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Stowaways in imported horticultural plants: alien and invasive species

- assessing their bioclimatic potential in Norway

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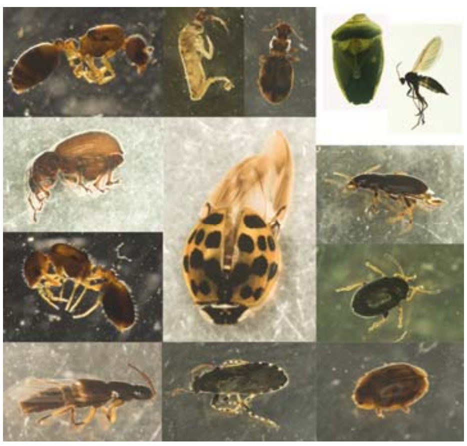

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1. Abstract

Dispersal of alien species, plant pests and other organisms through trade with living plants and plant parts increases with globalisation. Every year a significant amount of horticultural plants for use in urban landscapes and private gardens are imported to Norway from several other European countries. The last decade the amount of such import to Norway has doubled, while the resources allocated for phytosanitary control of this goods on arrival has not had a similar development.

Trees and bushes for outdoor use pose a special risk for carrying unwanted stowaways since they are mostly produced outdoors in the export country and are in addition frequently exported with a lump of soil from the production site. After arrival in Norway the plants are dispersed quickly to all parts of the country where they are sold to private and official buyers. The quick handling of this material makes it easy for an organism to stay alive and have the opportunity to establish in the new environment.

A study was carried out in 2006 to aiming to find out more about this trade, particularly emphasizing on identifying species of insects and arachnids that were suspected to pass through the national control system. Mattilsynet, the Norwegian Food Safety Authority, is the National Plant Protection Organization of Norway, and perform random sampling of imported plant commodities of this type. Unfortunately, there is practically no surveillance on the introduction of species that are not on the quarantine pest list, and the standard control routines fail in detecting and rejecting plant commodities that contain non-quarantine species.

In this study it was mainly searched for insects and arachnids, but snails and slugs, millipedes and other organisms were also found. The plant species sampled were mostly conifers, of which *Thuja* sp. and *Taxus* sp. were the majority. Conifers turned out to be excellent in providing shelter and hiding places for small organisms. Three sampling methods were used: 1. Shaking method, 2. Visual observation and 3. Sampling of the compost fallen off the consignments during the transport. The last method added most species to the list. In only six samples of compost investigated as much as 93 different species were identified. During a short period of sampling 1193 individuals were collected travelling as stowaways mainly from Germany, Denmark and the Netherlands. 156 species were identified and additional 26 organisms were identified to the genus level.

Among the 156 species recorded as much as 15 species turned out to be new to the Norwegian fauna: *Epitrix pubescens* Koch (Chrysomelidae), *Semiophonus signaticornis* Duftschmid (Carabidae), *Cartodere bifasciata* Reitter (Latridiidae), *Rhyzobius chrysomelides* Herbst (Coccinellidae), *Harmonia axyridis* Pallas (Coccinelidae), *Quedius scintillans* Gravenhorst (Staphylinidae), *Temnothorax unifasciatus* Latreille (Formicidae), *Temnothorax crassispinus* Karawajew (Formicidae), *Heterogaster urticae* Fabricius (Lygaeidae), *Piezodorus lituratus* Fabricius (Pentatomidae), *Orchesella quinquefasciata* Bourlet (Entomobryidae), *Chaetosciara estlandica* Lengersdorf (Sciaridae), *Lathys humilis* Blackwall (Dictynidae), *Brachyiulus pusillus* Leach (Julidae) and *Ectopsocus petersi* Smithers (Psocoptera). One more species might soon be added to the list of new species when the identification of several specimens of *Otiorhynchus* sp. (Curculionidae) is completed.

A general assessment of the bioclimatic potential for organisms imported from the Netherlands and Germany was conducted by the aid of CLIMEX. CLIMEX is a dynamic climate matching- and climate response estimation model, which predicts potential distribution of an organism. The results show that organisms imported from Aalsmeer in the Netherlands have a reasonable good chance of establishing a population in the southern parts of Norway based on the similarity of climatic parameters, and that organisms imported from Rellingen in Germany have an even greater potential for successful establishment in Norway.

One of the new species recorded was *Harmonia axyridis* Pallas, which is chategorized as an invasive alien species. This species has shown a great potential for adaptation to new areas, and is therefore considered as a possible threat to the biological diversity in Norway.

An assessment of *H. axyridis'* bioclimatic potential in Norway, Europe and worldwide was performed in three steps. Step one was to compare the climate in its area of origin with the climate in Norway and Europe. For this comparison the Match Climates function in CLIMEX was used and four native locations for *H. axyridis* were chosen (Gongshan in southern China (25ºN and 103ºE), Vladivostok in the far East of Russia (43ºN and 134ºE), Chita in Russia (52ºN and 113ºE), and Fang'ao in eastern China (27ºN and 120ºE)). Based on the analysis conducted here the climatic conditions in several parts of Norway are within the range of bioclimatic requirements for *H. axyridis* originating from Chita, and partly also from Vladivostock, to allow the species to establish in Norway.

Step two, was to develop specific climate response parameters for *H. axyridis* to be able to carry out a more sophisticated analysis for this species than the general analysis in step one. For the present study, two sets of climate response parameters for *H. axyridis* was developed. One is based on the requirements for a French population while the other is based on the requirements for a population from Oregon (USA). The subsequent predictions produced by the CLIMEX model (Compare locations) when running the two parameter sets gave quite different ecoclimatic indices (EI), or potential world distribution maps, for the two populations of *H. axyridis*: The Oregon population is clearly adapted to tropical and subtropical climates, while the French population showed a more limited distribution. The results obtained ruled out several countries in Europe where *H. axyridis* is known to occur, i.e. Belgium, The Netherlands, Germany, Luxemburg and UK, which leads to the conclusion that the species has developed sub-populations with rather different climatic requirements than the once tested here.

Step three, was to produce ecoclimatic indices (EIs) for both the French population and the population from Oregon of *H. axyridis* in Norway based on Norwegian agrometeorological data. (The agrometeorological data is more representative for agroecological zones, private gardens and urban areas in Norway than the more general meteorological data stored in CLIMEX.) The two sets of climatic parameters developed for *H. axyridis* was used and the CLIMEX model (Compare locations) run both under "current climate scenario" and under "greenhouse climate scenario" for the two respective populations.

The climate in Norway can be roughly divided into two climatic subzones. The western subzone is characterised by cool summers and mild winters, and most of the precipitation comes during autumn. The eastern subzone is characterised by warm summers and relatively low winter temperatures, and most precipitation comes during summer.

Model predictions for *H. axyridis* gave different EIs under current climate scenario for both populations of the species when applying agrometeorological data from 47 locations in Norway compared to the results obtained in step two above. The predicted EIs for the French population of *H. axyridis* were in the range 0-11, while the predicted EIs for the population from Oregon were in the range 0-13. This indicates that the current climate in Norway is not optimal for general establishment of the species, but that suboptimal microclimates for the species most certainly can be found at protected locations particularly in the coastal areas of the south-west. This confirms the initial idea that coldstress (winter temperatures) is a limiting factor for the species at higher latitudes.

Model predictions for *H. axyridis* under a Norwegian "greenhouse climate scenario" gave increased EIs for both populations of the species compared to the current climate scenario. It was, however, still only locations along the coastal area of western Norway that showed EIs above zero. The predicted EIs for the French population of *H. axyridis* were in the range 0-18, while the predicted EIs for the population from Oregon were in the range 0-22. This indicates that the greenhouse climate scenario for Norway is close to optimal for establishment of the species at some locations, and that suboptimal and optimal microclimates for the species will be available at protected locations in southern Norway.

The rapid spread of *H. axyridis* in Europe and elsewhere points to the conclusion that this is a species with extreme ecological plasticity. The presence of *H. axyridis* is confirmed in northern parts of USA and southern Canada where minimum air temperatures can exceed the species' minimum supercooling points (-27ºC til -12ºC depending on developmental stage), which should be lethal to the species. *H. axyridis* adults most likely find microclimates for overwintering that provide protection from extreme low temperatures. It is likely to conclude that *H. axyridis* is a species with a great capacity for adaptation and will continue to adapt to new climatic conditions and thereby continue to increase its distribution into new geographic areas.

Due to globalization alien species are spread with a speed that we have never seen before, and Norway being no exception in this context. The study and results reported here shows that the steadily increasing import of horticultural plants is a groing threat to biodiversity and a number of organisms are imported as stowaways in connection to this trade. In addition, it may cause problems for the domestic plant nursery industry as new plant pests also can be among these organisms. Such pests may as well pose problems for the management of parks, public areas, and private gardens, and eventually be the cause of increased pesticide use. Climate change will only accelerate these changes in northern latitudes.

In Norway, the National Plant Protection Organisation, Mattilsynet, is responsible for controlling the import of these plants. However, the control is not sufficient to avoid the spread and introduction of new species and the experiences from our investigation suggests that we have only seen the tip of the iceberge.

Norway now has a national strategy to combat harmful alien species and it is only to hope that this strategy is carried forward to action immediately.

2. Norsk sammendrag

Det importeres i dag en lang rekke planteslag til Norge som skal ut i grøntanlegg eller til videre dyrking i norske planteskoler. Men det fins ingen god oversikt over hva slags materiale som kommer inn eller hvilke organismer som kan følge med plantesendingene. Bevegelsen av plantemateriale internasjonalt og inn til Norge er uoversiktlig. Det samme gjelder den videre distribusjon av varene innenlands.

For å få mer innsikt i og et mer nyansert bilde av denne situasjonen ble det i januar 2006 satt i gang et masteroppgavearbeid som resulterte i avhandlingen med tittel: "Fremmede arter og andre uønskede blindpassasjerer i import av grøntanleggsplanter" (Staverløkk, 2006).

I dette arbeidet ble det avdekket at det er en god del organismer som følger med importerte grøntanleggsplanter. Det ble tatt prøver av ulike importerte planter, hovedsaklig *Thuja* sp. og *Taxus* sp., og en god del organismer ble funnet (cirka 1200 insekter, edderkoppdyr og andre grupper). Identifiseringsarbeidet var omfattende og ble gjennomført med økonomisk støtte fra Norsk Garnerforbunds' FoU-fond.

Under feltarbeidet ble det tatt 27 prøver fordelt på tre metoder; visuell observasjon, ristemetoden og innsamling av oppsop fra gulv i containere. Ved innsamling av oppsop og strø fra 6 containere ble det identifisert hele 93 arter. I alt ble 160 arter av insekter og edderkoppdyr registrert hvorav 15 av disse var nye for Norge: *Epitrix pubescens* Koch (Chrysomelidae), *Semiophonus signaticornis* Duftschmid (Carabidae), *Cartodere bifasciata* Reitter (Latridiidae), *Rhyzobius chrysomelides* Herbst (Coccinellidae), *Harmonia axyridis* Pallas (Coccinelidae), *Quedius scintillans* Gravenhorst (Staphylinidae), *Temnothorax unifasciatus* Latreille (Formicidae), *Temnothorax crassispinus* Karawajew (Formicidae), *Heterogaster urticae* Fabricius (Lygaeidae), *Piezodorus lituratus* Fabricius (Pentatomidae), *Orchesella quinquefasciata* Bourlet (Entomobryidae), *Chaetosciara estlandica* Lengersdorf (Sciaridae), *Lathys humilis* Blackwall (Dictynidae), *Brachyiulus pusillus* Leach (Julidae) og *Ectopsocus petersi* Smithers (Psocoptera). Enda en art vil sansynligvis snart bli plusset på listen av nye arter da flere individer av en snutebille fortsatt er under identifisering (*Otiorhynchus* sp. (Curculionidae)).

I denne rapporten blir det redegjort for de nye artene som ikke er registrert i Norge tidligere. En generell vurdering av det bioklimatiske potensialet for organismer importert fra Nederland eller Tyskland ble foretatt ved hjelp av CLIMEX. Resultatene viste at organismer importert fra Aalsmeer i Nederland har et rimelig godt utganspunkt for å etablere seg i de sørlige deler av Norge (basert på klimatiske kriterier), og at organismer fra Rellingen i Tyskland har enda bedre mulighet for etablering her til lands.

En av de nye artene som ble funnet var marihøna *Harmonia axyridis* Pallas. Arten er opprinnelig fra Asia og ble tidligere introdusert i flere land for bruk i biologisk kontroll. i Norge ble en søknad om bruk av denne predatoren i biologisk kontroll avslått av Mattilsynet i 2001 med begrunnelsen: "*Fare for etablering*". Marihøna har vist seg å være en invaderende art i flere land og kan tenkes å kunne etablere seg også i Norge. Negative konsekvenser av arten er at den er i stand til å utkonkurrere andre bladluspredatorer, spise sommerfuglegg og aggregerer i stort antall på/inni husvegger på leting etter et sted å overvintre. Den har blitt et problem i vinproduksjon i USA og gjør skade på frukt senhøstes.

En vurdering av det bioklimatiske potensialet for *H. axyridis* i Norge, Europa og globalt ble foretatt som en tre-stegs prosess ved hjelp av ulike funksjoner i CLIMEX. Det første steget var å foreta en klimatisk sammenligning mellom fire av opprinnelsesområdene til arten og klimaet Norge og Europa. De fire områdene var Gongshan i Sør-Kina (25ºN og 103ºE), Vladivostok i østlige deler av Russland (43ºN og 134ºE), Chita i Russland (52ºN og 113ºE), og Fang'ao i østlige Kina (27ºN og 120ºE)). Resultatene av analysen viste at de klimatiske forholdene i flere deler av Norge er innenfor de klimatiske kravene til populasjoner fra Chita, og delvis populasjoner fra Vladivostock, og at arten derfor trolig kan etablere seg i Norge.

Steg to var å utvikle et sett av klima-response parametre for *H. axyridis* for å kunne foreta en mer sofistikert analyse enn analysen i steg en. To ulike parameter sett ble utviklet, det ene basert på klima krav for en fransk populasjon av arten, mens det andre settet var basert på klimakravene til en populasjon fra Oregon (USA). De to parametersettene ga svært ulike resultater da de ble kjørt i CLIMEX modellen "Compare locations". Den økoklimatiske indeksen (EI) estimert av modellen ga to ulike potensielle globale utbredelseskart for de respektive populasjonene av *H. axyridis*: Populasjonen fra Oregon er tilpasset et tropisk eller subtropisk klima, mens den franske populasjonen hadde en mye mer begrenset utbredelse. Begge disse resultatene utelukket flere lokaliteter i Europa der *H. axyridis* er bekreftet utbredt, for eksempel Belgia, Luxenburg og Storbrittania, noe som tyder på at arten har utviklet subpopulasjoener med andre krav til klima enn de to populasjonene vi testet her.

Steg tre var å produsere EI for både den franske og den amerikanske populasjonen av *H. axyridis* for Norge basert på landbruksmeteorologiske data. Disse klimadataene anses å være mer representative for landbruksområder, private hager og bynære strøk i Norge enn de mer generelle meteorologiske data som CLIMEX operer med. Klimakravene for både den franske og den amerikanske populasjonen ble kjørt i CLIMEX (Compare locations) mot dagens klimaforhold her til lands og under et fabrikert "greenhouse climate scenario".

Klimaet i Norge kan grovt sett deles i to klimatiske subsoner. I vest er klimaet karakterisert av kjølige somrer og milde vintre, og mesteparten av nedbøren kommer om høsten. i øst er klimaet karakterisert ved varme somrer og forholdsvis kjølige vintre, og mesteparten av nedbøren kommer om sommeren.

Modellens estimeringer ga ulike EI for Norge for begge populasjonene ved bruk av landbruksmeteorologiske klimadata fra 47 lokaliteter i Norge enn det som var estimert i steg to. Estimerte EI under dagens norske klima for den franske populasjonen av *H. axyridis* var fra 0-11 mens resultatene for den amerikanske var 0-13. Dette indikerer at dagens klima ikke er optimalt for en generell etablering av denne arten her, men at suboptimale mikroklima nokså sikkert vil finnes på beskyttede steder særlig lang fjordstrøkene på vestlandet. Disse resultatene bekreftet den opprinnelige ideen om at kuldestress var en begrensende faktor for etablering av *H. axyridis* ved høyere breddegrader.

Et norsk "greenhouse scenario" ga som ventet økte EI for begge populasjonene sammenlignet med dagens klima. Det var likevel fortsatt bare lokaliteter på vestlandet og delvis sør-Helgeland der EI kom over null. De estimerte EI for den franske populasjonen var 0-18, mens EI for den amerikanske populasjonen var 0-22. Dette indikerer at ved en klimaøkning i Norge på +1ºC vil flere lokaliteter være optimale klimatisk sett for etablering av *H. axyridis*, og lokaliteter med suboptimale til optimale klimaforhold vil finnes i hele sør-Norge.

Den raske spredningen av *H. axyridis* i Europa og andre steder i verden viser at dette er en art med ekstrem økologisk plastisitet. Arten er også bekreftet etablert i områder i nordlige deler av USA og sørlige Canada der minimums temparaturen kan væreunder den kritiske temperaturen som *H. axyridis* er rapportert å tåle (supercooling point) (-27ºC til -12ºC avhengig av utviklingsstadium), og disse temparaturene er derfor dødelige. Man vet at denne arten er flink til å søke beskyttede steder for overvintring der temperaturene sansynligvis ikke er så lave som de generelle målingene i luft tilsier. Det er likevel grunn til å konkludere at H. axyridis er en art med stor kapasitet for tilpasning og at den vil fortsette å tilpasse seg stadig nye klimatiske forhold og dermed øke sitt geografiske utbredelsesområde ytterligere.

Den stadig økende globaliseringen medfører at fremmede arter spres med en hastighet som vi aldre har sett tidligere, og Norge er ikke noe unntak i så henseende. Denne rapporten viser at den stadig økende importen av grøntanleggsplanter utgjør en stadig større trussel mot biodiversitenen og at et utall organismer følger med denne handelen som blindpassajerer. En slik import avlevende organismer kan også medføre problemer for den innenlandske produskjonen i form av nye skadegjørere. Slike nye skadegjørere kan også føre til problemer i parker, grøntanlegg og private hager, og til slutt være årsak til en økt bruk av plantevernmidler. En klimaendring vil bare aksellerere en slik utvikling på nordlige breddegrader.

I Norge er det Mattilsynet som er ansvarlig for å kontrollere denne typen import. Dagens kontroll er ikke god nok til å unngå en stadig introduksjon av nye arter, og erfaringene fra denne undersøkelsen tyder på at vi bare har sett toppen av isfjellet.

Norge har nylig fått en nasjonal strategi mot fremmede skadelige arter, og man kan bare håpe at denne strategien umiddelbart blir satt ut i handling.

