can also be **synergistic** (Kaufman et al. 2001, 2012; Geden & Hogsette 2006). For example, predatory species might avoid consumption of parasitized eggs or pupae, which has been reported for omnivorous bugs *Nesidiocoris tenuis* feeding on moth eggs exposed to parasitoid wasps *Trichogramma* sp. (Cabello et al. 2015). Additive and synergistic interactions are less desirable outcomes if non-native species co-occur in natural areas and affect native biodiversity. Additive or synergistic interactions have the potential for **major effects** on native biodiversity.

Predation and competition can also lead to **antagonistic** interactions within or among the different biocontrol agents that could suppress population performance. For example, adult hister beetles can become cannibalistic at high densities and begin to eat eggs and larvae of their own and other species (Geden & Stoffolano 1987). Lab trials have also shown that the different species of parasitoids have competitive interactions for hosts to parasitize, especially when the wasps occur at high densities relative to host numbers (Legner 1967, Ables & Shepard 1974). The parasitoid wasp *S. cameroni* has been cultured on the black dump fly *H. aenescens* for commercial production (Birkemoe et al. 2009). The predatory larvae would not be parasitized until they have matured into the pupal stage but species interactions among biocontrol agents could reduce population numbers of dump flies as a desirable species for control of filth flies. *Muscidifurax raptorellus* has also been recorded parasitizing the dump fly as a host species (Appendix 3). Birkemoe et al. (2004a) noted that *N. vitripennis* has better performance on sarcophagids as preferred hosts instead of house flies, but the species is also competitive superior to *S. cameroni* when parasitising the same pupae. The overall effectiveness of joint releases could be reduced due to antagonistic interactions because *N. vitripennis* is more competitive but then reduces the population densities of *S. cameroni* as a more effective parasitoid. Antagonistic interactions among biocontrol agents are the potential for **minor effects** on native biodiversity.

6.5.3 Likelihood of impact

If the indirect interactions among biological control agents are **antagonistic**, it is **unlikely** (with medium confidence) to be a problem for native species because the species are competing for house and stable flies as a food resource to compete their life-cycle. However, the combination of predation and parasitism from the eight different species of biocontrol agents is **moderately likely** to be **additive** (with low confidence) because the predators and parasitoids also target different life-stages of the house and stable flies. In the current risk assessment for biocontrol of filth flies, the likelihood of **synergistic** effects is **unlikely** (with low confidence) because the species do not have strong trophic relations and do not co-occur elsewhere in their range. In addition, the species are unlikely to come into contact because there is a low risk of establishment and spread of multiple species of biocontrol agents into natural areas of Norway.

6.5.4 Risk characterization

VKM determines that the potential negative effects caused by species interactions among biocontrol agents on native biodiversity in Norway are characterized by the following risks:

- **Low risk with medium confidence** for the antagonistic effects of trophic interactions among non-native species including intraguild patterns of competition, predation and parasitism.
- **Medium risk with low confidence** for the additive or synergistic effects of interspecific interactions among non-native species on native species.
- **Medium risk with low confidence** for the additive or synergistic effects of interspecific interactions among non-native species on native species.

7 Mitigating measures

VKM identifies seven mitigation measures that could be used to reduce the potential negative impacts of biocontrol agents on native biodiversity in Norway.

a. Product labelling. Commercial suppliers market biocontrol agents under different tradenames where the species content or composition can be difficult to determine. Products should be clearly labeled for species and quantities for import to Norway.

b. Shipping and handling. Packing materials and shipping services should be designed to avoid accidental release of biocontrol agents during transit. Packaging could use heavy plastic bags and multiple layers of boxes to contain biocontrol agents until their intended release in an animal production facility.

c. Verification of product contents. Formal testing of commercial products has frequently revealed the presence of other biocontrol agents or their hosts that were not disclosed in the product descriptions. Estimation of numbers is also difficult because the products are shipped as dormant pupae and the actual number of insects can be lower or higher depending on emergence rates which are determined by the temperatures and humidity encountered in transit. Mass production of biocontrol agents in a sterile environment helps to ensure that they are free of *Salmonella* or other disease agents. Independent testing or certification of commercial products would help to ensure that only the approved species of biocontrol agents and disease free organisms are released in Norway.

d. Use products as directed. Commercial suppliers have developed a detailed set of guidelines for applications for predatory insects and parasitoid wasps to maximize efficiency on reducing outbreaks of house and stable flies. Restricting use to indoor sites within a confined facility and at recommended densities per domestic animal will help to reduce losses from dispersal out into adjacent areas. Proper disposal of shipping materials and containers will help to prevent accidental introductions to natural areas.

e. Manure management. The dump fly and hister beetles are predatory insects that colonize manure piles to feed on the larvae of filth flies. Capture, storage and spreading of manure on agricultural fields or gardens should include treatment procedures that reduce the risk of introducing non-native species to natural areas.

f. Integrated pest management. Applications of biocontrol agents could be developed as part of an integrated pest management program. Joint releases of different species with complementary effects that target different life-stages of filth flies may reduce the total numbers of agents that are needed for effective control. On the other hand, dump flies, parasitoid wasps and beetles differ in their environmental requirements and not all species may be suited for the same type of facilities. Release of biocontrol agents is itself a mitigation measure to reduce use of insecticides and other agricultural chemicals for control of filth flies.

g. Monitoring of artificial and natural ecosystems. Species status was uncertain for some of the biocontrol agents but targeted sampling and monitoring at animal production facilities could help clarify whether the species are already established in Norway. The most likely area of entry is

southern Norway because previous releases and detections of the dump flies and parasitoid wasps have been near to Oslo and in adjacent counties. Systematic surveys in natural areas such as surveillance programs for non-native plants and insects in the municipalities around Oslofjorden and the national insect monitoring program in Norway are well-positioned to detect potential changes in abundance or ranges if biocontrol agents unexpectedly become established in Norway. On the other hand, the parasitoid wasps are small-bodied and cryptic organisms which would be impossible to eradicate if an established population becomes an invasive species.

h. Evaluations of approved biocontrol agents. National and international authorities maintain lists of biocontrol agents that have been approved for import and release in Norway (Appendix 1, Mattilsynet Plantvernmidler 2026) and Europe (EPPO 2021, BPDB 2026). If changes in species status or undesirable impacts on non-target hosts are detected in insect monitoring programs, the status of species on approved list can be revised. For example, the aphid parasitoid *Lysiphlebus testaceipes* (Hymenoptera: Braconidae) was downgraded by EPPO to a 'no longer recommended' species for biocontrol after reports of unintended spread and attack on non-target host species (Lemanski & Herz 2025).

8 Uncertainties

VKM identifies seven sources of uncertainty that reduce confidence in the conclusions of the risk assessment.

8.1 Uncertainty related to identification of the species

The biocontrol agents are small-bodied and cryptic species of flies (*H. aenescens*), wasps (*Spalangia* spp., *N. vitripennis*, *Muscidifurax* spp.) and beetles (*C. pumilio*). The species can be reliably identified from morphology by a specialized entomologist or other specialist or by genetic markers in a molecular analysis but could be less likely to be recognized or reported by a citizen science observer.

8.2 Uncertainty regarding the population status of the species in Norway

Two of the biocontrol agents (*N. vitripennis* and *C. pumilio*) are established species that are already present in many areas of Norway. *N. vitripennis* is a native species of parasitoid that occurs as two ecotypes associated with bird nests and animal carcasses, but it is uncertain if import and release of *N. vitripennis* from other regions would be different stocks that could come in contact or displace local populations. *Carcinops pumilio* is a non-native species of beetle, but it is widespread from Trøndelag to southern Norway where it commonly occurs in compost piles. The two species of *Spalangia* wasps are cosmopolitan with global distributions such that it is difficult to determine their native range. *Spalangia cameroni* appears to be a non-native species but is established and common on pig farms in southern Norway. The dump fly *H. aenescens* and parasitoid wasp *M. raptor* have relatively few records in Norway and neighbouring countries but their established range in Norway could be much larger because these species are unlikely to be captured in a Malaise trap or detected in a national monitoring scheme. Targeted sampling schemes to recover parasitoid wasps from parasitized fly larvae collected in animal production facilities have routinely detected large numbers of individuals.

8.3 Uncertainty regarding the commercial suppliers

Commercial suppliers in Europe and North America often provide limited information on their product specifications. Parasitoid wasps are regularly marketed under tradenames without specifying the species composition as 'larvae and pupae' (Miljøfluen in Denmark), 'FlyForce' (Beneficial Insectary in Canada), 'Fly Predators' (Spalding Labs in USA), or 'Fly Eliminator' (Arbico Organics in USA). Other vendors may use tradenames instead of the species names such as 'Biofly' for *H. aenescens* or 'Biopar' for *M. raptorellus* (Koppert in Netherlands). Commercial suppliers also regularly produce products that are a mixture of different species of parasitoid wasps (Rincon-Vitova Insectaries in USA). Products sold as pure cultures are still likely to be mixtures of different species of parasitoids because it is difficult to avoid cross-contamination. Commercial availability of invertebrate species used as biocontrol agents is dynamic with regular turnover in availability of products (Lemanski & Herz 2025). Challenges with mass-rearing of biocontrol agents and the economic viability of mass production can lead to products being seasonally unavailable or discontinued, whereas new companies or products can enter the market at any time.

8.4 Uncertainty regarding past releases and future demand

Biocontrol agents for control of filth flies have been available on the market for decades but import and release were not regulated in Norway until the Regulations on Alien Organisms was adopted in 2015. Early releases for experimental field trials are documented in the scientific literature, but no information is available on imports and releases by agricultural producers. Demand for biocontrol agents appears to be relatively low with six permit applications and approvals in the past decade (2016 to 2026). It is unclear if demand is low because the use of pesticides, mechanical traps, and other methods are more commonly used or effective for management of filth flies in animal production facilities. Current permit terms allowing import and release of up to 2600 individuals are several orders of magnitude lower than the numbers needed for a typical management application. It is unknown if a one-time release of small numbers of predatory insects or parasitoids can be effective for reducing numbers of filth flies in an animal production facility.

8.5 Uncertainty regarding role of competition and predation

The beetles and dump flies are generalist predators whereas the parasitoid wasps can use a variety of insect species as suitable hosts (Appendices 3–4). Some species of parasitoid wasps preferentially parasitize the same species of host that they emerged from, whereas others are more flexible in seeking alternative hosts. The biocontrol agents target different life-stages of flies: hister beetles *C. pumilio* feed mainly on eggs and small larvae, the larvae of dump flies *H. aenescens* feed on the larvae, whereas the six species of parasitoid wasps will parasitize the pupal stage of host flies. The biocontrol agents have the potential to impact a wide range of native species but substantial knowledge gaps remain regarding the diversity of native species, the trophic relationships among predators, parasites and other groups of insects, and the potential loss of ecosystem services if changes in community structure affect pest control, pollination, seed dispersal, or the availability of insects as a food resource. The presence of *N. vitripennis* and *C. pumilio* in compost heaps and bird nests suggests that the two species have a limited range of suitable habitats, but it is uncertain if they have ecological impacts on native species that co-occur in the same habitats.

8.6 Uncertainty regarding role of disease transmission

One of the potential benefits of biocontrol of house and stable flies is that disease transmission should be reduced with likely benefits for both animal production and human health. However, the biocontrol agents are also known to be hosts for a variety of pathogens. For example, the dump fly *H. aenescens* is known to be a mechanical vector for *Campylobacter* spp. and *E. coli*, whereas the hister beetle *C. pumilio* is both a reservoir and vector for *Salmonella* spp. The parasitoid wasps carry a variety of viral, bacterial and protozoan pathogens, although some of the microbes are also beneficial symbionts. No information is available on the dynamics of disease transmission in a multi-species system resulting from joint release of biocontrol agents for control of several species of filth flies.

8.7 Uncertainty regarding potential effects of climate change

The species of predatory insects and parasitoid wasps have been described as likely confined to animal production facilities because they are dependent on human activities, have limited dispersal, and are warm-adapted species. Nevertheless, the hister beetle *C. pumilio* is clearly widespread and occurs in much of southern Norway. It is unknown if the distribution of the beetle and potentially

other species are dependent on the availability of warm microhabitats, such as compost piles, or if the non-native organisms could be more cold-tolerant than expected based on their native range. The two alternatives have implications for the possible establishment and spread of non-native species if climate change leads to better growing conditions or milder winters.

9 Conclusions

The conclusions of our risk assessment are structured according to the Terms of Reference (ToR) provided to VKM by the Norwegian Environment Agency. The six specific objectives from the ToR are listed below in italics with a grey background.

9.1 ToR 1 - Species compilation

Create a compilation of species within different orders of insects that are used for biological control of pests that plague animals in stables and barns.

VKM compiled a list of eight species of biocontrol agents that have been used for control of house and stable flies in animal production facilities. Three species have been previously approved for import by the Norwegian Environment Agency, and we identified an additional five species that are relevant for management applications in Norway. The eight species have been evaluated with field trials in Norway and abroad and have been available for purchase from commercial producers in Europe or North America. The eight species included a predatory fly *Hydrotaea aenescens* (Diptera: Muscidae), the six parasitoid wasps *Spalangia cameroni*, and *S. endius* (Hymenoptera: Spalangiidae), *Nasonia vitripennis*, *Muscidifurax raptor*, *M. raptorellus*, and *M. zaraptor* (Hymenoptera: Pteromalidae), and the predatory beetle *Carcinops pumilio* (Coleoptera: Histeridea). We considered but did not review two other groups of biocontrol agents that did not meet one or more of the project criteria including predatory macrochelid mites (Mesostigmata: Machrochelidae) and the parasitoid wasp *Trichomalopsis sarcophagae* (Hymenoptera: Pteromalidae).

9.2 ToR 2 - Likelihood of entry, establishment, and spread

Assess the likelihood of establishment today, and in the future, by introducing insects for use as biological control in stables and barns that do not guarantee against escape. The probability of establishment should include a description of uncertainty.

The likelihood of entry is confirmed or likely for all of the biocontrol agents because imports were unregulated in the past and because early permits allowed import of up to 12 million individuals of three species (section 1.4). Recent permits have allowed for import and release of up to 2,600 individuals, which is 2–3 orders of magnitude lower than the numbers of insects needed for a typical management application. Nevertheless, even if permit terms were increased to one million individuals, field trials in Norway and elsewhere suggest that the likelihood of establishment and spread is still likely to be low. We evaluate establishment and spread separately for the dump fly, parasitoid wasps, and the hister beetle.

- The dump fly *H. aenescens* is a non-native species that has been detected in Norway and could be a ‘doorknocker’ species or populations may already be established. *Hydrotaea aenescens* uses manure and compost piles that provide a warm and more stable environment, and the species is unlikely to be able to cope with cold winter conditions in natural habitats. **VKM assesses the likelihood of entry for *H. aenescens* to be confirmed with high confidence, and the likelihood of establishment and spread to be low with medium confidence.**
- The parasitoid wasp *N. vitripennis* is a native species that naturally occurs as two ecotypes in Norway, whereas the parasitoid wasp *S. cameroni* is a non-native species established on pig farms in Vestfold, southern Norway. The non-native parasitoid wasp *M. raptor* has also

been detected in low numbers and could also have established populations. Three other non-native species of parasitoid wasps have not been detected in Norway, including *S. endius*, *M. raptorellus*, and *M. zaraptor*. The likelihood of establishment and spread into natural areas is assessed to be low because the non-native species of parasitoid wasps are associated with barns and stables, compost or manure piles, and other modified habitats. In addition, all these species have poor dispersal abilities and are warm-adapted, making them unlikely to survive cold winter conditions in Norway. Mass releases of *N. vitripennis* in Norway and *S. cameroni*, and *M. raptorellus* in Alberta and Nebraska resulted in low overwinter survival rates and did not lead to successful establishment of viable populations. **VKM assesses the likelihood of entry and establishment to be confirmed with high confidence for *S. cameroni* and *N. vitripennis*, whereas the likelihood of spread is assessed as low with medium confidence. VKM assesses the likelihood of entry, establishment, and spread for *S. endius* and three species of *Muscidifurax* to be low with medium confidence.**

- The hister beetle *C. pumilio* is a non-native species that is already widely established in southern Norway. *Carcinops pumilio* uses microhabitats, such as compost piles and bird nests that provide a relatively warm and stable environment, and they may be less likely to cope with cold winter conditions in natural habitats. VKM assesses the **likelihood of entry and establishment of *C. pumilio* to be confirmed with high confidence, and the likelihood of spread linked to being used as a biological control agent to be low with medium confidence.**

9.3 ToR 3 - Risk of adverse effects for biodiversity

Assess the risk of adverse effects for biodiversity in Norway, when insects used for biological control in stables and barns escape into the wild. Such risks should be assessed for both scenarios where the insects do not establish themselves and scenarios where they do, as well as include a description of uncertainty for both scenarios.

VKM identified six impact mechanisms under the EICAT classification system (1–5 and 12) that were relevant to import and release of biocontrol agents and with potential risk of adverse effects for native biodiversity in Norway. The impact mechanisms covered the direct effects of non-native organisms on native biodiversity and included the trophic interactions of competition (1), predation (2) and parasitism (5), along with the potential effects of hybridization (3) and disease transmission (4). In addition, we evaluated the potential for indirect or cumulative effects potentially resulting from joint releases of multiple non-native species (12), which could lead to additive or synergistic impacts on native biodiversity. A range of establishment scenarios were considered because the pool of biocontrol agents included one native species, two non-native species with established populations, and five species that were either reported in low numbers or not yet detected in Norway. Overall, the adverse effects of the six impact mechanisms are likely to be realized only if populations of the non-native species become established. We address the risk of adverse effects for native biodiversity separately for the dump fly, parasitoid wasps and the hister beetle.