3. Introduction

3.1 Alien species and invasive alien species

Alien species are non-indigenous species that are spread by human activities to areas where they naturally do not belong. The exchange rate of biological material across biogeographic barriers that have separated continents for millions of years has been extremely slow until very recently. Similarly, climate has been rather constant in recent millennia. However, both climate change, as driven by the changing composition of the atmosphere, and the large scale intercontinental movement of biological material have greatly accelerated in recent times (Mooney 2005).

Among the numerous non-indigenous species that are continously transferred by trade, tourism, transport and travel only a few become invasive alien species which are recognised as one of the leading threats to biodiversity. (An invasive species can be defined as non-native to the ecosystem and whose introduction causes or is likely to cause harm to the economy, environment, or human, animal, or plant health. An invasive species can be plants, animals, and other organisms such as microbes.) In addition to being a threat to natural ecosystems they also impose an enormous cost on agriculture, forestry, fisheries, and other human enterprises, as well as on human health. The ways in which non-indigenous species affect native species and ecosystems, are numerous and usually irreversible. The impacts are sometimes massive but often subtle. Introduced species often consume or prey on native ones, overgrow them, infect or vector diseases to them, compete with them, attack them, or hybridise with them. Invaders can change whole ecosystems by altering hydrology, fire regimes, nutrient cycling, and other ecosystems processes (Wittenberg & Cock 2001).

Often the same species as are threatening biodiversity also cause grave damage to various natural resource industries. Invading non-indigenous species in the United States causes major environmental damages and losses adding up to more than $138 billion per year (Pimentel et al. 1999). Several introduced species cause problems for the Norwegian agricultural and horticultural production, like for instance the Western flower thrips (*Frankliniella occidentalis* (Pergande) and Potato late blight (*Phytopthora infestans*) (Sæthre et al. 2006).

In the USA approximately 50,000 foreign species are known and the number is increasing (Pimentel et al. 1999). About 42% of the species on the Threatened or Endangered species lists in the US are at risk primarily because of non-indigenous species. In Norway only 10 endangered species or Red list species, are thought to be adversely affected by alien species (Kålås et al. 2006). However, that number may be underestimated since it is difficult to identify the causes and so far few investigations have been carried out. In other regions of the world, particularly in tropical areas and islands, as many as 80% of the endangered species are threatened due to the pressures of non-native species. Many other species worldwide that are not listed are also negatively affected by alien species and/or ecosystem changes caused by alien species.

Alien species may enter a new continent, region or country in different ways (Wittenberg & Cock 2001):

- Natural dispersal (new species arriving new areas by their own movement)
- With human help
    - Intentional introductions
    - Unintentional introductions

Intentional introductions: plants introduced for agricultural or forestry purposes; fish, birds and mammals released for fishing and hunting purposes; releases to "enrich" the native flora and fauna; organisms introduced for biological control; and others.

Unintentional introductions usually happens when organisms manage to cross natural barriers as stowaways: contaminants of agricultural produce; seed and invertebrate contamination of nursery plants and cut flowers; soil inhabiting species by shipping soil or soil attached to plant material; machinery, equipment, military; ballast water of ships; and similar.

3.2 National strategy to combat harmful alien species

Eleven years after the 1996 Norway/United Nations Conference on Alien Species held in Trondheim, the Minister of Environment, Helen Bjørnøy, launched on 31 of May 2007 Norway's first national strategy against alien species (*"Tverrsektoriell nasjonal strategi og tiltak mot fremmede skadelige arter"*). The Minister said that the goal of the Government is to stop loss of biodiversity within 2010. She added that the battle against harmful alien species can only succeed if necessary measures are implemented and action is taken in all the different sectors that contribute to introductions and spread of alien species.

The national strategy is based on three main pillars:

1. *"Forebygge introduksjon (Prevent introduction). Når en fremmed art først er etablert i norsk natur, er bekjempelse både vanskelig og dyrt. Det aller viktigste er å forebygge at nye arter kommer inn. Strategien varsler derfor forbedret lovverk, styrket kontroll og utstrakt informasjon om miljøtruslene fra fremmede arter."*
2. *"Fjerne etablerte problemarter (Eradicate established harmful species). Det er et mål å fjerne fremmede skadelige arter fra norsk natur der dette er praktisk mulig. Regjeringen har i revidert statsbudsjett bevilget ytterligere 21 millioner kroner til styrket kamp mot lakseparasitten Gyrodactylus salaris og bekjempelse av signalkreps i Telemark. Overvåkningen av fremmede arter skal styrkes for å muliggjøre raske tiltak. Det skal utarbeides egne handlingsplaner for utvalgte etablerte problemarter."*
3. *"Begrense spredning og skade (Limit further spread and damage). I tilfeller der fjerning av en fremmed skadelig art ikke er hensiktsmessig eller mulig, vil innsatsen rettes mot å begrense spredning og skadevirkninger."*

3.3 Import of horticultural plants to Norway

In Norway, the import of horticultural plants for outdoor use and for further cultivation in plant nurseries has doubled between 1997 and 2005 (NGF, 2006). The driving force for this steadily growing business is likely to be a result of the general increased wealth in the Norwegian society and the trend of decorating our urban areas and private gardens to a much larger extent than previously done. Another factor driving this import is also the fact that plants produced in other countries (outside Norway) is more competitive on price compared to the domestic production. As a result import of plants has become a rather big industry.

This steadily increasing import to Norway gave fuel to the hypothesis that a possible side effect of this trade is unintentional introductions of alien species and possibly also invasive alien species. In addition to introducing non-native species there is a possibility of introducing individuals from populations of species that are indigenous to Norway, but which may possess other traits and properties than the native populations. Many of the plants imported for outdoor use are grown in the field for one to several years in other parts of Europe (or elsewhere). These plants therefore become part of the site-specific-ecosystem where they are grown and they may serve as host plants, refugee sites and habitats for organisms native to that specific location. In addition, many of the plants exported are grown directly in the fields and they are imported with a lump of the soil from the production site. Soil-living organisms and organisms with stage(s) of its lifecycle in soil are likely to be in the soil at the time of exportation. For some plant species the demand is so high that they are not even produced in the normal way in a plant nursery, but are literally taken out of a natural forest and exported immediately.

This may particularly be the case for certain tree species that are scarce in the market, or when the customers in Norway demand to have a rather big tree right away and do not have the patience to wait and watch the tree grow taller and bigger every year.

In light of the above the assumption was reached that unintentional introductions of biological organisms are very likely to happen in connection with this trade and that these organisms are spread and dispersed between and within countries, as unwanted stowaways following these plant commodities. To test our hypothesis a study was carried out in 2006 aiming to detect possible stowaways and to get an overview of the trade pattern and the phytosanitary control mechanisms involved in this business. Samples were taken from consignments with horticultural plants newly imported from different countries in Europe. In addition, information about phytosanitary control routines and general information about the trade was gathered as part of a master thesis (Staverløkk 2006).

3.4 Bioclimatic potential

It has long been recognized that the distribution of poikilothermic animals is largely determined by climate (Andrewartha & Birch 1954). Climate also to a large extent determines the distribution of host plants, and thereby indirectly influences the distribution of phytophageous insects. Because of that climate will strongly influence the distribution of organisms from all trophic levels in an ecosystem: the distribution of predators, parasitoids, and hyperparasitoids, is determined by the distribution of the preys and hosts that they depend on as food source(s), and so on.

Assessing the bioclimatic potential for an organism, or in other words its innate capacity to maintain a population in an area, in a country or a region, may provide important information either on the establishment potential of exotic organisms or for the management of native or immigrant organisms. Two basic approaches are used for assessing an organisms bioclimatic potential: bioclimatic analysis and laboratory assessment (Meats 1989). Laboratory assessment is based on biological experiments with the target organisms itself and the results obtained in the laboratory is used to predict the species response to the natural environment. Bioclimatic analysis in its original form was based on a comparison of climatic conditions in areas where the pest was known to occur with conditions in the uninfested area under study (Cook 1929, Nash 1933). The latter approach has evolved to a whole class of models for bioclimatic analysis (Sutherst et al. 1995). These models can be applied at a lower cost and they are less time-consuming than laboratory assessments. However, the outcome of using models become more reliable when data from laboratory assessments or other biological and ecological information about a species is available and can be used as input data in the model.

In the past, assessment of bioclimatic potential for a given species has been frequently applied in connection with known plant pests and particularly when dealing with plant quarantine pests and international trade for assessing the risk of spreading such pests from one country to another. However, the same approaches can also be applied for any other organism of interest. In this report, we have used bioclimatic analysis (CLIMEX) to assess the bioclimatic potential in Norway for an invasive alien species, *Harmonia axyridis* Pallas 1773, and as a tool to increase our general knowledge about alien species that enter Norway as stowaways on horticultural plants from two other European countries and these organisms' potential for establishment in the new area.

4. Materials and Methods

4.1 Sampling of imported plants

The sampling was conducted in collaboration with the Norwegian Food Safety Authority (Mattilsynet) and one of the importing plant nurseries (Rustad Planteskole). It was emphasized that sampling was carried out at the time of, or very shortly after, arrival of the individual consignments. The geographic areas for our investigations were Akershus county and Oslo, which are the biggest import area of such goods into Norway. Most samplings were carried out during April and May 2006 (peak import season), while a few were conducted in August 2006.

The initial plan for this study was to carry out the investigations throughout an entire import season that is from about April till approximately October. By doing so, we expected to have a complete picture of the different organisms entering the country as stowaways in connection with this trade. However, it became evident that it was not possible to continue the collections at the same speed because handling of the material (particularly the identification part) became too timeconsuming and it was decided to stop the investigations earlier than originally planned.

Three different methods were used: 1. Shaking method (on the spot), 2. Visual detection (on the spot), and 3. Collecting soil and other organic material that had fallen off the consignments during transport (further investigations in the laboratory).

Shaking method

Method 1 was carried out by holding the plants above a piece of white A3-paper, while shaking it with the other hand and carefully hitting the branches. The organisms that fell down to the paper were then quickly collected by the aid of an “exhauster”. The number of plants shaken during each sampling varied between 5-10 of the same plant species or variety. The 5-10 plants in a sample were all from the same consignment. Quite a lot of organisms fell off the plant while shaking, and to obstruct them from running away/escaping, it was mainly focused on collecting as much as possible and not trying to separate the different organisms on the spot. With the exception of the largest specimens, all organisms from one sample where therefore put in the same glass, and separated later.

Visual observation

Method 2 was performed by a visual inspection, using the naked eye, of the plants and subsequent collection of the insects and larvae discovered during this inspection. This method was used on larger plants where shaking was impossible due to the size and weight of the plants. There were also some practical reasons for using this method. In several cases the different plants in a container/truck had different destinations which made it difficult to sample them by other methods than visual inspection (unless unloading the whole container/truck). Plants may also be loaded into the truck in a way that makes other methods impossible unless the entire load is unloaded and unpacked. For instance, pallets with plants may be covered with plastic for easier handling.

Sampling the organic material and compost

Method 3 was carried out by collecting compost, soil and whatever organic material that had fallen off during the transport. This material could be found at the bottom of the containers as they were unloaded. The material was collected using a big brush, put in plastic bags and brought to the laboratory for further investigation. The material was then studied using magnifying glass and tweezers and organisms found inside were picked out and taken care of.

Handling of the material after sampling

The material was brought to the laboratory in Ås for separation and handling of individual organisms. The specimens found were separated individually or in groups, put in tubes, preserved in 70 % alcohol, and properly labelled, all at the same day of collection. A database containing all information about each sample, including information written on the plant certificate such as certificate number, place of origin, exporting/importing entity, and so on, was created. Some materials, like larvae and cocoons, were set aside in an attempt to incubate them. This would make identification easier, but in most cases this failed. The material was further categorized into their respective taxonomic orders and identified by different experts from Norway, Sweden and the UK.

4.2 Species Information

More than 150 species were identified from the material collected in this study (see results and discussion, and Appendix 1). In this report, however, we have emphasized on presenting information about the 15 species found to be new to the Norwegian fauna. Several of the species new to Norway recorded in this study are only very briefly described in the literature. In several cases the literature available to the authors is for instance only records of a specific species, while very little information is available regarding biology, ecology, species distribution, and so on. As a result, we were left with quite unsufficient information regarding several of the species new to Norway. For this reason we were not able to make proper assessments of the ecological risks associated with the interceptions/introductions recorded. This situation is, however, rather common when dealing with biological introductions: The information needed for assessing an alien species may be scarce, difficult to locate and even unavailable. For those species where information was difficult to find, we could only provide the most basic information about the species, and in some cases we were able to locate information about the genus or family level only.

4.3 Assessment of bioclimatic potential - CLIMEX

CLIMEX is one of several similar software tools developed for bioclimatic analysis. The CLIMEX software (CLIMEX Version 3) contains two quite different climate-matching tools (Sutherst et al. 2004). One is a generic model of organism's response to climate ("CLIMEX model"), while the other is for comparing meteorological data of different places without reference to any particular species ("Match Climates" function). In this report both the Match Climates function and the CLIMEX model (Compare Locations) have been applied.

<u>The CLIMEX model</u> attempts to mimic the mechanisms that limit species' geographical distributions and determine their seasonal phenology and to a lesser extent their relative abundance (Sutherst et al. 2004). The model enables the user to estimate the potential distribution and seasonal abundance of a species in relation to climate. CLIMEX is applied to a species by selecting a set of parameters that describe its response to temperature, moisture and light. The model generates an annual growth index (GI), 'describing the overall potential for population growth', generated by weekly indices of temperature (TI), moisture (MI), day length (LI) and diapause (DI), summed and averaged to give the annual GI. The annual GI is combined with four stress indices (representing hot, cold, wet and dry weather) to produce an ecoclimatic index (EI), describing "the overall suitability of the location for the propagation and persistence of the species"

The two indices predicted by the CLIMEX model are scaled between 0 and 100 where 100 express optimal conditions for the growth and ecoclimatic potential of the species and 0 the lover limit, where no growth can occur and where ecoclimatic conditions do not support persistence of a population of the species. As the climate of a given area is hardly constant and ideally suited to any species, the EI very rarely approaches a value of 100. An EI of more than 30 represents a very favourable climate for the long-term survival of the species (Sutherst et al. 2004).

The Match Climates function is a much less sophisticated tool than the CLIMEX model, but can be very useful when little or no information is available about a species, as was the case with several of the species described in this report (see section 5. Results and discussion). The Match Climates analysis can be conducted with no knowledge of the species, except that it does occur in certain locations. Thus, if there are no biological data or distribution map of the species, the Match Climates analysis enable the user to qualitatively assess the risk of establishment of the species in a new area (Sutherst et al. 2004).

Agrometeorological data

The meteorological data stored and used by CLIMEX is based on official recordings in each country for the period 1961-1990. For Norway the location of these stations reflects the topography in the country very well, i.e. some stations are in the mountains, some are close to the North Sea or in other very exposed areas. For this reason the typical agroecological zones in Norway are not so well represented in the CLIMEX database. The topography in Norway is very different from for instance the topography in the Netherlands from where several of the alien species were introduced from, and therefore Norwegian agrometeorological data was included as additional input in CLIMEX. The species' of concern (Appendix 1) are introduced to private gardens and urban areas which have a climate more comparable to agricultural fields than to for instance the mountains and other very exposed locations.

To meet the requirements mentioned above, additional data from the network of automatic agrometeorological stations (run by Bioforsk since 1987) was transferred into the CLIMEX database. This network consists of 52 standard meteorological stations placed in rural districts all over the country (between 58°N and 69°N and between 8°E and 30°E) (Sivertsen 2000). The stations are placed near or within orchards and agricultural fields, and are equipped with Campbell loggers. Most of the figures recorded are hourly mean values of the parameters in Central European Time (CET), and the data are collected and stored in a database on a daily basis (Sivertsen 2000).

For the study presented here it was decided to only use data from stations that had been operational at the same location for the period 1997-2006 (Appendix 3). The selection criteria used in this study ensured similarity between and within each dataset (10 years) for the respective 47 locations used for this study. The data required for input in CLIMEX are monthly average values of five variables: average maximum daily temperature, average minimum daily temperature, average monthly rainfall, and average daily relative humidity at 09.00 and 15.00 hours.

The data described above were used when running the CLIMEX model in 5.13, while for running the Climex model in 5.12 and when using the Match Climates function (5.10 and 5.11) the data available in CLIMEX (period 1961-1990) were used.

Greenhouse scenario

In connection with 5.13 ("Ecoclimatic indices for two populations of *H. axyridis* in Norway") a greenhouse scenario was created to predict how a possible climate change (increased temperature) would influence on the potential for establishment of *H. axyridis* in Norway. The greenhouse scenario was created by using the Norwegian agrometeorological data described above and adding +1ºC to the average minimum and maximum daily temperatures. We did not change any other parameters for input in the CLIMEX model. The CLIMEX model were run both under "current climate" and under "greenhouse scenario climate" for two populations of *H. axyridis*, one from France and one from Oregon (see below for explanations of differences between the two populations).

Climate response parameter fitting for *Harmonia axyridis* Pallas, 1773

For each individual species the inputs required in CLIMEX to run the CLIMEX model are one set of climate response parameter values. For some common pests such values are already available in the manual of the system, but for *H. axyridis* no set of climate response parameters existed. Parameter fitting was therefore performed by consulting different sources of biological and ecological information on *H. axyridis*, such as published reports (Schanderl et al. 1985, LaMana & Miller 1998, Iperti & Bertand 2001, Watanabe 2002, Soares et al. 2003, Koch et al. 2004, Honek et al. 2007) and by following the CLIMEX manual for parameter fitting (Sutherst et al. 2004).

Temperature has often been found to be the main factor limiting the distribution, abundance and number of generations of insect species at higher latitudes, including Norway (Rafoss & Sæthre 2003, Sæthre & Hofsvang 2005). When fitting the parameters for *H. axyridis* it was evident that the most critical CLIMEX parameters for this species are the lower temperature threshold for development, the lower optimal temperature for population growth and cold stress.

H. axyridis is a species that has been introduced and established in many parts of the world far outside its geographic area of origin, and it continuous to spread to new areas at a high speed. When going through the literature regarding this species, indications were found that pointed to the conclusion that it is likely that certain adaptations to new environments have taken place in individual populations of *H. axyridis* in different parts of the world: For instance, Lamana & Miller (1998) reported that the lower development threshold for *H. axyridis* in Oregon (in the Pacific Northwest region of the United States) was 11.2°C and that a sum of 267.3°C degree-days (DD) was required for the species to complete one generation there, while Schanderl et al. (1985) reported 231.3 DD above 10.5°C to be the requirements for a French population of the species.

H. axyridis is probably not yet established in Norway and the chance of an introduction through plants and consignments from a European country is higher than an introduction from overseas (USA) or South East Asia. For the species to become established in Norway a lower development threshold of 10.5°C compared to 11.2°C could be the major factor making the difference between "likely to become established" or "unlikely to become established". Based on this and the biological and ecological information available it was therefore decided to create two sets of climate response parameter values for *H. axyridis*. One set was based on the temperature requirements for the Oregon population while the second set was based on the temperature requirements for the French population. On all other parameters there were no differences between the two sets. The bioclimatic analysis performed using CLIMEX for *H. axyridis* and the results presented in this report refer to these two sets of values as the Oregon and the French population, respectively.