- The dump fly *H. aenescens* is a generalist species with predatory larvae that attack and feed on the larvae of a wide range of prey species. The native biodiversity of Norway has a diverse community of predatory insects with a similar ecological niche, including at least 12

other congeneric species of *Hydrotaea*. However, no negative effects on native species have been documented for dump flies in Norway or elsewhere in their range. **VKM assesses the risks of adverse effects from *H. aenescens* by competition, predation, hybridization, and transmission of disease to be low with low to high confidence (Figures 5 and 9).**

- Parasitoid wasps in the genera *Spalangia*, *Nasonia* and *Muscidifurax* are obligate parasitoids that require insect hosts to complete their life cycle. The parasitoid wasps have a high potential for adverse effects due to competition with other native parasitoid species and parasitism of a wide range of suitable hosts that include dipteran species with important ecological roles in pollination and decomposition. However, parasitism rates are often strongly density-dependent and female wasps have difficulty locating suitable hosts at low densities. Introductions of parasitoid wasps elsewhere have rarely been documented to have major ecological effects or lead to extirpation of native hosts or other parasitoids. Risk of hybridization was only relevant for *N. vitripennis* because the species occurs naturally as two different ecomorphs in Norway. **VKM assesses the risk of adverse effects by parasitoid wasps from competition and parasitism to be medium with low to medium confidence (Figures 6 and 9). The risk of adverse effects from hybridization was medium with medium confidence for *N. vitripennis* and low with high confidence for the other five species of parasitoid wasps. The risk of adverse effects from transmission of disease was low with low confidence.**
- The hister beetle *C. pumilio* is a generalist predator where adults feed on eggs and small larvae of a wide range of prey species. The native biodiversity of Norway includes other predatory insects with a similar ecological niche but no congeneric species. Hister beetles are not reported to have negative effects on native species anywhere in their range. **VKM assesses the risk of adverse effects by hister beetles from competition, predation, hybridization, and disease transmission to be low with low to high confidence (Figures 7 and 9).**
- VKM considered the possibility of cumulative effects due to species interactions among the non-native organisms. The different biocontrol agents are likely to have antagonistic interactions through interference competition, intraguild predation, or parasitism. **VKM assesses the risk of cumulative effects from antagonistic interactions to be low with medium confidence (Figures 8 and 9).** Joint releases could lead to additive effects on non-native species but are unlikely to lead to synergistic impacts in which negative effects on native species exceed those expected from the individual species acting alone. Thus, **VKM assesses the risk of cumulative effects from additive or synergistic interactions to be medium with low confidence (Figures 8 and 9).**

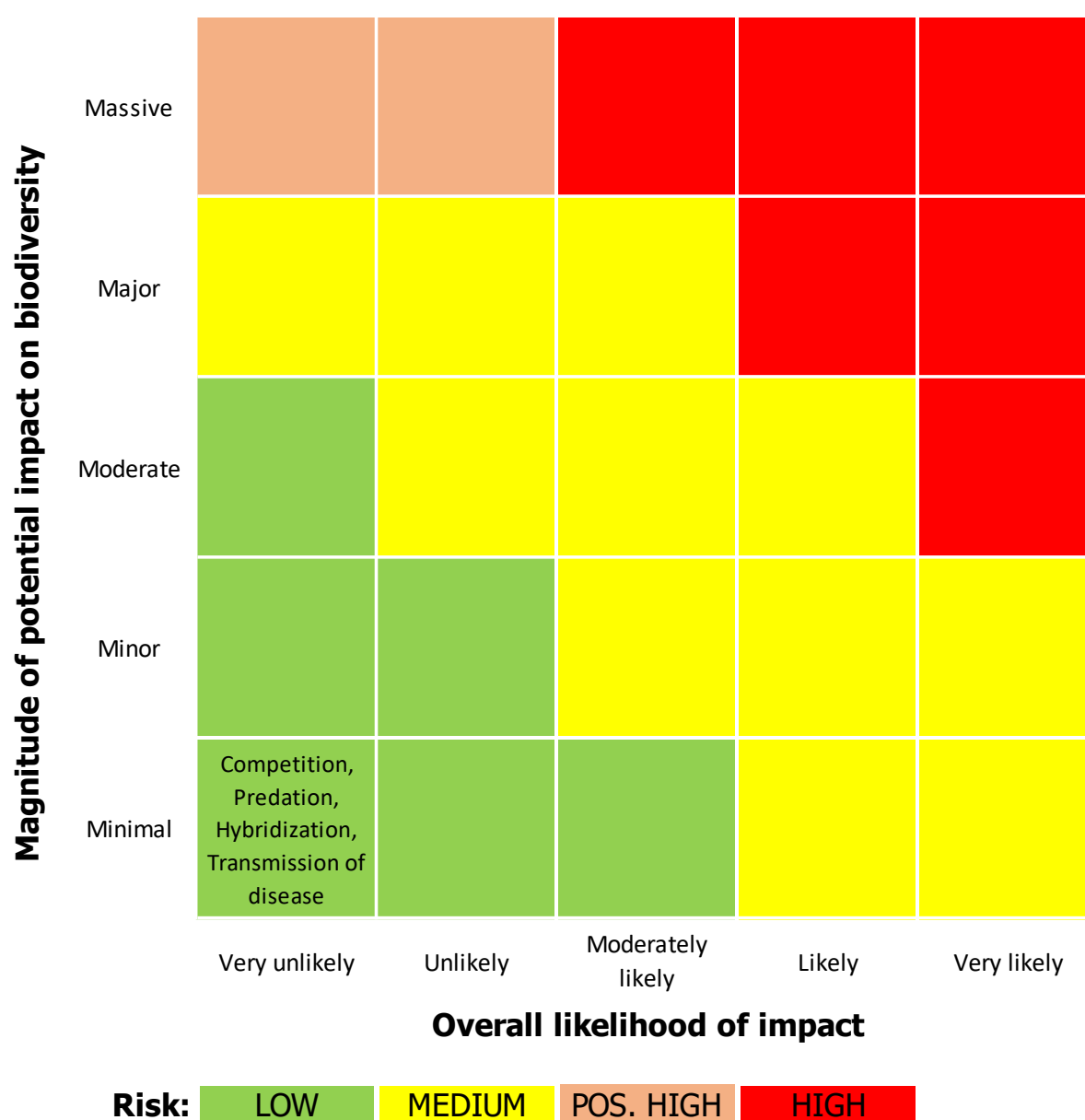


Figure 5. Summary of risks to natural biodiversity associated with the import and release of the black dump fly (*Hydrotaea aenescens*) as a biocontrol agent in Norway. For confidence assessments, see Figure 9.

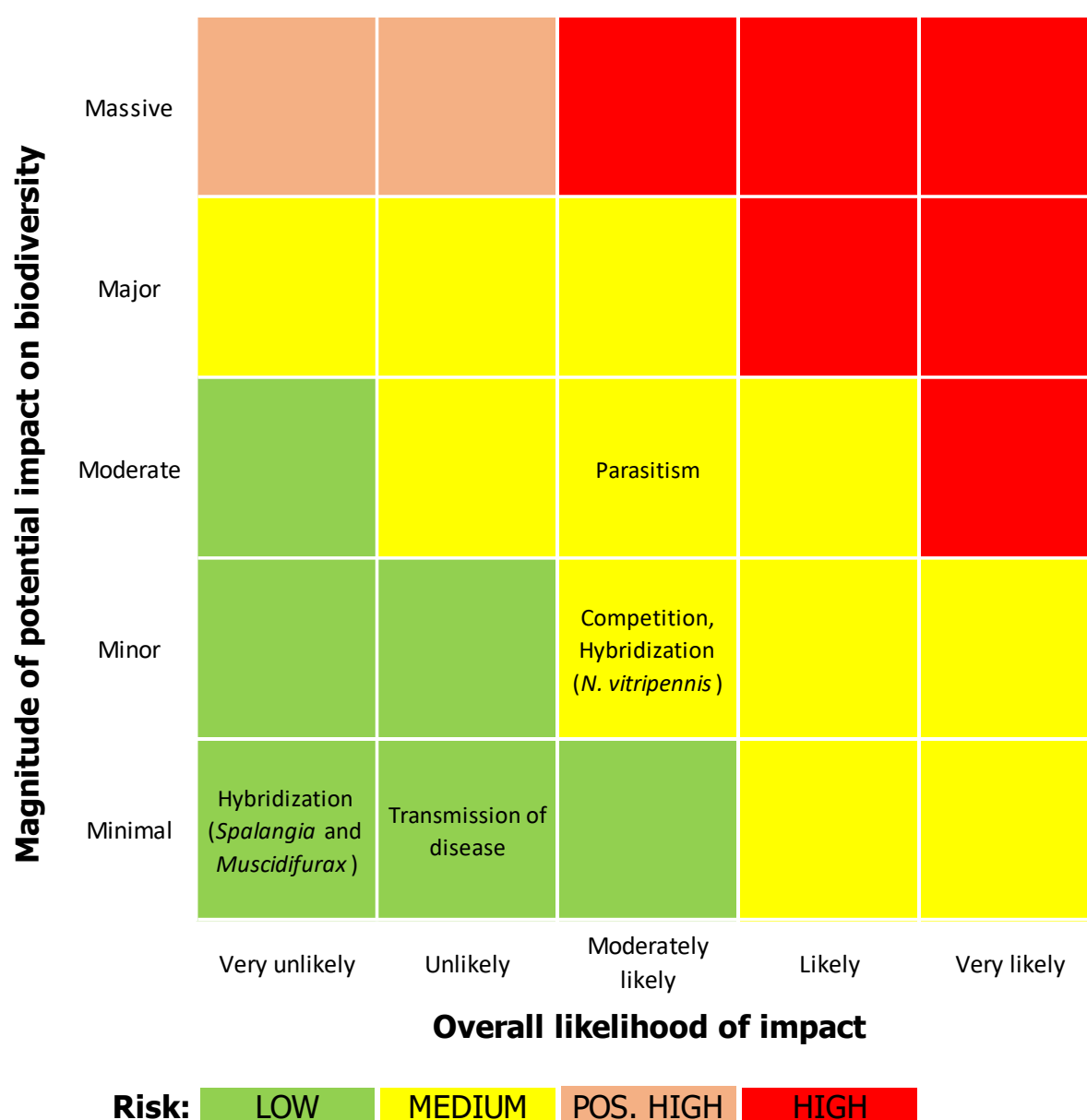


Figure 6. Summary of risks to natural biodiversity associated with the import and release of six species of parasitoid wasps as biocontrol agents in Norway, including *Spalangia cameroni*, *S. endius*, *Nasonia vitripennis*, *Muscidifurax raptor*, *M. raptorellus* and *M. zaraptor*. Assessments apply to all species unless stated otherwise in parentheses. For confidence assessments, see Figure 9.

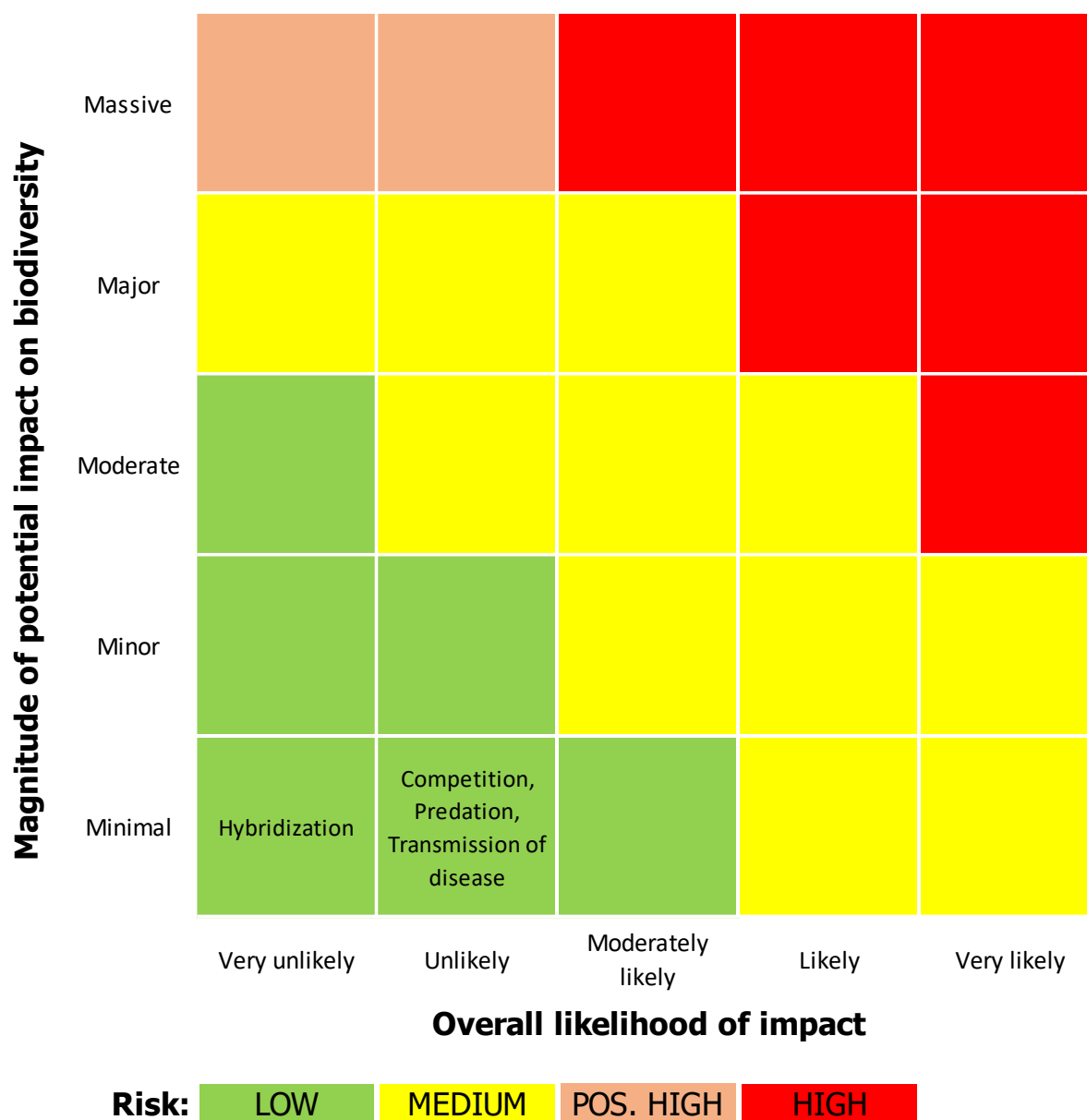


Figure 7. Summary of risks to natural biodiversity associated with the import and release of the hister beetles (*Carcinops pumilio*) as a biocontrol agent in Norway. For confidence assessments, see Figure 9.