5. Results and discussion

5.1 Interceptions and species new to Norway

The three sampling methods used resulted in quite a large number of organisms after rather few investigations (Table 1). Insects and arachnids were prioritized in the collection process, but also species in the classes of Gastropoda, Diplopoda and the orders Isopoda and Haplotaxida were represented in the material collected. Another consequence of the work load experienced during the sampling period was that it was decided to focus mainly on larger insects, while smaller insects (like Homoptera), and egg, larvae and pupal stages were collected to a much lesser extent than adults. From Table 1 it can be seen that the compost method appeared as the most efficient sampling method in this study and added more species to the list compared to the other two methods used. In only six samples of compost a total of **93** species was identified.

Table 1: Overview of the number of organisms and species found by using three different sampling methods.

Method	Number of samples	Number of species identified	Number of individuals found	Average amount of organisms per sample
Compost	6	93	620	103
Shaking	17	85	523	31
Visual	4	5	50	13

The material collected contained 1193 specimens and from this material 156 species were identified, while a smaller amount of the total number of specimens were identified to the order, family or genus level only (Appendix 1). A few were left unidentified and those are not included in the total number of 1193 organisms reported here or in Appendix 1.

Among the 156 species identified in this study the following 15 species were new to the Norwegian fauna (these 15 are highlighted in Appendix 1):

1 species of **Collembola:** *Orchesella quinquefasciata* (Bourlet) *(Entomobryidae).* 2 species of **Heteroptera:** *Heterogaster urticae* (Fabricius) *(Lygaeidae), Piezodorus lituratus (*Fabricius) *(Pentatomidae).* 6 species of **Coleoptera:** *Semiophonus signaticornis* (Duftschmid) *(Carabidae), Harmonia axyridis* (Pallas) *(Coccinellidae), Rhyzobius chrysomeloides* (Herbst) *(Coccinellidae), Quedius scintillans* (Gravenhorst) *(Staphylinidae), Epitrix pubescens* (Koch) *(Chrysomelidae), Cartodere bifasciata* (Reitter) *(Latridiidae).* 1 species of **Diptera***: Chaetosciara estlandica* (Lengersdorf) *(Sciaridae).* 2 species of **Hymenoptera:** *Temnothorax unifasciatus* (Latreille) *(Formicidae), Temnothorax crassispinus* (Karajew) *(Formicidae.* 1 species of **Araneae** (Arachnidae)**:** *Lathys humilis* (Blackwall) *(Dictynidae.* 1 species of **Julida** (Diplopoda)**:** *Brachyiulus pusillus* (Leach) *(Julidae).*

One more species may soon be added to the list of new species, making it 16, as a weevil, *Otiorhynchus* sp. *(Curculionidae),* is presently at the Natural History Museum in London for identification.

In 5.2-5.9 below a presentation of the 15 species new to Norway is given as well as a summary for each species of available information regarding their biology, ecology and any other information of interest for assessing their potential for establishment and spread in Norway.

The distribution maps used to demonstrate the distribution of the 15 species in Europe can be found at Fauna Europaea's web-site (http://www.faunaeur.org/). It should be emphasized that these maps are not regularly updated and minor mistakes may therefore occur when comparing to the literature or other sources of information. The website is, however, a good source when looking for distribution maps of species that are not listed as quarantine pests.

All photos by Arnstein Staverløkk (© Arnstein Staverløkk).

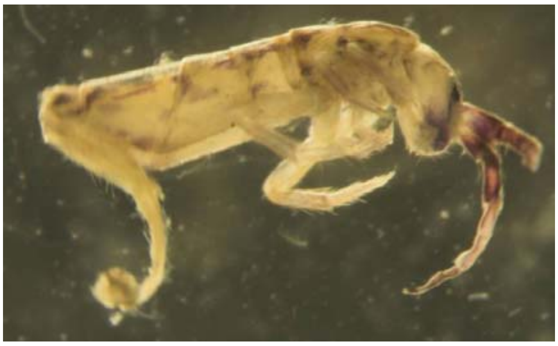
5.2 Collembola

Family Entomobryidae

5.2.1 Orchesella quinquefasciata (Bourlet, 1843)

Identity

Suborder	Entomobryomorpha
Family	Entomobryidae
Subfamily	Orchesellinae
Genus	*Orchesella*
Species	*quinquefasciata*

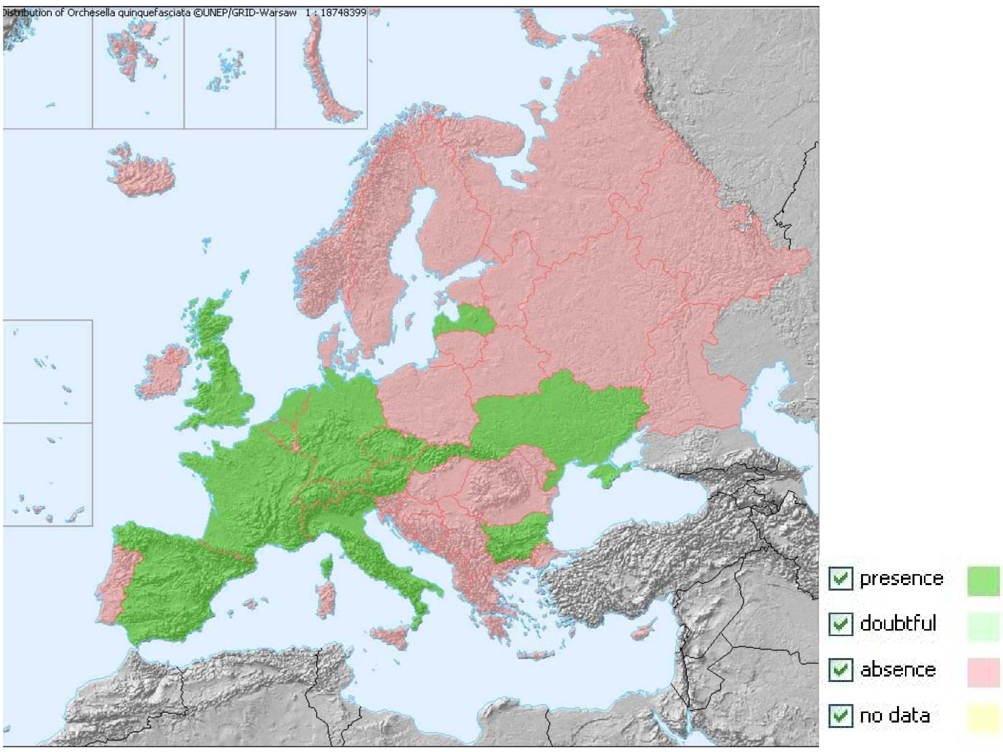


The history of *O. quinquefasciata* in Norway

Thirteen adults were detected on *Thuja occidentalis* imported from the Netherlands to Oslo on the 19th and 26th of April 2006 (Staverløkk 2006).

Impact

According to the distribution map below the species is absent from the whole of Fennoscandia (Fauna Europaea 2006), and this interception is the first record of this species in Norway (Staverløkk 2006). *O. quinquefasciata* represents one of the species where lack of biological information limited further discussion about this species.



5.3 Hemiptera

Family Pentatomidae

Pentatomidae, with 4123 described species is one of the largest families within the order Heteroptera. Plant feeding stink bugs (Pentatominae) comprise its largest subfamily with several economically important pest species (Panizzi et al. 2000). Along with several species of heteroptera, this subfamily has vibratory communication between the two sexes. In fact the species' have different vibratory signals which they use to attract the other part during the mating period (Moraes et al. 2005).

5.3.1 *Piezodorus lituratus* (Fabricius, 1794)

Identity

Suborder	Heteroptera
Infraorder	Pentatomomorpha
Superfamily	Pentatomoidea
Family	Pentatomidae
Subfamily	Pentatominae
Tribe	Piezodorini
Genus	*Piezodorus*
Species	*lituratus*

Biology

The Danish name of the shieldbug is "Gyvelbredtæge", because it is found on *Cytisus scoparius* (Gyvel) and other plants of the Fabacae family in hot and dry biotops. *Piezodorus lituratus* overwinter as imago, nymphs in June-September (Tolsgaard 2001). Host plants include gorse (*Ulex europaeus*), broom (*Sarothamnus scoparius*), the legumes (*Lupinus angustifolium, Lupinus albus, Trifolium medium, Melilotus* sp., and *Medicago* sp.*)* and the woody Papilionaceae of the tribe Genisteae (Panizzis et al. 2000). Newly emerged adults migrate to forest or woodlands during sunny warm days and aestivate for 2-4 months on trees in temperate climate or at higher altitude on mountains in subtropical climate (Panizzis et al. 2000). In the early fall after rain and cool periods, they migrate again or move down to the ground and hibernate under grasses or leaves. According to Javahery (1967 (in Schaefer and Panizzis 2000)) *Piezodorus lituratus* complete one generation per year in its northern distribution with an obligatory diapause.

Damage to host plants

In *Heteroptera of Economic Importance* (Schaefer and Panizzis 2000) this species is listed as a species of only minor economical importance.

The history of *P. literatus* in Norway

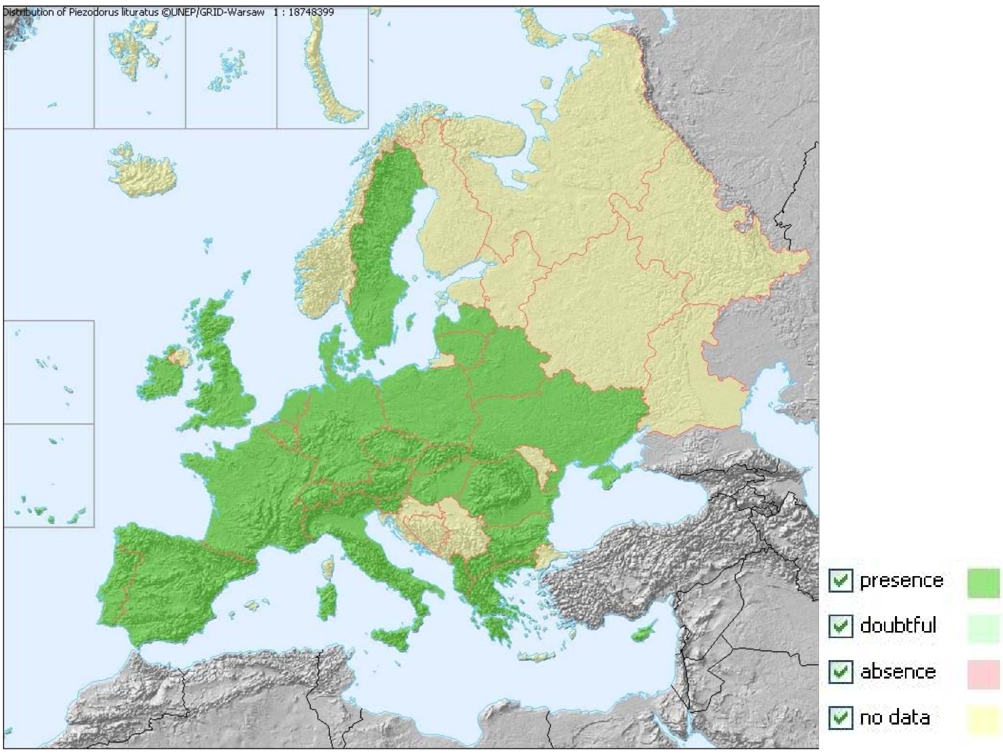
Two adults were detected on *Thuja sp.* imported from the Netherlands on the 3rd of May 2006 (Staverløkk 2006).

Means of movement and dispersal

Recorded in Denmark for the first time in 1974 and is most truly introduced or dispersed from the south. This pentatomid occurs in most countries of the Palearctic region. Migration may occur over shorter distances while spread with planting material is a more likely way of dispersal over longer distances.

Impact

Since it is already present in Sweden and Denmark it is expected that the species can also establish in Norway. Whether it can pose any threath to biodiversity or commercial farming (monocultures of legumes) in Norway, we do not have sufficient information to make a proper assessment of.



5.3.2 *Heterogaster urticae* (Fabricius, 1775)

Synonymous: *H. longirostris* (Wagner, 1949)

Identity

Suborder	Heteroptera
Infraorder	Pentatomomorpha
Superfamily	Lygaeoidea
Family	Lygaeidae
Subfamily	Heterogastrinae
Genus	*Heterogaster*
Species	*urticae*

Biology

Eggs are beeing laid in the soil, on the leaves of or close to nettleplants (*Urtica* spp.). In Europe the hostplants are *Urtica dioica* L. and the roots of European beachgrass, *Ammophila arenaria* L. (Stichel 1958). *H. urticae* overwinter as imago under bark or holes in trees close to its host plants (Southwood & Leston 1959). *H. urticae* inhabits warm, sunny fields and non-acid waste lands.

The history of *H. urticae* in Norway

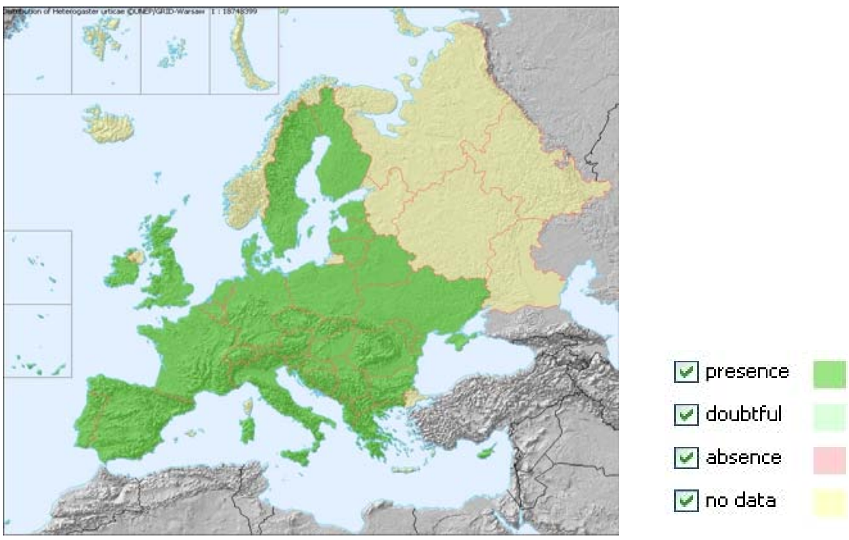
One adult were detected on *Thuja occidentalis* imported from the Netherlands to Oslo on the 19th of April 2006 (Staverløkk 2006).

Means of movement and dispersal

The species became established on New Zealand after being introduced as eggs through the import of European beach grass from England in early 1900-century. It may also have been introduced through the import of other consignments as for example fruits (Scudder & Eyles 2003). Passive dispersal seems to be the known ways of movement to new areas for this species.

Impact

Whether *H. urticae* may pose a threat to biodiversity or become a pest of economic significance in a new environment can not be assessed due to lack of information.



5.4 Coleoptera

Family Lathridiidae

Members of this family, which in central Europe counts 67 species belonging to 9 genera, live on the mycelia and the spores of all kinds of fungi, especially moulds. 62 species are found in Norway (Silfverberg 2004). Since fungi occur in every possible situation, lathridiids occur wherever it is damp or where organic material is in the process of decomposing. They are also found in stables and cowsheds, sometimes in quite large numbers, but from man's point of view they are said to be absolutely harmless (Harde 1984).

5.4.1 *Cartodere (Aridius) bifasciata* (Reitter, 1877)

Synonymous: *Aridius bifasciatus* Motschulsky, *Lathridius bifasciatu*s Herbst.

Identity

Suborder	Polyphaga
Infraorder	Cucujiformia
Superfamily	Cucujoidea
Family	Latridiidae
Subfamily	Latridiinae
Genus	*Cartodere*
Subgenus	Aridius
Species	*bifasciata*

NIKON CORPORATION (NIKON D200)
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Appearance and biology

Three species of *Cartodere* is found in central Europe. They are notable for the thick ribs on their elytra, and waxy secretion on the sides of the protothorax which appears like translucent margin in dorsal view. This is sometimes lacking in mounted specimens, especially if they have been cleaned with organic solvents (Watt 1969). The elytra of *C. bifasciata* have dark markings on a lighter background, but can be somewhat variable in colour (Hodge & Jones 1995).

As mould-feeders they are to be found on bark, wood and leaves, in hay and straw debris and occasionally on mildewed wallpaper in damp houses (Harde 1984). On margins of deciduous woods, clearings, parks, plantations, hedges, river floodplains and banks, heaths, gardens, weedy places, more rarely in fields. Especially on decaying and drooping grasses and herbs, also in mouldy grass, leaves, litter and twigs, singly in dry rotting fungi, fungoid wood mould and compost heaps (Koch 1989). They are also attracted to fire damaged woodland (Lundberg 1984). Most of the literature that can be found about this species is mainly reports of new recordings and very little on its biology.

The history of *C. bifasciata* in Norway

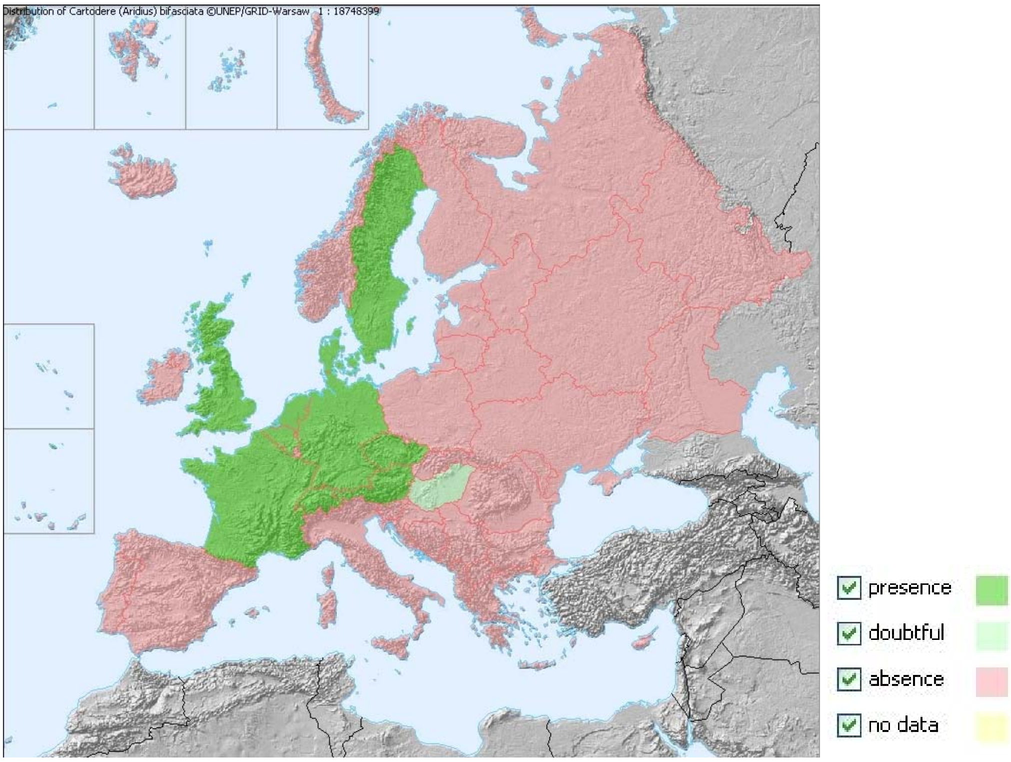
Three adults were detected in two consignments of *Thuja sp.* imported from the Netherlands and Germany on the 4th of April and the 11th of May, respectively, in 2006 (Staverløkk 2006).