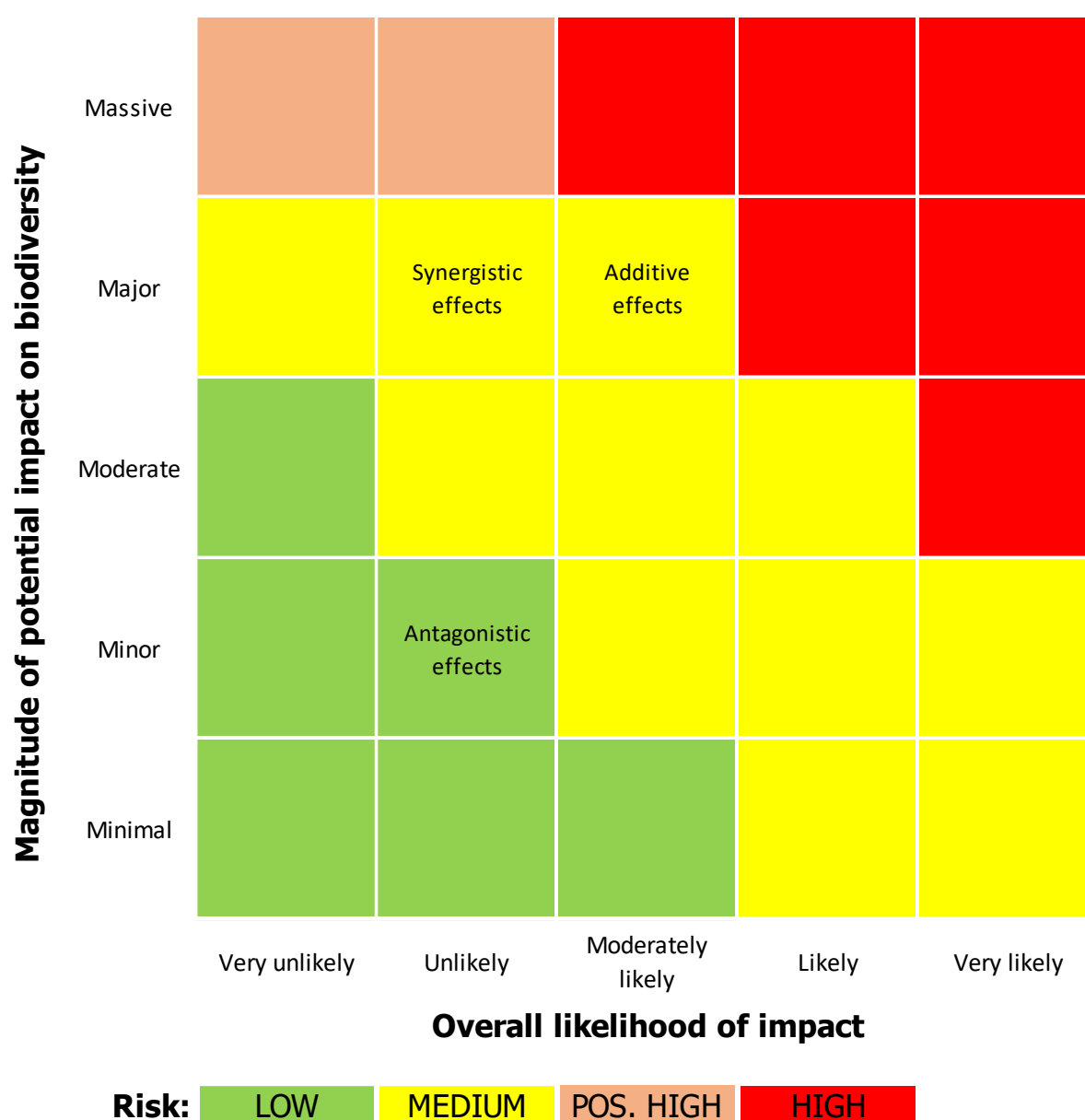


Figure 8. Summary of risks to natural biodiversity associated with interspecific interactions among non-native species of biocontrol agent in Norway. For confidence assessments, see Figure 9.

Data quality	High			
	Medium		Parasitization (parasitoid wasps), Hybridization (<i>N. vitripennis</i>), Antagonistic effects	Hybridization (all other species)
	Low		Transmission of disease (all species), Synergistic and additive effects	Establishment and spread (all species), Competition (all species), Predation (dump fly and hister beetle)
		Inconsistent	Partly consistent	Consistent
		Data consistency		
Confidence:		LOW	MEDIUM	HIGH

Figure 9. Summary of confidence in the assessments regarding six EICAT mechanisms in relation to import and release of eight biocontrol agents in Norway and their potential cumulative effects. Data quality reflects both the amount of data and its intrinsic quality, while data consistency refers to whether the available information is in agreement or not.

9.4 ToR 4 - Magnitude and frequency of releases

Assessment of both the probability of establishment and the risk of adverse effects should be made from the perspective of individual cases of introduction, repeated cases of introduction and the introduction of large numbers of individuals in one place.

VKM determined that the magnitude of releases has changed dramatically over the past 25 years but the management history has been similar for both dump flies and parasitoid wasps. Import and release of biocontrol agents for control of filth flies in barns and stables was unregulated in Norway before 2015. Six permits for import and release of *H. aenescens*, *N. vitripennis*, and *S. cameroni* were approved by the Norwegian Environmental Agency in the past decade of 2016 to 2026. We reviewed the magnitude and frequency of releases separately for the dump fly, parasitoid wasps and the hister beetle.

- We found no examples of experimental trials with the dump fly *H. aenescens* in Norway before 2015. Since 2016, two permits allowed import and release of *H. aenescens* in unrestricted numbers or up to 12 million individuals, whereas the last four permits included terms restricting numbers to 2600 individuals. Product descriptions from commercial suppliers suggest that one-time application of 10 000 fly pupae per 93 m² of manure can be sufficient to establish a breeding population of *H. aenescens* (Rincon-Vitova Insectaries 2009). *Hydrotaea aenescens* is likely already established in Norway. **VKM assesses the risk of adverse effects from a one-time release of up to ten thousand individuals of *H. aenescens* to be low with high confidence.**
- The magnitude of imports and releases of parasitoid wasps by agricultural producers before 2015 is unknown. Experimental field trials included releases of 70 000 to 440 000 parasitoid wasps of *S. cameroni* and *N. vitripennis* at pig farms in Vestfold during 2002–2005. In the past decade, two early permits allowed import and release of either unrestricted numbers or up to 12 million individuals of the same two species. In contrast, three recent permits restricted numbers to up to 2600 individuals of the parasitoid wasp *S. cameroni*. Typical management applications require sequential releases of up to one million individuals in a season. However, we found several examples of field trials where one-time introductions of up to 1.3 million parasitoid wasps failed to lead to an establishment of new populations. *N. vitripennis* is a native species and *S. cameroni* is already established in Norway. **VKM assesses the risk of adverse effects from a one-time release of up to one million individuals of *N. vitripennis* and *S. cameroni* to be low with moderate confidence.** The parasitoid wasps *S. endius* and *Muscidifurax* spp. have not been imported or released in Norway but two of the species have been recorded in low numbers. Management applications based on mixtures of *M. raptorellus* and *M. zaraptor* with *S. cameroni* can require releases of up to one million individuals in a season (Rincon-Vitova Insectaries 2009). **VKM assesses the risk of establishment and adverse effects from a one-time release up to one million individuals of *S. endius*, *M. raptor*, *M. raptorellus* and *M. zaraptor* to be medium with moderate confidence.**
- The hister beetle *C. pumilio* is already established as a non-native species. One-time application of 10 000 beetles per manure pit may be sufficient to establish a breeding population of *C. pumilio* (Rincon-Vitova Insectaries 2009). **VKM assesses the risk of adverse effects from one-time introduction of up to 10 000 individuals of *C. pumilio* to be low with high confidence.**

VKM determined that the releases of biocontrol agents in Norway have been intermittent, typically occurring once every two to three years. The duration of experimental releases in field trials conducted before 2015 was typically 1–2 years, whereas all permits issued during the past decade have been valid for only six months to one year. Field trials from Denmark, Canada, and other northern countries have also been short-term studies lasting one to two years, and we did not locate any examples of repeated introductions conducted over multiple years. **VKM is therefore unable to assess the possible risks associated with repeated introductions over multiple years at the same facility.**

9.5 ToR 5 - Potential effects of climate change

Furthermore, both the assessment of the likelihood of establishment and the risk of adverse effects for biodiversity shall include an assessment of how future climate change may affect the risk of adverse consequences. The assessments shall be made in a 10-year perspective, and beyond in a long-term climate perspective.

VKM concluded that the starting point for the potential effects of climate change differed among species depending on their current status and distribution in Norway (see ToR 2). Thus, we review the potential effects of climate change separately for the dump fly, parasitoid wasps and the hister beetle.

- The dump fly *H. aenescens* has only been reported from animal production facilities in southern Norway. Dispersal distances are up to 10 km and the optimal temperature for growth and development has been reported as 26.7°C. Impacts of climate change are expected to differ among regions of Norway due to topographic variation that creates geographic gradients in precipitation and temperature. Nevertheless, even the southern region of Norway is unlikely to develop favorable conditions for dump flies in the next decade. **VKM concludes that future climate change, on either a decadal or a long-term perspective, is very unlikely to increase the risk of adverse consequences from the dump fly *H. aenescens*.**
- The jewel wasp *N. vitripennis* is a native species for which climate change could lead to greater dispersal and increased contact between mass-reared populations released for biocontrol and native populations in natural habitats. Two of the other five species of parasitoid wasps (*Spalangia* and *Muscidifurax* spp.) have been reported in Norway but only occur at animal production facilities. Dispersal distances are <100 m for all of the parasitoid wasps, and the optimal temperature ranges for growth and development are usually between 20–30°C. Climate change is unlikely to affect the likelihood of entry and establishment into natural areas for the parasitoid wasps because they are associated with manmade habitats, have poor dispersal abilities and are warm-adapted species unlikely to survive cold winter conditions in Norway. Climate change in the southern region of Norway is unlikely to develop favorable conditions for parasitoid wasps in the next decade. **VKM concludes that future climate change, on either a decadal or a long-term perspective, is very unlikely to increase the risk of adverse consequences from the parasitoid wasps.**
- The hister beetle *C. pumilio* is a widely established non-native species that occurs in compost piles and bird nests, with a distribution that extends from southern Norway up to Trøndelag. Compost piles are thought to provide a relatively warm and stable microclimate that might

be buffered against changes in the surrounding environment. Climate change leading to milder winters with more precipitation could improve environmental conditions for hister beetles and lead to a northward expansion of their distribution. However, hister beetles are not known to have negative effects on native biodiversity and changes in abundance or range are unlikely to have adverse effects on ecosystem function. **VKM concludes that future climate change, on either a decadal or a long-term perspective, is unlikely to increase the risk of adverse consequences from the hister beetle *C. pumilio*.**

9.6 ToR 6 - Mitigation measures to reduce risk

Identify and describe possible risk-reducing measures and assess the effect of these.

VKM identified seven mitigation measures that could minimize impacts of biocontrol agents on native biodiversity in Norway (section 7). Three measures were related to import from commercial suppliers included: a) product labeling that includes accurate information on species content, b) shipping materials and handling measures to avoid accidental escape, and c) verification of product contents to ensure that only approved species are imported and released in Norway. Three measures were related to release of biocontrol agents in animal production facilities and included: d) use of products as directed at indoor and at recommended densities to minimize losses to dispersal, e) manure management to avoid transport of non-native species into natural areas, and f) use of biocontrol agents as part of an integrated pest management program to minimize the total numbers released. A last measure (g) focused on post-release monitoring to detect unexpected arrivals of non-native species or major changes in the range or abundance of native species. National and regional programs have been using standardized sampling based on Malaise traps to sample insects in Norway. Continued support of long-term monitoring programs could provide early warning of sudden changes in the community dynamics of native and invasive insects.

10 Data gaps and future research directions

VKM identified five data gaps where additional information would be helpful for assessing the potential impacts of biocontrol agents on native biodiversity in Norway.

a. Current status of biocontrol agents. The dump fly *H. aenescens* and parasitoid wasp *M. raptor* have been detected in Norway and neighbouring countries but have relatively few records in national databases or in the Global Biodiversity Information Framework (GBIF). The species status in Norway is still unclear, and the organisms could either be ‘doorknocker’ species that have recently entered Scandinavia, or they could be established species that have been overlooked because they are unlikely to be detected with standard sampling methods based on Malaise traps deployed in natural areas. Targeted sampling for predatory insects and parasitoid wasps at animal production facilities would be useful for confirming the range and abundance of the different species in Norway.

b. Products from commercial vendors. A variety of commercial vendors in Europe and North America have products for sale containing invertebrates that are used as biocontrol agents. Little information is currently available on whether the contents match the product descriptions. Controlled studies for testing and verification of products could help to minimize risks for import and release of non-native invertebrates in barns or stables.

c. Pathways to establishment. Use of biocontrol agents is confined to animal production facilities and the potential pathways to establishment in natural areas are largely unknown. Current regulations on manure management are targeted at management of water quality and nutrients, and do not incorporate risk of spread of non-native species (Forskrift om gjødselvarer mv. av organisk opphav). Field studies of dispersal ability and temperature tolerances of the agents in different types of closed and open animal facilities would address data gaps on the risks of entry and establishment.

d. Impacts on non-target species of native biodiversity. All the biocontrol agents are generalist species with high potential for competition, predation, or parasitism with a wide range of native species. Our risk assessment has been based on a high degree of overlap among larval substrates, diets, and host preferences, but data gaps remain on the possible ecological effects of the biocontrol agents on native biodiversity. Field studies that collect and culture larvae of different host species could provide useful information on background rates of predation and parasitism in natural systems. Similarly, deployment and monitoring of laboratory-reared sentinel larvae in animal facilities and natural areas would be an effective method for assessing potential spillover effects. All of the biocontrol agents can carry different types of viral, bacterial and protozoan parasites but the potential spillover onto native species has not been studied.

e. Efficacy of biocontrol agents for control of filth flies. The current information available for applications of biocontrol agents for control of filth flies in Norway is based on a limited number of field trials conducted with a subset of the parasitoid wasps and mainly at pig farms. Assessment of agricultural products is usually completed with field trials by NIBIO on contract from Mattilsynet. It would be useful to have information from additional field trials under controlled conditions with other biocontrol agents and in different types of production facilities to better understand the efficacy and potential pitfalls of mass releases of commercially reared insects.

11 References

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12 Appendices

12.1 Appendix 1 Approved biocontrol agents

Five species of nematodes and 29 species of arthropods that have been approved for use as biocontrol agents in Norway. *Source:* Mattilsynet Plantvernmidler (2026).

Phylum	Order	Scientific name	Description
Nematoda		<i>Heterorhabditis bacteriophora</i>	Nematode parasite
Nematoda		<i>Phasmarhabditis hermaphrodita</i>	Nematode parasite
Nematoda		<i>Steinernema carpocapsae</i>	Nematode parasite
Nematoda		<i>Steinernema feltiae</i>	Nematode parasite
Nematoda		<i>Steinernema kraussei</i>	Nematode parasite
Arthropoda: Chelicerata		<i>Acarus siro</i>	Predatory mite
Arthropoda: Chelicerata		<i>Amblydromalus limonicus</i>	Predatory mite
Arthropoda: Chelicerata		<i>Amblyseius andersoni</i>	Predatory mite
Arthropoda: Chelicerata		<i>Amblyseius cucumeris</i>	Predatory mite
Arthropoda: Chelicerata		<i>Amblyseius montdorensis</i>	Predatory mite
Arthropoda: Chelicerata		<i>Amblyseius swirskii</i>	Predatory mite
Arthropoda: Chelicerata		<i>Carpoglyphus lactis</i>	Dried fruit mite
Arthropoda: Chelicerata		<i>Hypoaspis miles</i>	Predatory mite
Arthropoda: Chelicerata		<i>Phytoseiulus persimilis</i>	Predatory mite
Arthropoda: Chelicerata		<i>Thyreophagus entomophagus</i>	Storage mite
Arthropoda: Crustacea		<i>Artemia spp.</i>	Brine shrimp
Arthropoda: Hexapoda	Hemiptera	<i>Macrolophus pygmaeus</i>	Predatory bug
Arthropoda: Hexapoda	Hemiptera	<i>Orius majusculus</i>	Predatory bug
Arthropoda: Hexapoda	Hemiptera	<i>Rhopalosiphum padi</i>	Bird cherry-oat aphid
Arthropoda: Hexapoda	Hemiptera	<i>Sitobion avenae</i>	Cereal aphid
Arthropoda: Hexapoda	Hymenoptera	<i>Anagyrus vladimiri</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Aphidius colemani</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Aphidius ervi</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Dacnusa sibirica</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Diglyphus isaea</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Encarsia formosa</i>	Parasitoid wasp
Arthropoda: Hexapoda	Hymenoptera	<i>Eretmocerus eremicus</i>	Parasitoid wasp
Arthropoda: Hexapoda	Neuroptera	<i>Chrysoperla carnea</i>	Green lacewing
Arthropoda: Hexapoda	Coleoptera	<i>Atheta coriaria</i>	Greenhouse rove beetle
Arthropoda: Hexapoda	Coleoptera	<i>Cryptolaemus montrouzieri</i>	Ladybird beetle
Arthropoda: Hexapoda	Lepidoptera	<i>Ephestia sp.</i>	Flour moths
Arthropoda: Hexapoda	Lepidoptera	<i>Ephestia kuehniella</i>	Mediterranean flour moth
Arthropoda: Hexapoda	Diptera	<i>Aphidoletes aphidimyza</i>	Predatory gall midge
Arthropoda: Hexapoda	Diptera	<i>Feltiella acarisuga</i>	Predatory gall midge

12.2 Appendix 2 Commercial suppliers of biocontrol agents

Examples of commercial suppliers of the biocontrol agents used for control of filth flies in animal production facilities. *Sources:* Hale (2010), BPDB (2016), EPPO (2021), LeBeck & Leppla (2023), White & Johnson (2026), and this report.

Biocontrol agent	Commercial supplier
<i>Hydrotaea aenescens</i>	Koppert, Miljøfluen, Rincon-Vitova
<i>Spalangia cameroni</i>	Buglogical Control Systems, Kunafin, Plant Products, Rincon-Vitova, Spalding Laboratories
<i>Spalangia endius</i>	Kunafin, Spalding Labs
<i>Nasonia vitripennis</i>	Buglogical Control Systems
<i>Muscidifurax raptor</i>	Arbico Organics , Buglogical Control Systems, Evergreen Growers Supply, IPM Laboratories, Kunafin, Natural Insect Control, Rincon-Vitova, Sound Horticulture, Spalding Labs
<i>Muscidifurax raptorellus</i>	Arbico Organics , Buglogical Control Systems, Evergreen Growers Supply, IPM Laboratories, Koppert, Kunafin, Natural Insect Control, Plant Product, Rincon-Vitova, Spalding Labs
<i>Muscidifurax zaraptor</i>	Buglogical Control Systems, Evergreen Growers Supply, Kunafin, Plant Products, Rincon-Vitova
Mixtures of parasitoid wasps	Beneficial Insectary, Bugs for Bugs, Evergreen Growers Supply, Green Methods, Kunafin, Miljøfluen, Natural Insect Control, Nature's Control, Sound Horticulture, Tip Top Bio-Control
<i>Carcinops pumilio</i>	Arbico Organics, Rincon-Vitova