Means of movement and dispersal

C. bifasciata originates from Australia and has been spread around the world through import of exotic crops, grass and rushes. It is rarely recorded in native habitats, but has been found on flowering shrubs, in moss and in leaf litter (Watt 1969). The first record of this *C. bifasciata* in the UK was in 1949. Before that it was accidentally introduced to Germany through Australian tobacco. Unlike many other mould-feeding species it is not restricted to indoor situations, to man-made accumulations of mouldy vegetable matter or to specialized habitat such as wood in certain stage of decay (Hammond 1974). This means that this species can not be matched by many other introduced species which are restricted to more man made habitats. *C. bifasciata* has been spread to many countries from its origin and is now widespread in central Europe (Watt 1969, Hammond 1974, Tempere 1979, Silfverberg 2004).

Impact

C. bifasciata do not appear to be a pest of economic importance and it may even be a useful organism in the decomposing process in nature in the countries where introduced. Whether it may pose a threat to other organisms with a similar diet and similar way of living is, however, unclear.



Family Coccinellidae

In Norway 54 species of Coccinellidae or ladybeetles are present (Silfverberg 2004). Some species are better known and/or more common than others, and most people have a very relaxed relationship with these insects thinking of them as cute, fragile and innocent creatures. Ladybirds have often been associated with superstition. Finding a ladybird and make it fly is associated with nice weather or good harvest the following season (Hodek & Honek 1996).

5.4.2 *Rhyzobius chrysomeloides* (Herbst, 1792)

Rhyzobius chrysomeloides Herbst 1792
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Identity

Suborder	Polyphaga
Infraorder	Cucujiformia
Superfamily	Cucujoidea
Family	Coccinellidae
Subfamily	Coccidulinae
Tribe	Coccidulini
Genus	*Rhyzobius*
Species	*chrysomeloides*

R. chrysomeloides belongs to the family of Coccinellidae, and is one of two species of its genera found in Central Europe. The other one is *R. litura*. *R. chrysomeloides* is associated with coniferous plants, especially *Pinus* spp.

Biology

The beetles and the larvae live on a variety of plants, where they feed on aphids and scale insects. The beetles can be caught in the summer on vegetation, and in the winter they can be found in moss, at plant roots, and under bark. *R. chrysomeloides* is generally abundant near water. This species are to be found chiefly on pine-trees and shrubs (Harde 1984).

Eggs are laid in the cortex of pine and the species is an effective predator on aphids and scale insects, especially *Matsucoccus feytaudi* Ducasse. *R. chrysomeloides* has 1-year life cycle but they are long lived insects. The adults get reproductive after overwintering in various sheltered places, i.e. in bark scales and in bark crevices. Females lay their eggs from February to the middle of June after the temperature has reached 10-12ºC. Eggs start to hatch after 7-15 days and it goes through four larval stages (Toccafondi et al. 1991).

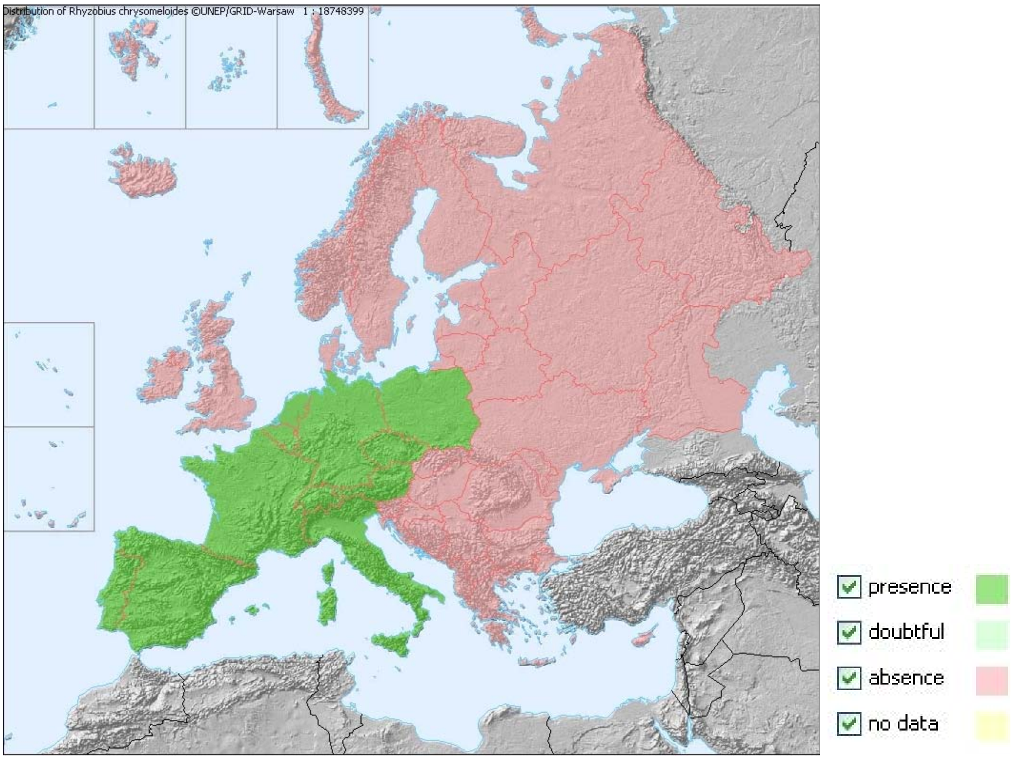
Typically eurytopic species: Found in meadows, river pastures, often on banks; heaths; weedy places; field margins; woodland margins; plantations and hedges; also in gardens; on herbs and shrubs; frequently on *Pinus* spp; in grass tussocks; moss; litter and marginal straw of field barns and heaps.

The history of *R. chrysomeloides* in Norway

The first record of the species in Norway in stray and debris from a consignment of horticultural plants imported from Germany on the 11th of May 2006 (Staverløkk 2006).

Impact

It is not a phytophageous species but a predator and therefore does not have any economic effect as a pest species on plants. It seems to be an easy species to rear because of the biological features and the fact that it is polyphagous and can be reared on several alternative preys (Toccafondi et al. 1991). Whether it has the ability to outcompete other aphid predators and thereby pose a threat to biodiversity is for the time being not known to the authors.



5.4.3 *Harmonia axyridis* (Pallas, 1773)

Synonymous: *Leis axyridis* (Iablokof-Khnzorian, 1982)

Identity

Suborder	Polyphaga
Infraorder	Cucujiformia
Superfamily	Cucujoidea
Family	Coccinellidae
Subfamily	Coccinellinae
Tribe	Coccinellini
Genus	*Harmonia*
Species	*axyridis*

Common names: Harlekin marihøne (N), Asiatisk marihøne, Kinesisk marihøne, Harmonia marihøne, Multicoloured Asian Ladybird (US), Halloween Beetle (US), Harlequin ladybird (UK).

Native distribution and history

H. axyridis originates from Central- and East Asia (Iablokoff-Khnzorian 1982) and Japan (Honek 1996), and has been introduced as a biological control agent in many parts of the world. The species is known to be a voracious predator on aphids and has been extensively used as a biological control agent in both North America and Europe (Gordon 1985, Ferran et al. 1996, Kotsoyannos et al. 1997). The later years, however, a number of negative impacts on the environment and biodiversity have been reported.

Biology/ecology

Like other aphidophagous coccinellids, *H. axyridis* has a holometabolous life cycle proceeding through egg, four larval stages, pupa, and adult (e.g. Hodek 1973).

Hibernation. The species is generally considered bivoltin in much of Asia, North America (LaMana & Miller 1996; Koch & Hutchinson 2003) and Europe (Trouve et al. 1997). However, up to four-five generations have been observed (Katsoyannos et al. 1997). In late-winter or early-spring, the adults switch from diapause to a quiescent state and upon arrival of warmer temperatures in spring they mate and disperse from their over-wintering sites (Lamana and Miller 1996, Iperti & Bertand 2001). The minimum temperature for eggs to hatch is 11.2°C (Lamana & Miller 1998).

During the summer, beetles may spend part of the summer in quiescence in response of uncomfortable conditions (Sakurai et al. 1992) and around October/November they start to migrate to their overwintering sites (LaMana and Miller 1996). In Japan *H. axyridis* acclimates to winter by decreasing its supercooling point (the temperature when body fluid freezes) and lower lethal temperature to approximately −19°C and −16°C, respectively (Watanabe 2002). Diapause is entered with an empty digestive tract, enlarged fat body, and most females over-winter unmated (Nalepa et al. 1996, Iperti & Bertand 2001). Koch et al. (2004) tested the cold tolerance on different stages of *H. axyridis* in North America. They also investigated the super cooling point for each stage and found it to be -27°C, -21.3°C, -14.17°C and -11.9°C for eggs, larvae, pupae and imago respectively. Populations of *H. axyridis* also occur in areas like northern United States and southern Canada (Koch & Hutchinson 2003, Coderre et al. 1995) that have temperatures below the "super cooling"-point. This may be due to favourable microclimate (Koch et al. 2004).

Diet. *H. axyridis* has a wide diet and although it feeds mostly on aphids in all stages, it can successfully complete its lifecycle with the supply of scale insects (Coccidae), adelgids (Adelgidae), psyllids (Psyllidae), and spidermites (Tedders & Schaefer 1994, Hodek 1996, Lucas et al. 1997, Koch 2003). This species is able to reduce aphid numbers below economically damaging levels within many crop systems and thereby reducing the dependency of chemical pesticides (Roy et al. 2006). Koch et al. (2006) lists arboreal hosts (trees and shrubs) and associated preys utilized by *H. axyridis*. More than 30 different species of aphids are listed and also a few species of Psyllidae, of which several are present in Norway (Appendix 2). Koch et al. (2003) identified *H. axyridis* as a predator also of the Monarch butterfly, *Danaus plexippus* L., an aposematic species well known for its seasonal migrating behaviour in North America and Mexico.

Natural enemies. Several natural enemies (e.g. parasitoids) of *H. axyridis* are reported from its native range and may be the reason why *H. axyridis* is not a problem/nuisance in Asia. According to Nechayev & Kuznetsov (1973) in Koch (2003) 8 species of birds are reported preying on *H. axyridis* in Russia. Indigenous natural enemies of *H. axyridis* in Norway have so far not been investigated, but since *H. axyridis* is an alien species it is reason to believe that the number of natural enemies will be very limited.

The history of *H. axyridis* in Norway

The ladybird *H. axyridis* was detected on *Thuja* sp. imported from Aalsmeer, the Netherlands, on the 19th of April 2006 (Staverløkk 2006). This record is the first report of this species in Norway. The specimen had the *succinea* –form (see below) which is one of the morphological forms found in the populations established in Europe (Majerus et al. 2006). It was a female, full of eggs.

The species had previously been assessed as a potential bio-control agent for use in Norwegian greenhouses in 2001 (Statens landbrukstilsyn 2001). The outcome of the assessment was negative with respect to import and commercial use in Norway. It was concluded that *H. axyridis* might survive and become established outdoors and thereby pose a risk to the environment.

Methods for identification and detection

H. axyridis is about 5-8 mm long, oval shaped and has a very variable appearance, which can make it difficult to distinguish from other ladybirds. The species shows wide morphological plasticity and varies a lot in colours of the elytra and the pronotum. It is represented by more than 100 morphs (Iablokoff-Khnzorian 1982). Ground colours of the elytra differ between pale yellow, orange, orange-red, red or black. It can be painted with 0 to 21 orange-red or black spots or in some cases a sort of grid pattern. The most common morphs found in Great Britain and in Europe are orange with 15-21 black dots or black with 2 or 4 orange or red spots. Pronotum is mostly white or cream with up to 5 spots or fused lateral spots forming 2 curved lines, M-shaped mark or a solid trapezoid. Other characteristics are the wide keel at back and that the legs of this species are almost always brown. The harlequin ladybird can be distinguished from some other Norwegian species (The UK Ladybird Survey 2007):

• If it is less than 5 mm in length, it is definitely not a harlequin ladybird.

• If it is red with precisely 7 black spots, it is a 7-spotted ladybird, (*Coccinella septempunctata* L.).

• If it has white or cream spots, it is a striped ladybird (*Myzia oblongoguttata* L.), an orange ladybird (*Halyzia 16-guttata* L.) or a cream-spotted ladybird (*Calvia 14-guttata* L.).

• If it is large, burgundy coloured and has 15 black spots, it is an eyed ladybird (*Anatis ocellata* L.).

• If it is black with four or six red spots, two of which are right at the front of the outside margin of the elytra, it is a melanic form of the 2-spotted ladybird (*Adalia 2-punctata* L.).

A few different morphological forms occur on the British Isles and in Europe: f. *succinea* Hope are orange or red with zero to 21 black spots, f. *axyridis* which has an orange colour and a grid-like black pattern on the elytra, f. *conspicua* and f. *spectabilis* which are black or melanic with respectively two and four large orange or red spots (Majerus et al. 2006).

Geographical distribution, intentional and accidental introductions

The first release as a biological control agent is known from North America in 1916 (Gordon 1985). The first established population in the US was documented in 1988 (Lamana & Miller 1996). Scientists still discuss whether this population has established as a result of frequent release or through accidentally introduction with import (Tedders & Schaefer 1994). During a period of 20 years *H. axyridis* has spread across great distances and established in new areas in USA and in Canada where it is well established and has become the most common ladybird species (Hesler et al. 2001). In 2001 it was recorded in South-America (de Almeida & da Silva 2002), where it is still used as a bio-control agent (Koch et al. 2006). Koch et al. (2006) used the CLIMEX model and a biome model to assess the bioclimatic potential for this species in South America, and concluded that both climate and habitat are favourable for *H. axyridis* to establish in the region.

H. axyridis was first introduced to Europe in 1964 (EPPO 2006), and used commercially in biological control since 1982 (Ferran et al. 1996, Katsoyannos et al. 1997, Iperti & Bertand 2001). In Belgium they started to use the species commercially in 1997, but there were no reports of the beetle in the wild until 2001 (Adriaens et al. 2003). Since then, the numbers have increased steadily. In the UK it has not been approved for use in biological control. The first individual was found 19. September 2004 (Majerus et al. 2006). KOPPERT in the Netherlands and BioPlant in Denmark sold and distributed *H. axyridis* until the end of 2002/beginning of 2003 when they stopped after rising amounts of reports on negative impacts on the environment (pers. comm. L.O.G A/S and BioPlant). The species is confirmed established in France, Belgium, Netherlands, Germany, Luxemburg, Italy and UK (Adriaens et al. 2001, Roy et al. 2006).

Potential for establishment in Norway

Dispersal potential. Introductions of *H. axyridis* to regions outside its native range have been extensive. Many scientists have contributed to a big collection of scientific papers about the ecology, behaviour and distribution of this invasive lady beetle. It should also be noted that the spread of *H. axyridis* has not only occurred because of its use in biological control, but also undocumented commercial releases, unintentional introductions, and the species own dispersal capacities (i.e. flight) have certainly contributed to the extent of its invasion and success (Koch et al. 2006).

H. axyridis has a great ability to fly long distances (also when it searches for an over wintering site) and appears to be very adapted to tracking aphid populations in space and time (With et al. 2002). One of the problems using this species in biological control was that they were unwilling to stay on the plants after released. Therefore, Trouve et al. (1997) considered the larval stage the best for biological control. For not giving up the use of adults for bio-control, researchers managed to create a flightless variant. This one had the same biology but it spent more time foraging (Tourniaire et al. 1999).

Recent experiences from the UK have shown that *H. axyridis* compasses several of the traits characterizing a successful invasive alien species. After the first record in UK in 2004 a comprehensive survey was initiated. The survey shows how the Harlequin ladybird has conquered most of the island and continues to spread. It can now be found almost all over the country and people report that they find them inside their houses (UK Ladybird Survey 2007).

The distribution of *H. axyridis* in North America shows that this species can establish in big areas only a few years after introduction. In many states in USA, *H. axyridis* has become the most common aphidophagous ladybird of the approximately 475 species of Coccinellidae in North America north of Mexico (Gordon 1985, Hesler et al. 2001). Numbers of native ladybeetles may decrease and go locally extinct because of displacement and intraguild predation by *H. axyridis* (Elliot et al. 1996, Colunga-Garcia & Gage 1998).

A trip from Denmark to Norway crossing the Skagerak might be too long even for this ladybird. *H. axyridis* is not yet recorded in Denmark or Sweden, but has been used as a bio-control agent in Danish greenhouses. The most likely way that the species can enter Norway, is through accidental import on plant commodities. It can then spread across Norway through the domestic distribution of plants, and after establishment it can continue to spread over shorter distances by self dispersal.

H. axyridis is capable to survive the British winter as it is well established there. Roy et al. (2006) predicts that by 2008 *H. axyridis* will have spread across mainland Britain. The adaptability of *H. axyridis* regarding to climate change will probably provide it with a competitive advantage over less adaptable ladybirds in Great Britain as well (Roy et al. 2006). It is likely that the same will apply for the species in Norway. The fact that this insect can spend the winter indoors is an adaptation outside its native area. In addition, the ability to survive relatively low temperatures makes *H. axyridis* a species that is likely to become established in Norway, if introduced.

Distribution of prey in Norway. Aphids are widely distributed in agricultural land, urban areas, forests and private gardens in Norway (see also Appendix 2 where several preys commonly occurring in Norway are listed).

Impact

H. axyridis is known as a natural enemy of aphids in its place of origin in Central- and East Asia (Kuznetov 1997 in Koch 2003), and can therefore be found near aphid colonies during the growing season along with other aphidophagous species. It is not considered as a pest on plants, rather a beneficial species, though fruit farmers in the USA are not very fond of this new species. In the US, where most of the research on this species has been done, *H. axyridis* has been observed feeding on apples, grapes, pumpkins and raspberries. The extent of these damages on the annual production of berries and fruits are rather uncertain (Brown & Miller 1998, Koch & Hutchison 2003). However, *H. axyridis* has become an increasing problem in the wine production in Minnesota as adults follow the grapes when harvested and may actually taint the wine and make it useless (Ejbich 2003, Pickering et al. 2004).