Commercial suppliers	Webpage
Arbico Organics USA)	https://www.arbico-organics.com
Beneficial Insectary (Canada)	https://insectary.com
Buglogical Control Systems (USA)	http://www.buglogical.com
Bugs for Bugs (Australia)	https://bugsforbugs.com.au
Evergreen Growers Supply (USA)	http://www.evergreengrowers.com
Green Methods (USA)	https://greenmethods.com
Koppert Global (Netherlands)	http://www.koppert.com ; https://retail.koppert.ca/
Kunafin "The Insectary" (USA)	http://www.kunafin.com
Miljøfluen (Denmark)	https://miljofluen.dk
Natural Insect Control (Canada)	https://naturalinsectcontrol.com
Nature's Control (USA)	https://naturescontrol.com
Plant Products (Canada)	http://www.plantproducts.com
Rincon-Vitova (USA)	https://www.rinconvitova.com
Sound Horticulture (USA)	https://soundhorticulture.com
Spalding Labs (USA)	https://www.spalding-labs.com
Tip Top Bio-Control (USA)	http://www.tiptopbiocontrol.com

12.3 Appendix 3 Primary hosts of parasitoid wasps

Primary insect hosts reported for six species of parasitoid wasps: *Spalangia cameroni* (*Spa. cam.*), *S. endius* (*Spa. end.*), *Nasonia vitripennis* (*Nas. vit.*), *Muscidifurax raptor* (*Mus. rap.*), *M. raptorellus* (*Mus. r-el.*) and *M. zaraptor* (*Mus. zar.*). The list of documented hosts is taken from the global range of the parasitoids and includes species of insects not found in Norway. The total number of primary hosts per parasitoid species varied from 5 to 50 species and up to 97 host species recorded for *N. vitripennis*. Source: Biological associations for primary hosts reported in the individual species accounts at UCD Community (2023).

Order:Family	Host species	<i>Spa. cam.</i>	<i>Spa. end.</i>	<i>Nas. vit.</i>	<i>Mus. rap.</i>	<i>Mus. r-el.</i>	<i>Mus. zar.</i>
Total number of primary hosts		39	50	97	19	7	5
Blattodea:Blattellidae	<i>Blattella germanica</i>			X			
Blattodea:Blattidae	<i>Periplaneta americana</i>			X			
Blattodea:Rhinotermitidae	<i>Reticulitermes flavipes</i>			X			
Phasmatodea:Phasmatidae	<i>Diapheromera femorata</i>			X			
Dermaptera:Carcinophoridae	<i>Euborrellia annulipes</i>			X			
Hemiptera:Aphididae	<i>Aphis nerii</i>			X			
Hemiptera:Lygaeidae	<i>Oncopeltus fasciatus</i>			X			
Coleoptera:Curculionidae	<i>Ips acuminatus</i>			X			
Coleoptera:Curculionidae	<i>Ips typographus</i>			X			
Coleoptera:Tenebrionidae	<i>Tenebrio molitor</i>			X			
Lepidoptera:Bombycidae	<i>Bombyx mori</i>	X	X				
Lepidoptera:Lasiocampidae	<i>Malacosoma castrensis</i>			X			
Lepidoptera:Lymantriidae	<i>Lymantria dispar</i>			X			
Lepidoptera:Noctuidae	<i>Trichoplusia ni</i>			X			
Lepidoptera:Pyralidae	<i>Achroia grisella</i>			X			
Lepidoptera:Pyralidae	<i>Plodia interpunctella</i>			X			
Lepidoptera:Pyralidae	<i>Pyrausta nubilalis</i>			X			
Lepidoptera:Tortricidae	<i>Archips fumiferana</i>			X			
Lepidoptera:Tortricidae	<i>Choristoneura fumiferana</i>			X			
Diptera:Anthomyiidae	<i>Atherigona quadripunctata</i>	X					
Diptera:Anthomyiidae	<i>Atherigona soccata</i>	X	X				
Diptera:Anthomyiidae	<i>Delia antiqua</i>		X				
Diptera:Anthomyiidae	<i>Hydrotaea aenescens</i>					X	
Diptera:Anthomyiidae	<i>Hydrotaea australia</i>		X				
Diptera:Anthomyiidae	<i>Hydrotaea capensis</i>			X			
Diptera:Anthomyiidae	<i>Hydrotaea dentipes</i>	X					
Diptera:Anthomyiidae	<i>Hylemya antiqua</i>	X					
Diptera:Anthomyiidae	<i>Paregle cineralla</i>	X			X		
Diptera:Anthomyiidae	<i>Phaonia querceti</i>	X	X				
Diptera:Calliphoridae	<i>Aldrichina grahami</i>			X			
Diptera:Calliphoridae	<i>Apaulina avium</i>			X			
Diptera:Calliphoridae	<i>Apaulina metallica</i>			X			
Diptera:Calliphoridae	<i>Apaulina sialia</i>			X			

Order:Family	Host species	Spa. cam.	Spa. end.	Nas. vit.	Mus. rap.	Mus. r-el.	Mus. zar.
Diptera:Calliphoridae	<i>Calliphora augur</i>			X			
Diptera:Calliphoridae	<i>Calliphora erythrocephala</i>			X			
Diptera:Calliphoridae	<i>Calliphora grahami</i>			X			
Diptera:Calliphoridae	<i>Calliphora oceaniae</i>			X			
Diptera:Calliphoridae	<i>Calliphora quadrimaculata</i>			X			
Diptera:Calliphoridae	<i>Calliphora stygia</i>			X			
Diptera:Calliphoridae	<i>Calliphora vicina</i>			X			
Diptera:Calliphoridae	<i>Calliphora vomitoria</i>			X		X	
Diptera:Calliphoridae	<i>Callitroga hominivorax</i>			X			
Diptera:Calliphoridae	<i>Callitroga macellaria</i>			X	X		
Diptera:Calliphoridae	<i>Chrysomya aenea</i>		X				
Diptera:Calliphoridae	<i>Chrysomya albiceps</i>		X	X			
Diptera:Calliphoridae	<i>Chrysomya chloropyga</i>			X			
Diptera:Calliphoridae	<i>Chrysomya macellaria</i>				X		
Diptera:Calliphoridae	<i>Chrysomya megacephala</i>		X	X	X		
Diptera:Calliphoridae	<i>Chrysomya putoria</i>	X	X	X			
Diptera:Calliphoridae	<i>Chrysomya rufifacies</i>			X			
Diptera:Calliphoridae	<i>Chrysomya varipes</i>			X			
Diptera:Calliphoridae	<i>Cochliomyia hominivorax</i>			X			
Diptera:Calliphoridae	<i>Cochliomyia macellaria</i>			X	X		
Diptera:Calliphoridae	<i>Hemilucilia flavifacies</i>		X				
Diptera:Calliphoridae	<i>Lucilia bufonivora</i>			X			
Diptera:Calliphoridae	<i>Lucilia caesar</i>			X			
Diptera:Calliphoridae	<i>Lucilia cuprina</i>			X			
Diptera:Calliphoridae	<i>Lucilia illustris</i>			X			
Diptera:Calliphoridae	<i>Lucilia pallescens</i>		X				
Diptera:Calliphoridae	<i>Lucilia sericata</i>		X	X			
Diptera:Calliphoridae	<i>Phaenicia eximia</i>			X			
Diptera:Calliphoridae	<i>Phaenicia mexicana</i>			X			
Diptera:Calliphoridae	<i>Phaenicia sericata</i>			X			
Diptera:Calliphoridae	<i>Phaenicia sericera</i>			X			
Diptera:Calliphoridae	<i>Phormia azurea</i>			X			
Diptera:Calliphoridae	<i>Phormia regina</i>			X	X		X
Diptera:Calliphoridae	<i>Phormia terraenovae</i>			X			
Diptera:Calliphoridae	<i>Pollenia stygia</i>			X			
Diptera:Calliphoridae	<i>Protocalliphora avium</i>			X			
Diptera:Calliphoridae	<i>Protocalliphora azurea</i>			X			
Diptera:Calliphoridae	<i>Protocalliphora metallica</i>			X			
Diptera:Calliphoridae	<i>Protocalliphora sialia</i>			X			
Diptera:Calliphoridae	<i>Protocalliphora sordida</i>			X			
Diptera:Calliphoridae	<i>Protophormia terraenovae</i>			X			
Diptera:Calliphoridae	<i>Pycnosoma rufifacies</i>		X	X			
Diptera:Chloropidae	<i>Hippelates collusor</i>	X					