H. axyridis becomes a pest when they occur on places where people do not want them to be (e.g. in houses, on fruits etc.). They are not poisonous and are not carrying any diseases, but they will bite in rare cases (Kovach 2004). Some of these episodes have led to allergic reactions for the patient, reacting on the fluid that this animals secrete to defend themselves (Yarbrough et al. 1999). As a result of this, ladybirds may loose their good reputation for causing nice weather, and to save the plants from the aphid-pests.

When searching for an overwintering site they can reach into houses through small siding gaps, cracks and attic vents, and the best method to prevent them coming inn, is to seal those entering gaps. In West Virginia *H. axyridis* was reported overwintering underneath the house siding in large amounts. The weep holes of the siding became clogged with insect debris which allowed moisture to accumulate. When the moisture broke through the clogged weep holes, it released a liquid mixture of insect debris that stroke down the side of the house leaving stains which were difficult to remove (McCutcheon and Scoot 2001).

H. axyridis is a good colonist and very competitive because of its wide diet (Appendix 2) and the many different morphological traits. This gives the species a genetic variation which can be very beneficial in new environments (Grill et al. 1997). In the USA the ladybird has established and dispersed in several states which reflect its skills to adapt to new habitats, climates, resources and to undergo selection (Grill et al. 1997). Its voracious appetite competes with other aphidophagous insects (Michaud 2000). *H. axyridis* can therefore become a threat for native ladybirds, including *A. bipunctata* and *C. septempunctata* which are common species in Norway, and other predators of aphids, like lacewings (*Chrysoperla* spp.), as well as of parasitoids (Adriaens et al. 2003). *H. axyridis* may have a direct impact on aphid parasitoids because both adult and larvae of *H. axyridis* feed on parasitized aphids that have not yet mummified (Nakata 1995). It becomes an intraguild predator (Yasuda et al. 2001), a predator that eats individuals and species that benefit from the same food source as itself.

Prospects for the future

The ecological price for introducing a new species without fully knowing the consequences can be very high. *H. axyridis* has a great ability to fly long distances and appears to be very adapted to tracking aphid populations in space and time. The same applies when searching for an over-wintering site (With et al. 2002). If *H. axyridis* become established in Norway, it may change the existing composition of ladybird species, and it may also become a pest and a nuisance for humans. In Norway there are 54 known species of ladybirds, some of these species have been reported to decline in numbers in other countries where *H. axyridis* has been introduced (Elliot et al. 1996). This could also pose a threat to the 8 species of Coccinellidae listed on the recently released National Red List of endangered species

(Kålås et al. 2006), and moreover *H. axyridis* is mentioned here as an example of a species that is a threat to the environment (Ødegaard 2006).

Labrie et al. (2006) compared the life history traits between *H. axyridis* and *Coleomegilla maculata lengi,* which is quite similar to the *H. axyridis* ecologically, seeking to explain the invasive skill of *H. axyridis*. The results from their study revealed a faster development, increased voracity and ability to gain weight and higher predation efficiency. Its ability to disperse over long distances and hibernating strategy, further contributes to the invasive skills of the *H. axyridis* (Trouve et al. 1997, Labrie et al. 2006). The ability to survive relatively low temperatures makes *H. axyridis* a possible species to establish in Norway. Establishment potential of *H. axyridis* is further discussed in 5.10-5.13.

In addition, the continuous import of tons of horticultural plants every year (Norsk Gartnerforbund 2006) from areas where *H. axyridis* is present increases the species chances of repeated introductions and thereby increases the establishment potential of the species. This record may therefore only be the first in a number of such, as it is likely that this species will survive outdoors at least in the southern parts of Norway (more on this in 5.10-5.13).

Family Carabidae

5.4.4 *Semiophonus signaticornis* (Duftschmid, 1812)

Synonymous: *Harpalus signaticornis, Ophonus signaticornis*

Identity

Suborder:	Adephaga
Superfamily:	Caraboidea
Family:	Carabidae
Subfamily:	Harpalinae
Tribe	Harpalini
Subtribe	Harpalina
Genus	*Semiophonus*
Species	*signaticornis*

The genus *Semiophonus* is represented in the Palaearctic region by 28 species whose length ranges from 4.6 -17mm. 13 species are found in Norway (Harde 1984, Silfverberg 2004). They all have a similar body form – long oval or straight-sided with relatively short legs and only moderate long antenna.

Biology

The beetles like dry, sandy habitats and are mostly found in open areas, at both low and high altitudes. Many are nocturnal, buried in the soil during daytime. Unlike many other ground beetles, *Semiophonus* species are not entirely carnivorous, but also eat vegetable matter (seeds, pollen, fruits, etc.) (Harde 1984, Lindroth 1986). Beetles are found on open, sandy or chalky ground (Lindroth 1986).

The history of *S. signaticornis* in Norway

The first record of the species in Norway was in a consignment of *Thuja occidentalis* imported from the Netherlands to Oslo on the 24th of April 2006 (Staverløkk 2006).

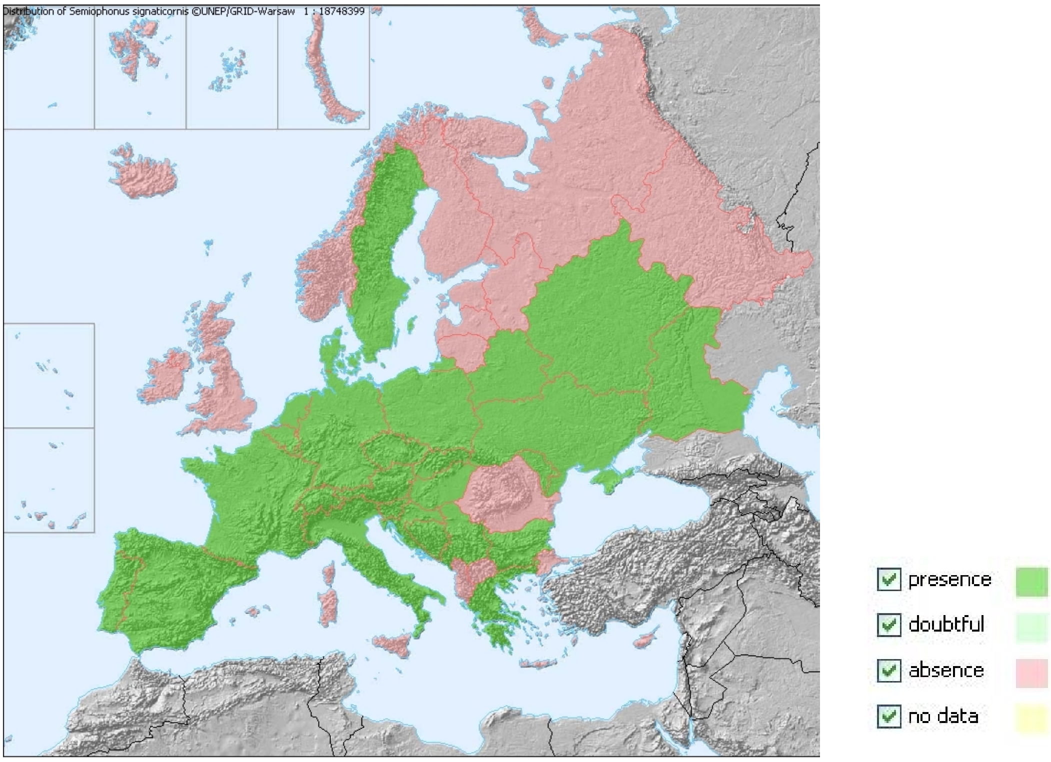
Means of movement and dispersal

Recordings of stray individuals of *S. signaticornis* along the southern coast of Denmark and Sweden are the only specimens found in Scandinavia (Lindroth 1986). Gärdenfors & Baranowski (1974) studied the consequences of insects being transported by the wind drift phenomenon and randomly found *S. signaticornis* among other species found in drift material, concluded that these specimens was undoubtly washed ashore. Another specimen found in Estland in drift material strengthens this assertion (Biström 2004).

S. signaticornis is well adapted to a life on the ground. They hunt and feed on other soil living insects. This species was probably introduced to Norway only because we import plants with a lump of soil and in that soil a number of organisms may be present.

Impact

Lack of information about *S. signaticornis* makes it difficult to predict how it will behave in a new environment. Its present distribution is Middle and South Europe, where it is more common in the east. Until now the records of this species from Scandinavia are reported from along the shore in southeast Denmark and south Sweden.


Distribution of Semiophonus signaticornis ©UNEP/GRID-Warsaw 1 : 18748399
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doubtful
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Family Chrysomelidae

5.4.5 *Epitrix pubescens* (Koch, 1803)

Identity

Infraorder	Cucujiformia
Superfamily	Chrysomeloidea
Family	Chrysomelidae
Subfamily	Alticinae
Genus	*Epitrix*
Species	*pubescens*

Biology/ecology

E. pubescens is associated with swamps, bogs, carrlands and swampy banks, singly in weedy places, field margins, and on arable land (Koch 1992). These tiny beetles hibernate as adults and may appear in the fields very early in the season and cause serious damage to young plants. Host plants of this species belongs to the Solanaceae family and the *Solanum* genus which contains a lot of species that benefit humans. It is oligophagous especially on *S. dulcamara*, but also on *S. nigra*, more rarely on *Lycium* and *Hyoscyamus* sp. The beetle seems to live equally on both species of nightshade, also the *S. dulcamara* L. (Allen 1984, Allen 1988). Halstead (1998) report an observation on *E. pubescens* infesting *S. crispum*, so this species may have several host plants. In winter it can be found singly in litter, grass tussocks, leaves and moss on trunks.

Symptoms and damage

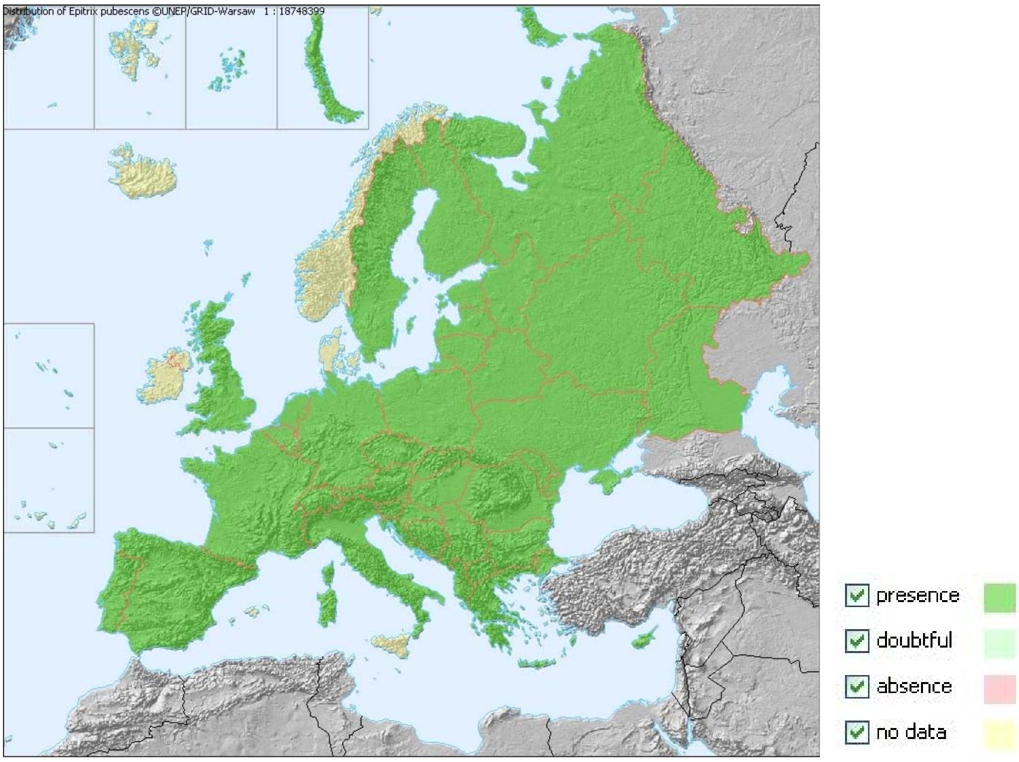
Flea beetles cause small shot-hole damage to leaves. The literature refers to some new recordings on the British Isles where it is found on woody nightshade, *S. nigrum* L., an annual plant on disturbed soils.

The history of *E. pubescens* in Norway

The first record of the species in Norway was in stray and debris collected from a consignment of horticultural plants imported from Germany to Oslo on the 11th of May 2006 (Staverløkk 2006).

Prospects for the future

Alexander (2002) reviews the spreading of this beetle during a period of eight years, in the context of modern climate change. In an area where beetles are well documented, *E. pubescens* has been recorded in every main location during the last eight years, indicating that beetles may spread north when the climate change.


Distribution of Epitrix pubescens ©UNEP/GRID-Warsaw 1 : 18748399
presence
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Family Staphylinidae

5.4.6 *Quedius scintillans* (Gravenhorst, 1806)

Quedius scintillans Gravenhorst 1806
NIKON CORPORATION (NIKON D200)
© Bioforsk Plantehelse

Identity

Suborder	Polyphaga
Infraorder	Staphyliniformia
Superfamily	Staphylinoidea
Family	Staphylinidae
Subfamily	Staphylininae
Tribe	Staphylinini
Subtribe	Quediina
Genus	*Quedius*
Subgenus	*Raphirus*
Species	*scintillans*

Biology

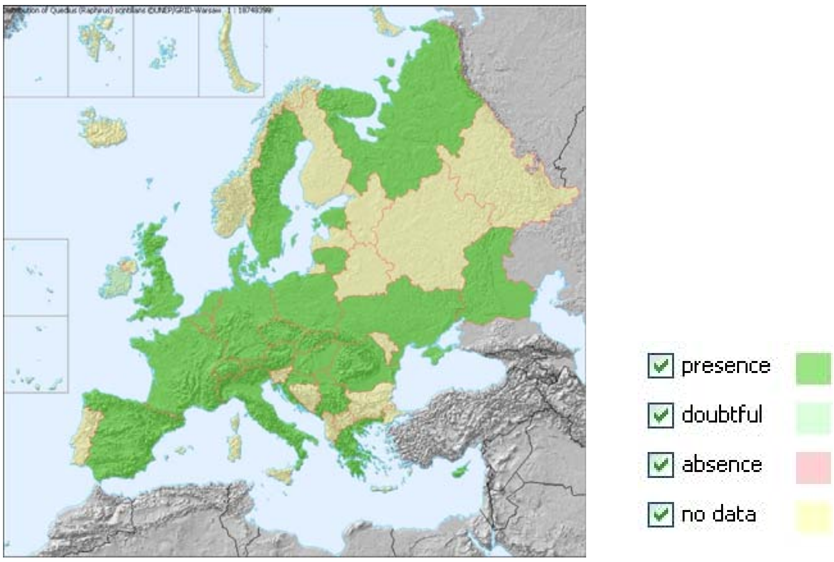
Approximately 70 species of this genus is registered in central Europe (Harde 1984). The majority of the species live in ground litter and moss, mostly in wet places. Some inhabit dead wood and decaying fungi, while a few live in nests and holes in trees (Harde 1984).

The history of *Q. scintillans* in Norway

The first record of the species in Norway was in stray and debris collected from a consignment of horticultural plants imported from Denmark on the 2nd of May 2006 (Staverløkk 2006).

Impact

No further data could be found about this species and predictions regarding ecological or economic impact could not be performed.



5.5 Diptera

Family Sciaridae

5.5.1 *Chaetosciara estlandica* (Lengersdorf, 1929)

Identity

Suborder: Nematocera
Infraorder: Bibionomorpha
Superfamily: Sciaroidea
Family: Sciaridae
Genus: *Chaetosciara*
Species: *estlandica*

Biology

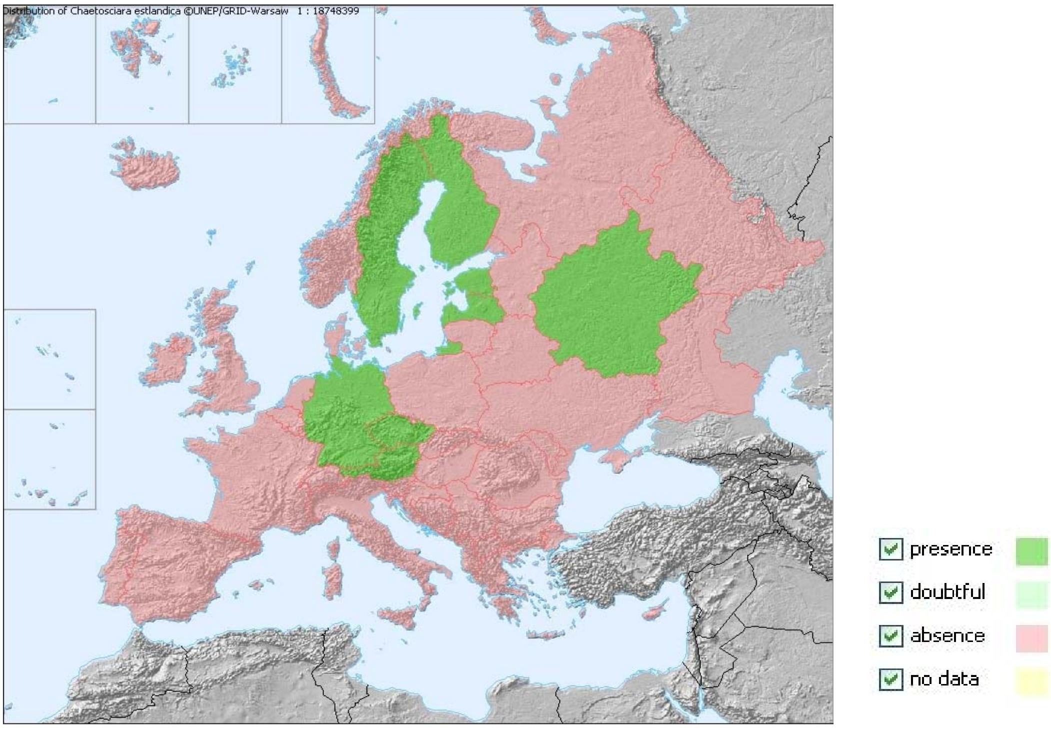
This species is probably part of the Norwegian diptera fauna (pers. com. Øvind Gammelmo). The species belongs to a diptera-family which is very common in the soil of indoor plants.

The history of *C. estlandica* in Norway

The first record of the species in Norway was from a consignment of *Taxus media* imported from the Netherlands on the 24th of April 2006. Two adults were found (Staverløkk 2006).

Impact

No further data could be found to predict possible ecological or economic impact of the species.



5.6 Hymenoptera

Family Formicidae

5.6.1 *Temnothorax crassispinus* (Karavaiev, 1926)

Identity

Suborder: Apocrita
Superfamily: Vespoidea
Family: Formicidae
Subfamily: Mymicinae
Genus: *Temnothorax*
Species: *crassispinus*

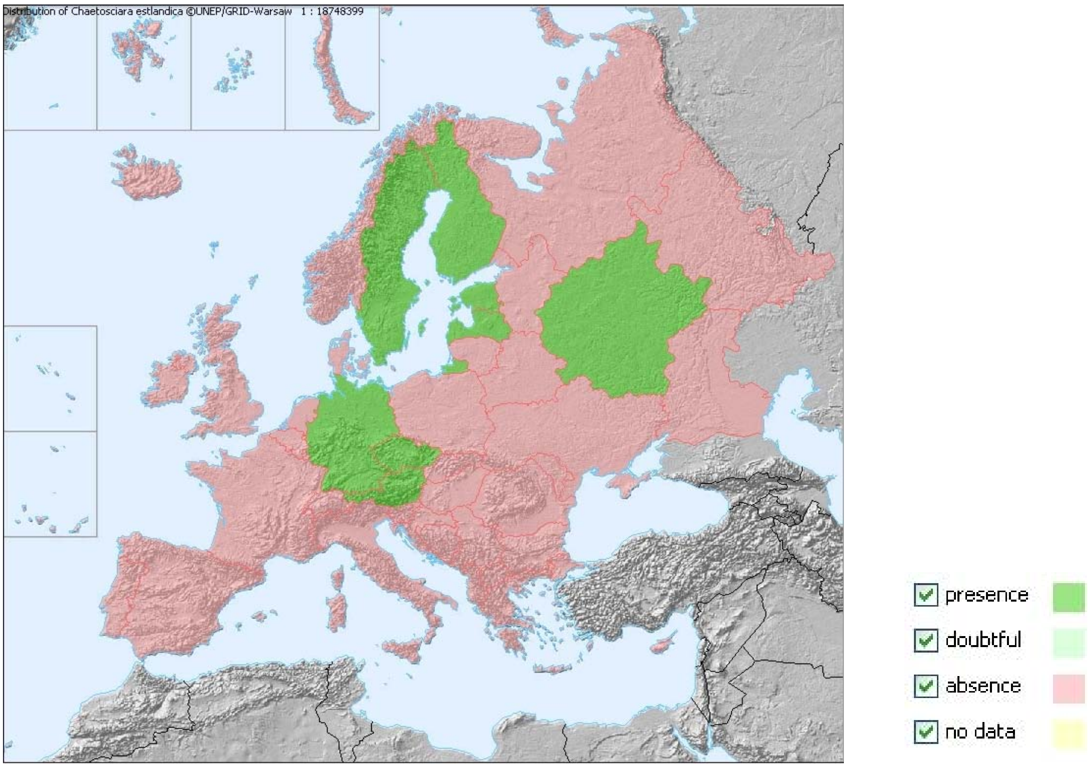
NB: Until recently, most *Temnothorax* species were placed in the similar genus, *Leptothorax*.

The history of *T. crassispinus* in Norway

The first record of the species in Norway was from stray and debris collected from a consignment of horticultural plants imported from the Netherlands to Oslo on the 2nd of May 2006. The specimen was a queen (Staverløkk 2006).

Impact

No further data could be found to predict ecological or economic impact of this species.



5.6.2 *Temnothorax unifasciatus* (Latreille, 1798)

Identity

Suborder:	Apocrita
Superfamily:	Vespoidea
Family:	Formicidae
Subfamily:	Mymicinae
Genus:	*Temnothorax*
Species:	*crassispinus*

Biology/ecology

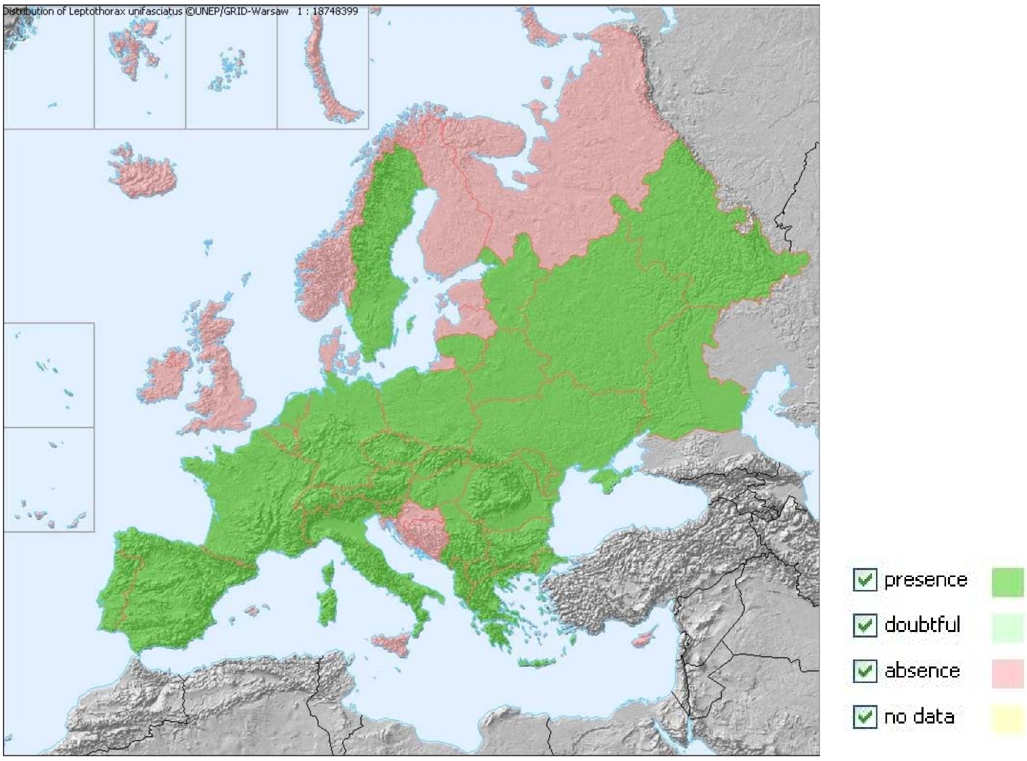
Temnothorax unifasciatus lay their nests right under the soil surface, under a flat stone or in hacks of stones.

The history of *T. unifasciatus* in Norway

The first record of the species in Norway was in stray and debris collected from a consignment of horticultural plants imported from the Netherlands to Oslo on the 3rd of May 2006. The specimen was a queen (Staverløkk 2006).

Impact

No further data could be found to predict ecological or economic impact of this species.



5.7 Psocoptera

5.7.1 *Ectopsocus petersi* (Smithers, 1978)

Identity

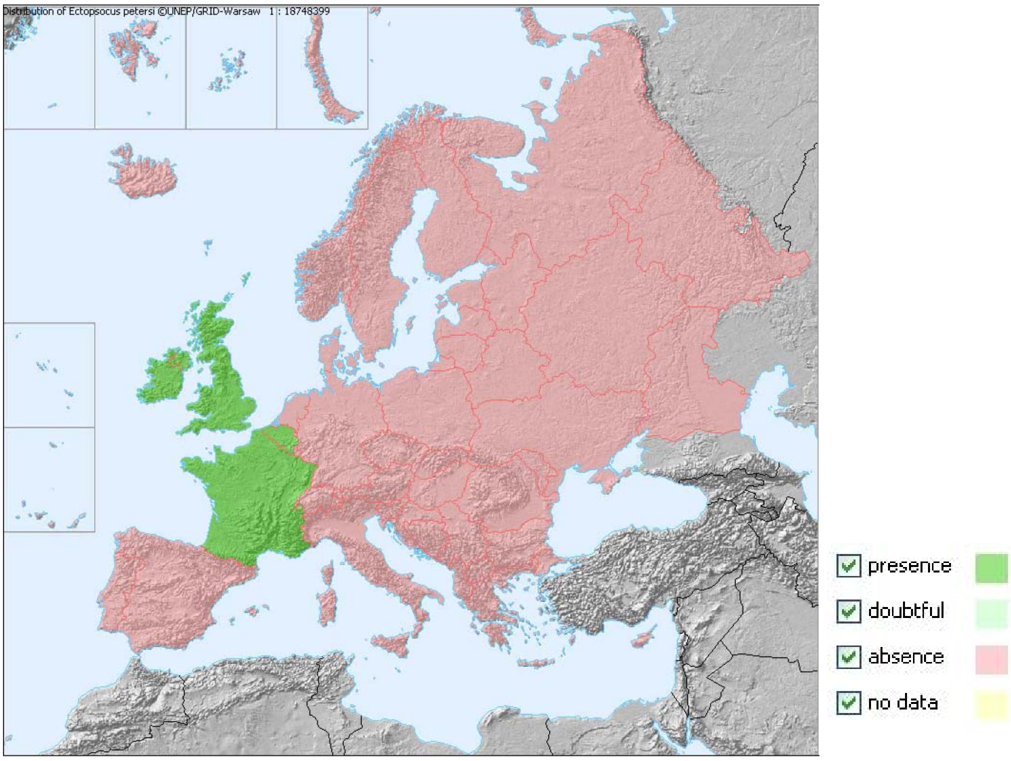
Suborder	Psocomorpha
Infraorder	Homilopsocidea
Family	Ectopsocidae
Genus	*Ectopsocus*
Species	*petersi*

The history of *E. petersi* in Norway

Nine adult specimens were found in four different consignments of *Thuja occidentalis* and *Taxus media* imported from the Netherlands on the 18th, 19th and 24th of April 2006 (Staverløkk 2006).

Impact

No further data could be found to predict ecological or economic impact of this species.



5.8 Araneae

5.8.1 *Lathys humilis* (Blackwall, 1855)

Identity

Suborder: Labidognatha

Family: Dictynidae

Genus: *Lathys*

Species: *humilis*

Biology/ecology

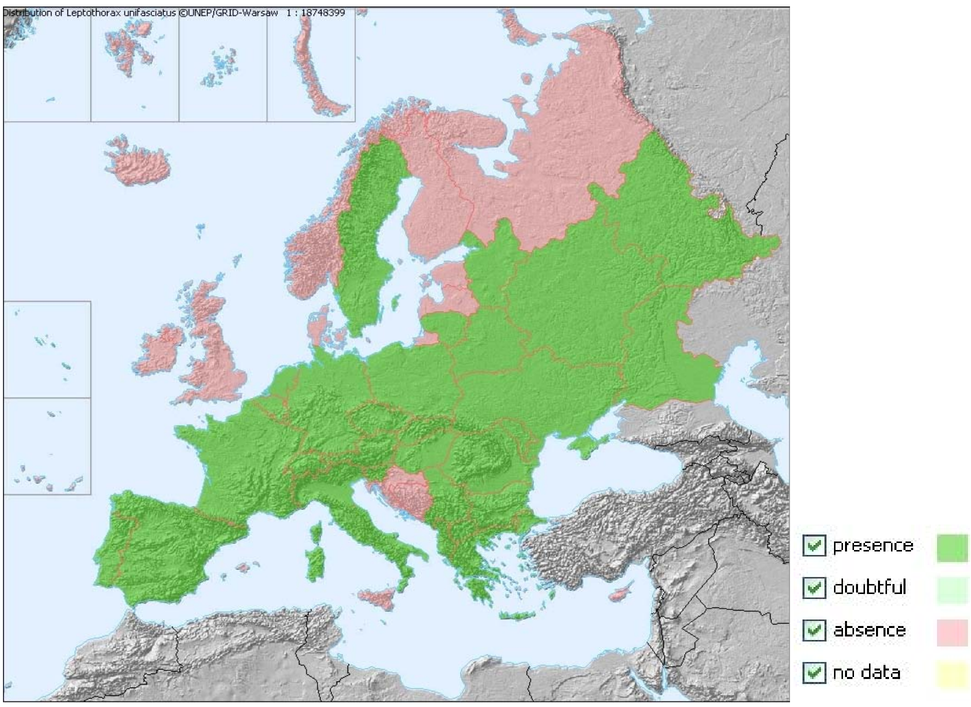
L. humilis spins its small web among leaves and branches of trees and bushes. Three species can be found of this small spider. *L. humilis* has a size of about 2 mm long and can be found in small cribellate webs on vegetation or ground level. It can be found in a variety of habitats, common on bark of trees such as pines and various broadleaved trees. This is a small, greenish-brown spider with black markings on the cephalothorax and a dark area on the abdomen. Legs are clearly annulated with dark brown. Males are similar to, but slimmer than females. Females are 2-2.5 mm while males are 1.75-2 mm. The species is known from most of Denmark and are locally common (http://www.jorgenlissner.dk/Dictynidae.aspx).

The history of *L. humilis* in Norway

The first record of the species in Norway was in stray and debris collected from a consignment of horticultural plants imported from Germany on the 11th of May 2006. Two adults, one male and one female were found (Staverløkk 2006).

Impact

No further data could be found to predict ecological or economic impact of this species.



5.9 Julida

5.9.1 *Brachyiulus pusillus* (Leach, 1814)

Synonymous: *Julus pusillus* (L.), *Microbrachyiulus pusillus* (Leach, 1815), *Brachyiulus littoralis* (Verhoeff, 1898)

Identity

Family: Julidae

Genus: *Brachyiulus*

Species : *pusillus*

Biology and appearance

B. pusillus occurs in alder stands among bushes along streams and field fringes in the south of Scandinavia. It can also be found in semi natural biotopes as churchyards, gardens, greenhouses and plant nurseries. The species is found under stones and woody debris and in litter, often by old walls (Djursvoll 2005). The length of the body is 7–13 mm (male 7–8 mm, female 10–13mm), with 29–33 body rings and between 47-57 pair of legs. Body is shiny, dark brown to black with a point of marbling, and similar to two other species in Scandinavia, it has two yellow bands along the dorsal midline. The head is paler and the legs are yellow. The caudal projection is indistinct.

The history of *B. pusillus* in Norway

The first record of the species in Norway was in stray and debris from a consignment of horticultural plants imported from the Netherlands to Oslo on the 2nd of May 2006 (Staverløkk 2006).

Means of movement and dispersal

The species occurs in Sweden north to Gothenburg and in Denmark, but has not been reported from Finland. It seems to have a western European distribution and is recorded in Great Britain, Ireland, The Netherlands, Belgium, Luxemburg, France and south to north of Spain and Italy. Further distribution in the eastern direction is Estland, Litauen, Poland, Russia and Balkan, and south to Greece. *B. pusillus* has been introduced to USA were it is widely distributed, and also to the Canary Islands, Madeira, Azores, Africa and Australia (Djursvoll 2005). The species' capacity to disperse by own means is limited, and movement is expected to take place via plant commodities, soil and similar.

Impact

No further data could be found to predict ecological or economic impact of this species.

5.10 Match Climates – the Netherlands & Germany versus Norway

Most of the species listed in Appendix 1 was stowaways on plants and plant commodities imported from Aalsmeer in the Netherlands or from Rellingen in Germany to Norway. The Match Climates function in CLIMEX is therefore used to perform a general assessment of all organisms' (listed in Appendix 1) bioclimatic potential, or establishment potential, in the new environment (Norway). As mentioned previously in section 4.3 this function is very useful when little or no biological data are available about specific species.

The Match Climates function compares the meteorological data from different places, with no reference to the preference of a given species (Sutherst et al. 2004). Such a comparison answers questions like: Are the extreme minimum and maximum temperatures similar? Do the compared locations have similar amounts of rainfall and similar seasonal rainfall patterns?

In figure 1 and figure 2 the results of comparing the climate of Aalsmeer and Rellingen, respectively, with the climate in Norway, and also with the climate in the rest of Europe are shown. The meteorological data used are those originally stored in CLIMEX (period 1961-1990), which include data from 28 meteorological stations in Norway 28 (Sutherst et al. 2004).

The red colours in figure 1 and 2 describe a good climatic match between locations while the blue colours describe a much lower climatic match between the locations compared. Match between locations are also given with a number ranging from 0 to 1. The closer to 1 the result for a specific location is the more similar are the climatic conditions at the locations compared, and contradictory, the closer to 0 the result for a specific location is the more different are the two locations climatically.

Based on the results shown in figure 1 it is clear that organisms imported from Alsmeer in the Netherlands have a reasonable good chance of establishing a population in the southern parts of Norway based on the similarity of climatic parameters. It is also evident from figure 2 that organisms imported from Rellingen in Germany have an even greater potential for successful establishment in Norway.

The assumption made here is that the species listed in Appendix 1, with particular reference to the 15 alien species described in section 5.1-5.9 above, occur in Aalsmeer or Rellingen. Since all plants sampled in the survey were produced outdoors in the fields in Germany or the Netherlands before exportation, we find this assumption very reasonable.

The Match Climates function in CLIMEX does not take into account availability of host plants, preys, natural enemies or any other biological factor that eventually also will strongly influence whether a given species can successfully establish a population in a new environment. The analysis conducted here have, however, revealed that the climatic conditions in several parts of Norway are favourable for organisms imported from Germany and the Netherlands in general, and with special reference to the 156 species listed in Appendix 1 (figure 1 and 2).

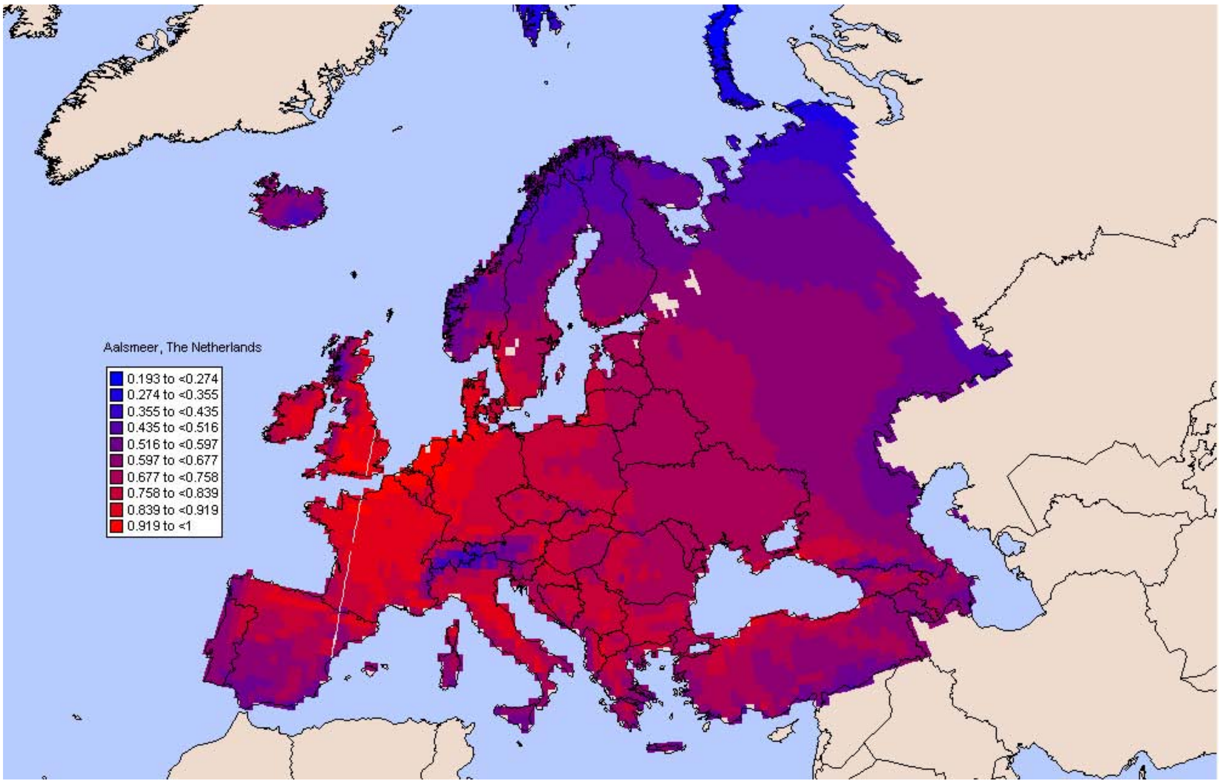


Figure 1: Comparing the climate of Aalsmeer (52.16°N, 4.46°E) in the Netherlands with the climate in Norway and in Europe. Model predictions made by CLIMEX.