Order:Family	Host species	Spa. cam.	Spa. end.	Nas. vit.	Mus. rap.	Mus. r-el.	Mus. zar.
Diptera:Drosophilidae	<i>Zaprionus indianus</i>		X				
Diptera:Glossinidae	<i>Glossina morsitans</i>			X			
Diptera:Hippoboscidae	<i>Pseudolynchia canariensis</i>			X			
Diptera:Muscidae	<i>Cyrtoneurina paraescita</i>			X			
Diptera:Muscidae	<i>Dendrophaonia querceti</i>	X					
Diptera:Muscidae	<i>Fannia canicularis</i>	X	X	X	X		X
Diptera:Muscidae	<i>Fannia femoralis</i>	X	X	X	X		
Diptera:Muscidae	<i>Fannia leucosticta</i>	X	X				
Diptera:Muscidae	<i>Fannia scalaris</i>	X	X	X			
Diptera:Muscidae	<i>Fannia trimaculata</i>	X					
Diptera:Muscidae	<i>Gymnodia cilifera</i>	X					
Diptera:Muscidae	<i>Gymnodia debilis</i>	X					
Diptera:Muscidae	<i>Haematobia exigua</i>		X				
Diptera:Muscidae	<i>Haematobia irritans</i>	X	X		X	X	
Diptera:Muscidae	<i>Lispe orientalis</i>			X			
Diptera:Muscidae	<i>Lyperosia exigua</i>	X	X				
Diptera:Muscidae	<i>Lyperosia irritans</i>	X	X				
Diptera:Muscidae	<i>Musca autumnalis</i>				X		
Diptera:Muscidae	<i>Musca domestica</i>	X	X	X	X	X	X
Diptera:Muscidae	<i>Musca sorbens</i>		X			X	
Diptera:Muscidae	<i>Musca stabulans</i>	X			X		
Diptera:Muscidae	<i>Muscina prolapsa</i>			X			
Diptera:Muscidae	<i>Muscina stabulans</i>	X	X	X			
Diptera:Muscidae	<i>Neomyia cornicina</i>	X	X				
Diptera:Muscidae	<i>Ophyra aenescens</i>		X	X			
Diptera:Muscidae	<i>Ophyra anthrax</i>	X	X				
Diptera:Muscidae	<i>Ophyra chalcogaster</i>		X				
Diptera:Muscidae	<i>Ophyra leucostoma</i>	X	X	X	X		
Diptera:Muscidae	<i>Ophyra nigra</i>			X			
Diptera:Muscidae	<i>Orthellia caesarion</i>	X					
Diptera:Muscidae	<i>Polietes lardaria</i>			X			
Diptera:Muscidae	<i>Stomoxys calcitrans</i>	X	X	X	X	X	X
Diptera:Muscidae	<i>Stomoxys calcitransid</i>	X					
Diptera:Muscidae	<i>Stomoxys niger</i>	X	X				
Diptera:Muscidae	<i>Synthesiomyia nudiseta</i>			X			
Diptera:Oestridae	<i>Gasterophilus intestinalis</i>			X			
Diptera:Otitidae	<i>Physiphora aenea</i>	X	X				
Diptera:Otitidae	<i>Physiphora demandata</i>	X					
Diptera:Piophilidae	<i>Piophila casei</i>			X			
Diptera:Sarcophagidae	<i>Agria affinis</i>			X			
Diptera:Sarcophagidae	<i>Bellieria mellanura</i>			X			
Diptera:Sarcophagidae	<i>Bercaea cruentata</i>			X			
Diptera:Sarcophagidae	<i>Coprosarcophaga haemorrhoidalis</i>	X	X				
Diptera:Sarcophagidae	<i>Peckia abnormis</i>			X			

Order:Family	Host species	Spa. cam.	Spa. end.	Nas. vit.	Mus. rap.	Mus. r-el.	Mus. zar.
Diptera:Sarcophagidae	<i>Ravinia assidua</i>				X		
Diptera:Sarcophagidae	<i>Ravinia querula</i>				X		
Diptera:Sarcophagidae	<i>Ravinia striata</i>	X	X				
Diptera:Sarcophagidae	<i>Sarcodexia sternodontis</i>			X			
Diptera:Sarcophagidae	<i>Sarcophaga barbata</i>			X			
Diptera:Sarcophagidae	<i>Sarcophaga bullata</i>			X		X	X
Diptera:Sarcophagidae	<i>Sarcophaga carnaria</i>			X			
Diptera:Sarcophagidae	<i>Sarcophaga crassipalpis</i>			X			
Diptera:Sarcophagidae	<i>Sarcophaga effrenata</i>		X				
Diptera:Sarcophagidae	<i>Sarcophaga impar</i>		X				
Diptera:Sarcophagidae	<i>Sarcophaga sueta</i>		X				
Diptera:Sciomyzidae	<i>Neottiophilum praeustum</i>			X			
Diptera:Sepsidae	<i>Sepsis neocynipsea</i>				X		
Diptera:Syrphidae	<i>Eristalis tenax</i>			X			
Diptera:Syrphidae	<i>Ornidia obesa</i>	X					
Diptera:Syrphidae	<i>Syritta pipiens</i>	X			X		
Diptera:Tachinidae	<i>Hubneria estigmenensis</i>			X			
Diptera:Tachinidae	<i>Omotoma fumiferanea</i>			X			
Diptera:Tachinidae	<i>Sturmia schineri</i>			X			
Diptera:Tephritidae	<i>Anastrepha alveatoides</i>		X				
Diptera:Tephritidae	<i>Anastrepha fraterculus</i>		X				
Diptera:Tephritidae	<i>Anastrepha ludens</i>		X				
Diptera:Tephritidae	<i>Anastrepha mombinpraeoptans</i>		X				
Diptera:Tephritidae	<i>Anastrepha obliqua</i>		X				
Diptera:Tephritidae	<i>Anastrepha sororcula</i>		X				
Diptera:Tephritidae	<i>Anastrepha suspensa</i>	X	X				
Diptera:Tephritidae	<i>Ceratitis capitata</i>		X		X		
Diptera:Tephritidae	<i>Ceratitis colae</i>		X				
Diptera:Tephritidae	<i>Dacus cucurbitae</i>	X	X				
Diptera:Tephritidae	<i>Dacus dorsalis</i>		X				
Diptera:Tephritidae	<i>Dacus ferrugineus</i>		X				
Diptera:Tephritidae	<i>Dacus passiflorae</i>	X					
Hymenoptera:Apidae	<i>Apis mellifera</i>			X			
Hymenoptera:Diprionidae	<i>Diprion pini</i>			X			
Hymenoptera:Diprionidae	<i>Neodiprion sertifer</i>			X			
Hymenoptera:Vespididae	<i>Dolichovespula saxonica</i>			X			

12.4 Appendix 4 Parasitoid hosts of parasitoid wasps

Parasitoid hosts reported for four species of three genera of parasitoid wasps (*Spalangia*, *Nasonia*, and *Muscidifurax*). Parasitoid hosts include species in the global range of the parasitoids and include species not found in Norway. The total number of parasitoid hosts ranged from 1-6 and up to 18 hosts for *N. vitripennis*. *M. raptorellus* and *M. zaraptor* had no reported parasitoid hosts in the database. *Source*: Biological associations for parasitoid hosts reported in the individual species accounts at UCD Community (2023).

Order:Family	Host Species	<i>Spa. cameroni</i>	<i>Spa. endius</i>	<i>Nas. vitripennis</i>	<i>Mus. raptor</i>
Total number of parasitoid hosts		2	6	18	1
Diptera:Sarcophagidae	<i>Agria housei</i>			X	
Diptera:Sarcophagidae	<i>Parasarcophaga argyrostoma</i>			X	
Diptera:Sarcophagidae	<i>Parasarcophaga dux</i>		X		
Diptera:Sarcophagidae	<i>Ravinia derelicta</i>	X	X		X
Diptera:Sarcophagidae	<i>Sarcophaga aurifrons</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga barbata</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga bullata</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga carnaria</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga crassipalpis</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga haemorrhoidalis</i>			X	
Diptera:Sarcophagidae	<i>Sarcophaga nodosa</i>			X	
Diptera:Sarcophagidae	<i>Seniorwhitea reciproca</i>		X		
Diptera:Tachinidae	<i>Diplostichus janithrix</i>			X	
Diptera:Tachinidae	<i>Exorista bombycis</i>		X		
Diptera:Tachinidae	<i>Exorista sorbillans</i>	X	X		
Diptera:Tachinidae	<i>Lydella stabulans</i>			X	
Diptera:Tachinidae	<i>Metagonistylum minense</i>		X		
Diptera:Tachinidae	<i>Sturmia sericariae</i>			X	
Diptera:Tachinidae	<i>Timavia fumiferanae</i>			X	
Diptera:Tachinidae	<i>Tricholyga bombycis</i>			X	
Diptera:Tachinidae	<i>Winthemia amoena</i>			X	
Hymenoptera: Braconidae	<i>Alysia manducator</i>			X	
Hymenoptera: Braconidae	<i>Phaenocarpa antipoda</i>			X	
Hymenoptera: Ichneumonidae	<i>Eulimneria alkae</i>			X	