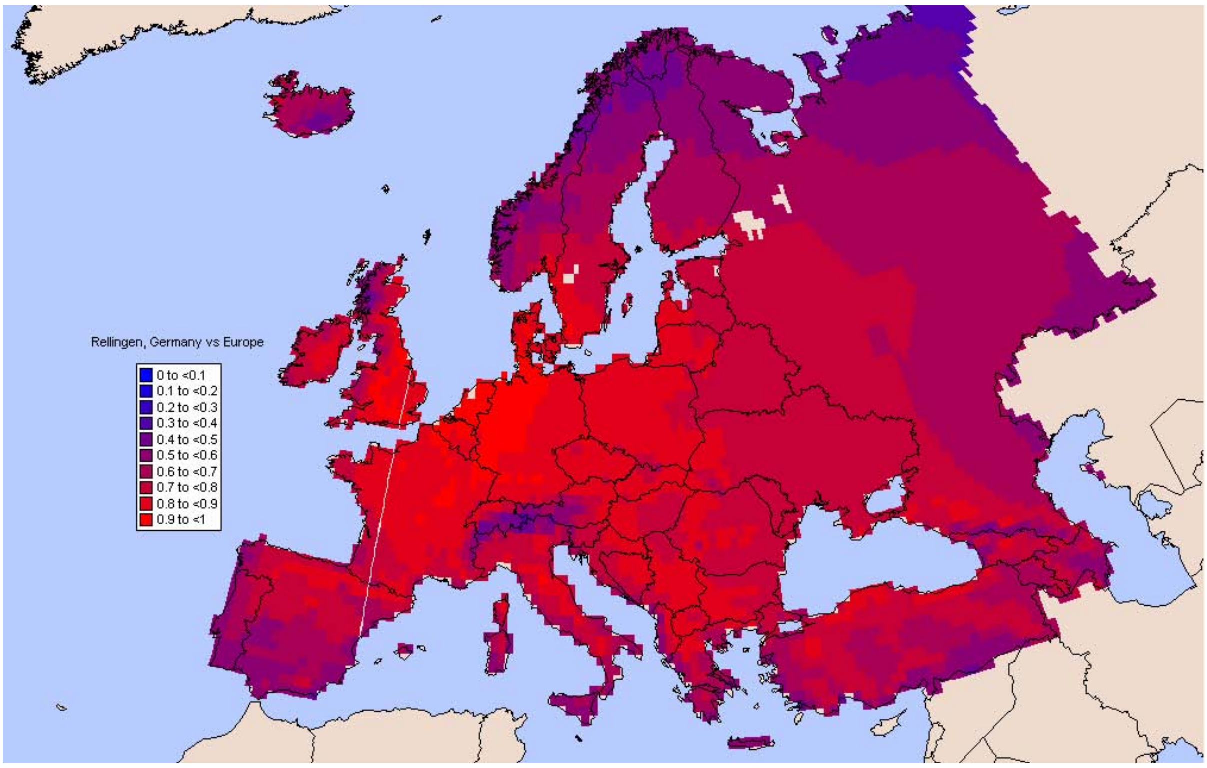


Figure 2: Comparing the climate of Rellingen (53.38°N, 9.49°E) in Germany with the climate in Norway and in Europe. Model predictions made by CLIMEX.

5.11 Match Climates – four locations of origin for *H. axyridis* versus Norway and Europe

H. axyridis was the only known invasive alien species found in the survey reported here (see section 5.4.4) (Staverløkk 2006). The species is regarded an invasive alien species in the US, Europe and other parts of the world, and it is also listed in the newly published Norwegian Black List as one of the potential threats to biodiversity in Norway (Gederaas et al. 2007).

H. axyridis has its origin in Central- and East Asia (Iablokoff-Khnzorian 1982) and Japan (Honek 1996) and although it was introduced as a biological control agent in many parts of the world, it has not been commercially utilized in Norway (Statens landbrukstilsyn 2001). The risk assessment performed by Norwegian experts in 2001 concluded that *H. axyridis* might establish outdoors in Norway and thereby pose a risk to the environment.

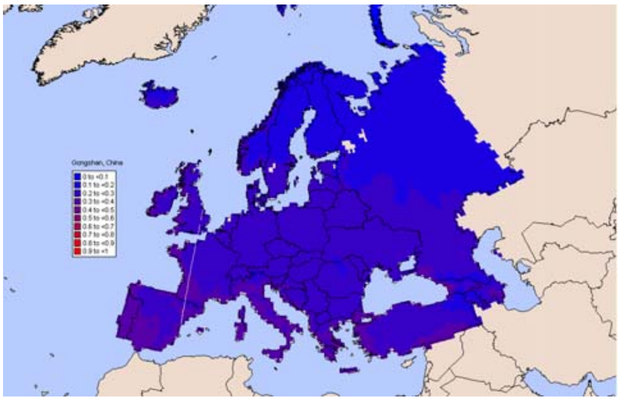
The first entry point for performing an assessment of *H. axyridis'* bioclimatic potential in Norway would be to compare the climate in its area of origin with the climate in Norway. For this comparison the Match Climates function in CLIMEX was used and the procedure and assumption made were similar to 5.10 above. The four native locations chosen for *H. axyridis* was Gongshan in southern China (25ºN and 103ºE), Vladivostok in the far East of Russia (43ºN and 134ºE), Chita in Russia (52ºN and 113ºE), and Fang'ao in eastern China (27ºN and 120ºE).

The results are shown in figure 3, and it is evident that the climate in Gongshan or Fang'ao does not match well with the climate in Norway. The climatic match between these two locations and most parts of Europe is also low. Only at some locations in southern Europe a partly climatic match can be seen with Gongshan and/or Fang'ao (figure 3). The result for Vladivostock versus Norway shows a climatic match of 40-50% for this location and the South Eastern parts of Norway (figure 3). The match between Vladivostock and the rest of Europe shows a good climatic match between this location and several European countries south of Norway (figure 3). Chita has a better climatic match with a greater part of Norway than any of the other three locations studied, and figure 3 shows that the climate matches up to 70-80% in some areas. Chita also has a good climatic match with several locations in the eastern part of Europe. This suggests that populations of *H. axyridis* from Chita is better adapted to colder climates and probably have a higher tolerance for cold stress than populations originating from Gongshan, Vladivostok or Fang'ao.

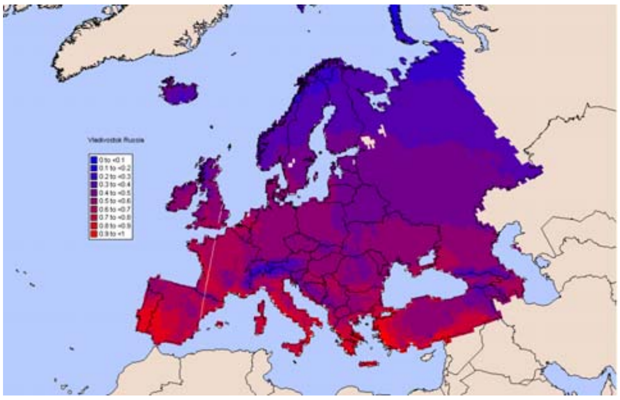
As already pointed out in 5.10 the Match Climates function does not take into account availability of host plants, preys, natural enemies or any other biological factors that will strongly influence on whether a species can succeed in establishing a population in a new environment. A number of different prey species of *H. axyridis* are available in all parts of Norway (and Europe, see Appendix 2), and the limiting factor(s) for establishment should be mainly due to unfavourable climatic conditions.

Based on the analysis conducted here the climatic conditions in several parts of Norway are within the range of bioclimatic requirements for *H. axyridis* originating from Chita, and partly also from Vladivostock, to allow the species to establish in Norway (figure 3).

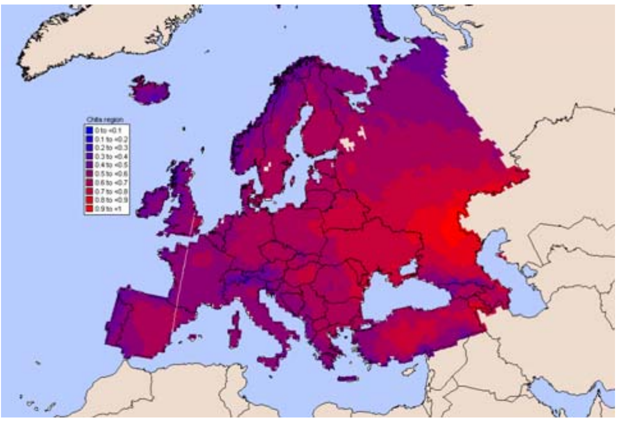
Gongshan (25ºN, 103ºE)



Vladivostok (43ºN, 134ºE)



Chita (52ºN, 113ºE)



Fang'ao (27ºN, 120ºE)

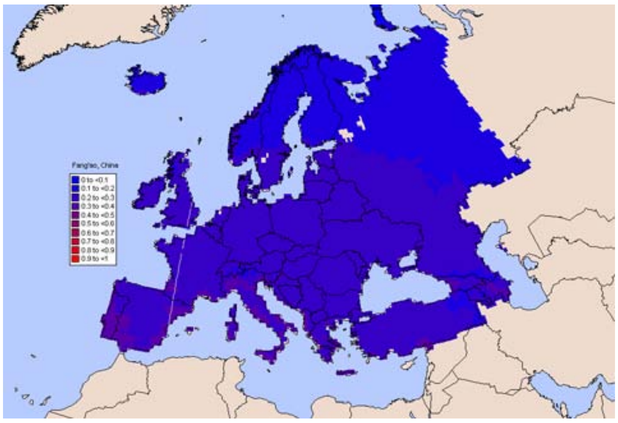


Figure 3: Comparing the climate of four locations in the area of origin of *Harmonia axyridis* **in Asia with the climate in Norway and Europe. Gongshan (southern China), Vladivostok (eastern Russia), Chita (Russia) and Fang'ao (China). Model predictions made by CLIMEX.**

5.12 Ecoclimatic indices for two populations of *H. axyridis* worldwide

For the present study, two sets of climate response parameters for *H. axyridis* was developed. One is based on the requirements for a French population while the other is based on the requirements for a population from Oregon (USA) (see the paragraphs explaining the procedure for "Climate response parameter fitting for *Harmonia axyridis* Pallas 1773" in section 4.3; and Sutherst et al. 2004).

The predictions produced by the CLIMEX model (Compare locations) when running the two parameter sets gave quite different ecoclimatic indices (EI), or potential world distribution maps, for the two populations of *H. axyridis* (figure 4 and 5).

The Oregon population is clearly adapted to tropical and subtropical climates (figure 4). The lower and upper optimal temperatures for population growth are 18ºC and 30ºC, respectively, and the limiting low and high temperatures for population growth of the Oregon population are 11.2 ºC and 34ºC, respectively. Because of the rather high temperature requirements for the Oregon population, the northern parts of Europe are not able to provide an EI above 30 (an EI of 30 or above, is regarded as a very favourable climate for a species, see also section 4.3, and Sutherst et al. 2004). There are, however, several locations in southern Europe where EI is 30 or above (figure 4). The results presented in figure 4 indicate that *H. axyridis* from populations with similar requirements as the Oregon population can establish on all continents and in a number of different countries around the world.

The temperature requirements for the French population of *H. axyridis* are much more limiting compared to the Oregon population in the sense that the range between the lower and upper optimal temperatures for population growth are very narrow: The lower optimal temperature for population growth is 20ºC while the upper optimal temperature is 25ºC. This narrow temperature range give the result that rather few locations in Europe can provide an EI close to 30, while an EI above 30 is only found in a small area in the south-west coastal parts of France (figure 5). Even if the lower limiting temperature for population growth for the French population is 10.5ºC (0.7ºC lower than for the Oregon population) most of Europe cannot provide a suitable climate for establishment of the French population of *H. axyridis*. In addition, the limiting high temperature for population growth for the French population is 30ºC, which also excludes tropical climates (figure 5).

The results presented in Figure 4 and 5 show that several countries in Europe where *H. axyridis* is known to occur, i.e. Belgium, The Netherlands, Germany, Luxemburg and UK (Adriens et al. 2001, Roy et al. 2006), are not included in figure 4 or 5 as countries/locations providing a favourable climate for the species to maintain a population over time (i.e. an EI of 30 or above).

Now, what is the explanation for the discrepancies between model predictions and observed distribution of the species? When working with climate response models the process of estimating climate response parameters for a species is a common problem: In this study, we estimated two sets of climate response parameters for two different populations of *H. axyridis* (France and Oregeon). Our estimation were based on publications about biology/ecology and experiments conducted with the respective populations (Schanderl et al. 1985, LaMana & Miller 1998, Iperti & Bertand 2001, Watanabe 2002, Soares et al. 2003, Koch et al. 2004, Honek et al. 2007). This approach can be very precise, but the results obtained will only apply close to 100% for the population(s) actually tested. The procedure does not take into account that the species involved may be very adaptable to changing conditions and have a high ecological plasticity, which can highly influence on some of the parameters estimated (for instance limiting upper and lower temperatures for population growth).

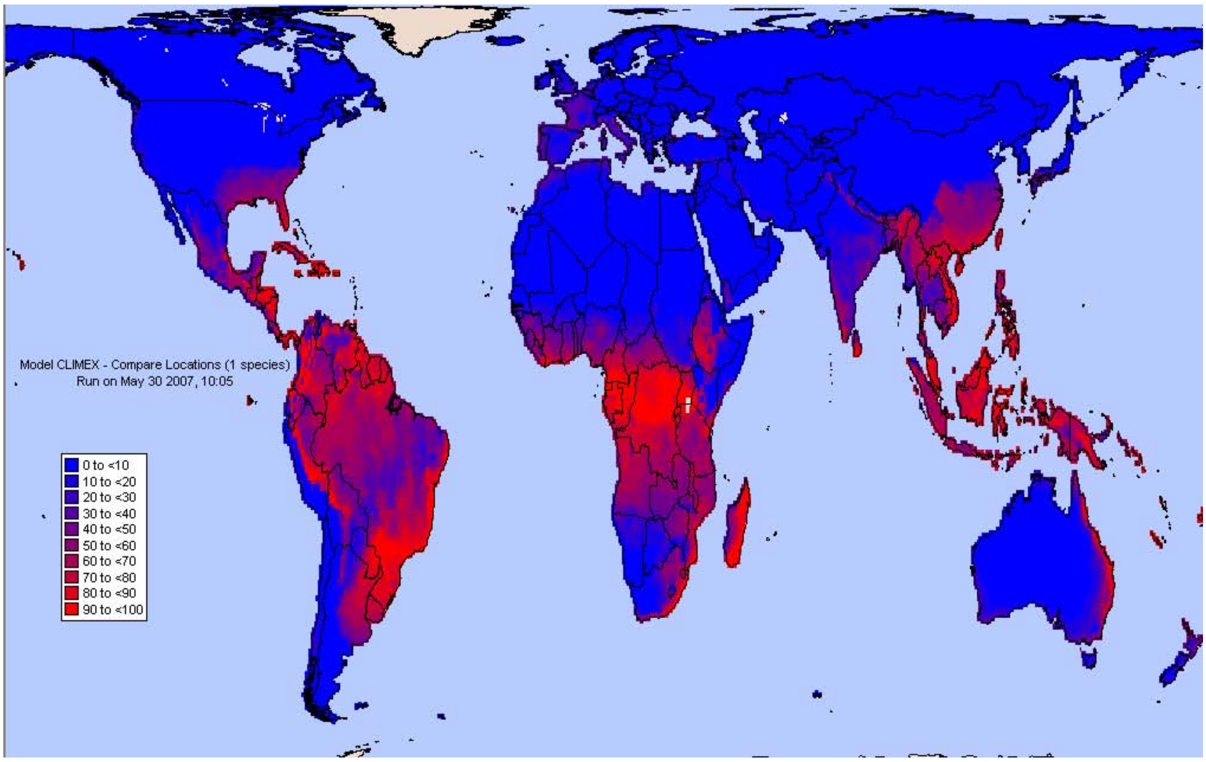


Figure 4: Worldwide ecoclimatic indices (EIs) for *Harmonia axyridis*. Climatic response parameters based on the requirements for a population of *H. axyridis* from Oregon (USA). Model predictions made by CLIMEX.

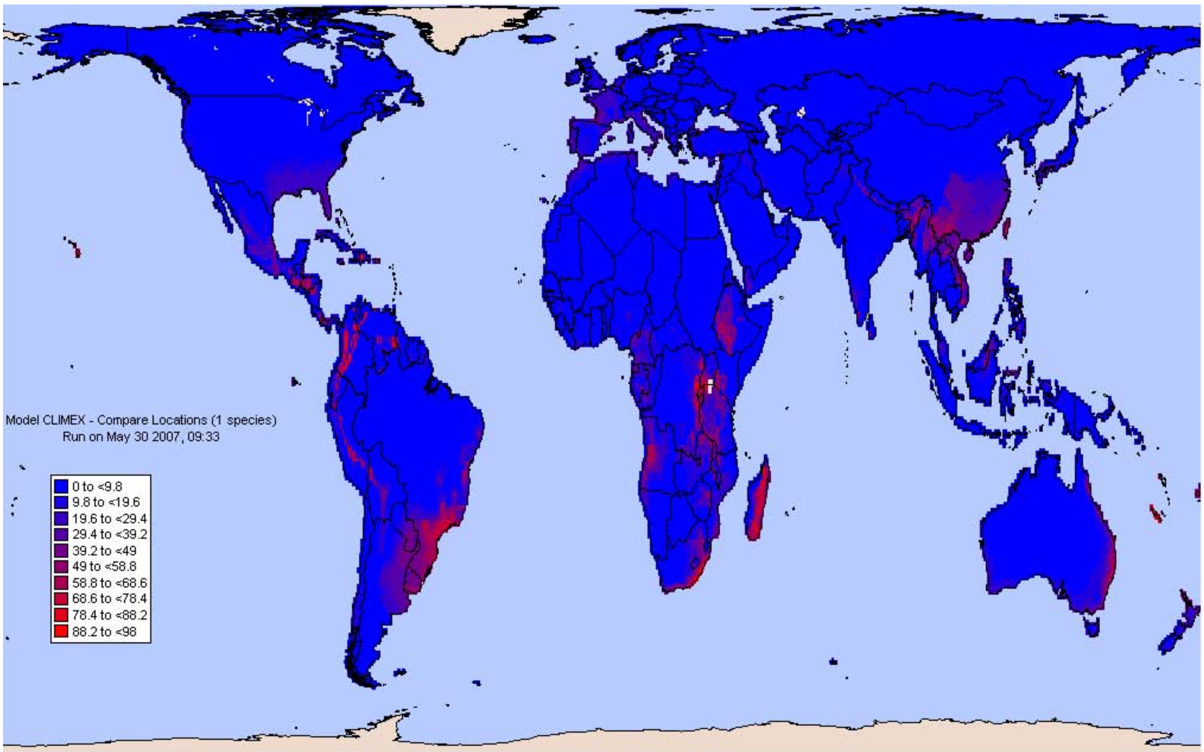


Figure 5: Worldwide ecoclimatic indices (EIs) for *Harmonia axyridis*. Climatic response parameters based on the requirements of a French population of *H. axyridis*. Model predictions made by CLIMEX.

Another approach for estimating climate response parameters for a species is to use the observed geographical distribution of the species to estimate the parameters needed. The limitation of this approach is that it is uncertain whether the species geographical distribution is an expression of its climatic tolerance, or whether it is only an expression of how far it has had time to spread or to adapt (Rafoss & Sæthre 2003). A single approach or a combination of the two approaches for parameter estimation mentioned here can be applied, and in either case the information obtained can be used to update our information base on quantitative biology of the species involved (Rafoss & Sæthre, 2003).

The surveillance program in the UK emphasizing on monitoring further spread of *H. axyridis* on the island is very interesting in this connection: The UK population seems to thrive in a cooler climate than the two populations from France and Oregon. The data achieved in the UK could contribute to create a refined set of climate response parameters for this particular population of *H. axyridis*. The climate in many parts of the UK is comparable to the climate in coastal northern Europe, including several parts of Norway. Climate response parameters for the UK population of *H. axyridis* would therefore provide useful information on both the climatic adaptability of *H. axyridis* as well as contribute to produce more accurate model predictions for countries with similar climate as in the UK.

5.13 Ecoclimatic indices for two populations of *H. axyridis* in Norway

In this section the Norwegian agrometeorological data were used to produce ecoclimatic indices (EIs) for both the French population and the population from Oregon of *H. axyridis* in Norway. As explained in 4.3 the agrometeorological data is more representative for agroecological zones, private gardens and urban areas in Norway than the more general meteorological data stored in CLIMEX. The two sets of climatic parameters developed for *H. axyridis* is used and the CLIMEX model (Compare locations) run both under "current climate scenario" and under "greenhouse climate scenario" for the two respective populations (figure 6 and 7).

Current climate scenario

Model predictions for *H. axyridis* gave different EIs under current climate scenario for both populations of the species when applying agrometeorological data from 47 locations in Norway compared to the results obtained in 5.12 above (compare figure 4 and 5 with figure 6). A list of EIs for each location are given in appendix 3, and as can also be seen from figure 6 it is the coastal parts of south-western Norway that shows EIs above zero for both populations. This confirms the initial idea that it is coldstress (winter temperatures) is a limiting factor for the species at higher latitudes. This idea was further supported by studying the background material produced by CLIMEX and used for calculation of EIs for the respective locations. This material revealed that in eastern Norway it was mainly cold stress that caused the EIs to be zero, while in coastal areas the lower temperatures for optimal population growth (in the summer) was not reached to produce higher EIs than those seen in figure 6 and appendix 3.

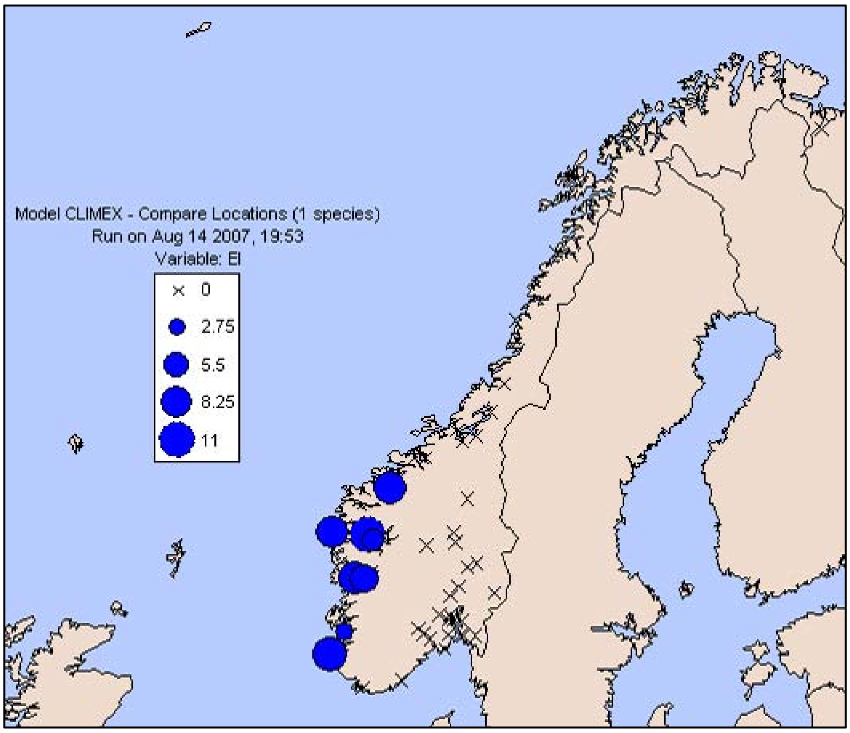
The climate in Norway can be roughly divided into two climatic subzones (Aune 1993). The western subzone is characterised by cool summers and mild winters, and most of the precipitation comes during autumn. The eastern subzone is characterised by warm summers and relatively low winter temperatures, and most precipitation comes during summer.

When looking at the EIs for the respective locations (Appendix 3) and the upper map in figure 6 it can be seen that the predicted EIs for the French population of *H. axyridis* were in the range 0-11, while the predicted EIs for the population from Oregon (lower map in figure 6) were in the range 0-13. This indicates that the current climate in Norway is not optimal for general establishment of the species, but that suboptimal microclimates for the species most certainly can be found at protected locations particularly in the coastal areas of the south-west.

Greenhouse climate scenario

Model predictions for *H. axyridis* under greenhouse climate scenario gave increased EIs for both populations of the species compared to the current climate scenario (compare figure 6 with figure 7).It was, however, still only locations along the coastal area of western Norway that showed EIs above zero (figure 7, appendix 3). An increase in temperature of one degree Celsius lowered the cold stress in eastern Norway, but not to a level that could be ignored by the model (according to the requirements set for the species).

When checking EI for each location (Appendix 3) and the lower map in figure 7 it can be seen that the predicted EIs for the French population of *H. axyridis* were in the range 0-18, while the predicted EIs for the population from Oregon (lower map in figure 7) were in the range 0-22. This indicates that the greenhouse climate scenarios for Norway is close to optimal for establishment of the species at some



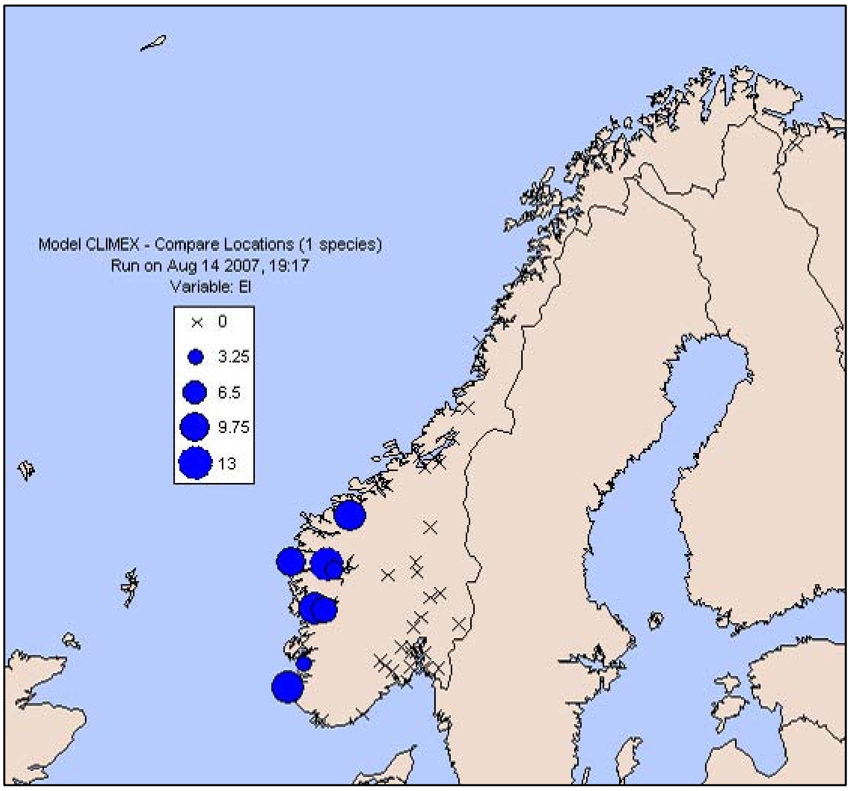
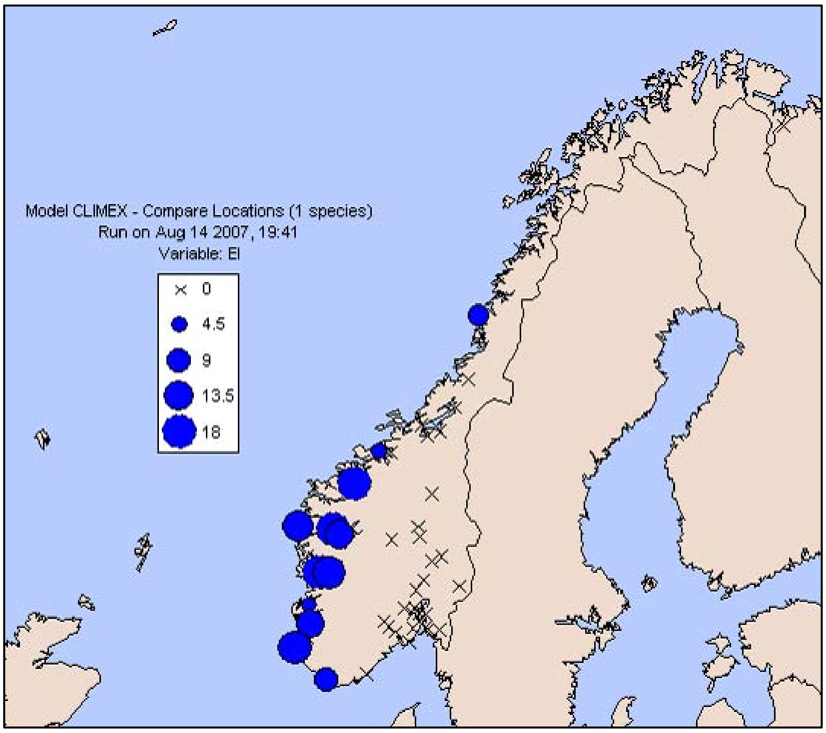


Figure 6: Ecoclimatic indices (EIs) for two populations of *Harmonia axyridis* **in Norway under the current climate. Climatic response parameters based on the requirements of a population of** *H. axyridis* **from France (upper map) and a population of** *H. axyridis* **from Oregon (USA) (lower map). Model predictions made by CLIMEX.**



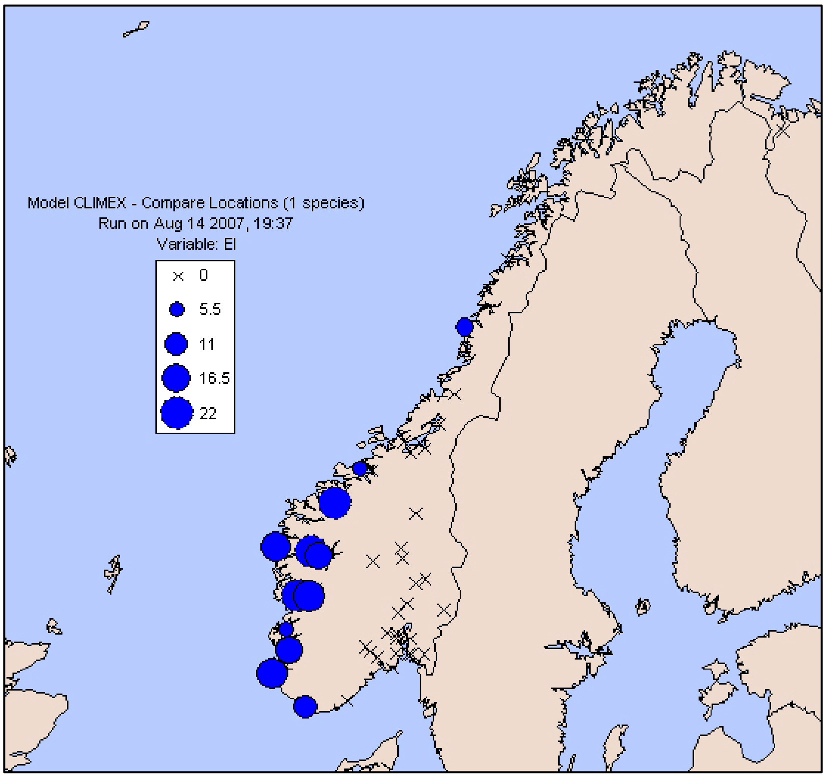


Figure 7: Ecoclimatic indices (EIs) for two populations of *Harmonia axyridis* in Norway under the greenhouse climate scenario (+1ºC). Climatic response parameters based on the requirements of a population of *H. axyridis* from France (upper map) and a population of *H. axyridis* from Oregon (USA) (lower map). Model predictions made by CLIMEX.

locations, and that suboptimal and optimal microclimates for the species will be available at protected locations in southern Norway (figure 7, appendix 3).

Conclusion for *H. axyridis*

The rapid spread of *H. axyridis* in Europe and elsewhere points to the conclusion that this is a species with extreme ecological plasticity. Another well-known species with an outstanding history of acclimatization and migration is the codling moth, *Cydia pomonella*, a worldwide pest of apples (Shel'deshove 1967). In the case of *C. pomonella* it was concluded that its original geographical distribution was determined by host plants rather than by climatic conditions. It is likely to conclude that *H. axyridis* is a species with similar capacity and ecological plasticity as *C. pomonella* and will continue to adapt to new climatic conditions and thereby continue to increase its distribution into new geographic areas.

Further, the presence of *H. axyridis* is confirmed in northern parts of USA (Koch & Hutchinson 2003) and southern Canada (Coderre et al. 1995, McCorquodale 1998 in Koch 2006) where minimum air temperatures can exceed the minimum supercooling points, which should be lethal to *H. axyridis*. Therefore local air temperature alone appears to be a poor predictor of the distribution of *H. axyridis*. *H. axyridis* adults most likely find microclimates for overwintering that provide protection from extreme low temperatures (Koch et al. 2004). The capacity of *H. axyridis* to survive winter conditions in northern locations may therefore be more related to the availability of quality overwintering sites than to its capacity to increase cold hardiness (Koch et al. 2004).

Figure 8: ***Harmonia axyridis*** **Pallas. Will this species become the most abundant lady beetle in Norway in a few years? (Photo: A. Staverløkk)**

6. Conclusions

Due to globalization alien species are spread with a speed that we have never seen before, and Norway being no exception in this context. The study and results reported here shows that the steadily increasing import of horticultural plants is a groing threat to biodiversity and a number of organisms are imported as stowaways in connection to this trade. In addition, it may cause problems for the domestic plant nursery industry as new plant pests also can be among these organisms. Such pests may as well pose problems for the management of parks, public areas, and private gardens, and eventually be the cause of increased pesticide use. Climate change will only accelerate these changes in northern latitudes.

The National Plant Protection Organisation, known as the Norwegian Food Safety Authority (Mattilsynet), is responsible for controlling the import of these plants. However, the control is not sufficient to avoid the spread and introduction of new species and the experiences from our investigation suggests that we have only seen the tip of the iceberg.

How can we stop this negative trend?

Plants with a lump of soil should not be allowed imported at all, as it brings along more organisms and is far more unpredictable than plants without soil or plants grown in an artificial medium.

Conifers and plants of a certain size should be thoroughly inspected before they are released in nature as they offer excellent hiding places for many organisms.

Would it be more efficient to carry out inspections at the export site rather than at the import site?

Mattilsynet needs to strengthen the phytosanitary part of their organisation, as the inspectors per today only are able to actually inspect a very small fraction of the numerous tons of plants imported every year.

Inspectors must be given authority (and the confidence) allowing them to consider biodiversity just as important as plant quarantine issues when carrying out their duties.

The ecological risk must be taken serious by our authorities, and necessary resources need to be allocated to develop better routines for this particular trade. There are numerous examples from Norway and the rest of the world that after establishment of a new species the resources needed to eradicate it are often too high for the society to pay.

Norway now has a national strategy to combat harmful alien species and it is only to hope that this strategy is carried forward to action immediately.

7. References

Adriaens, T., Branquart, E. & Maes, D. 2003. The Multicoloured Asian Ladybird Harmonia axyrids Pallas (Coleoptera : Coccinellidae), a threat for native aphid predators in Belgium? Belgian journal of zoology. 133, 195-196.

Alexander, N. A. K. 2002. Epitrix pubescens (Koch, J.D.W.) (Chrysomelidae) and other species spreading westwards across Gloucestershire. Coleopterist 11, 102.

Allan, A. A. 1984. Epitrix pubescens Koch (Coleoptera: Chrysomelidae) in W. Norfolk. Entomologist's record and journal of variation 96, 36-37.

Allan, A. A. 1988. Epitrix pubescens Koch (Coleoptera: Chrysomelidae) in West Kent. E Entomologist's record and journal of variation. 100, 84.

Andersson, G., Meidell, B. A., Scheller, U., Winqvist, J.-Å., Osterkamp Madsen, M., Djursvoll, P., Budd, G. & Gärdenfors, U. (2005) Nationalnyckeln till Sveriges flora och fauna. Mångfotingar Myriapoda. 351 pp. ArtDatabanken, SLU, Uppsala, Sweden.

Andrewartha, H.G. & Birch, L.E. 1954. The distribution and Abundance of Animals. University of Chicago Press, Chicago.

Aune, B. 1993. Nasjonal atlas for Norge. Hovedtema 3. Luft og vann. Klima (Climate), pp. 1-64. Statens Kartverk, Hønefoss.

Baniecki, J. F., Dabaan, M. E., Freeborn, J., Cheves, B. & Richmond, D. 2004. Multicolored Asian Lady Beetle (Harmonia axyridis). West Virginia University Extension Service publication. http://www.wvu.edu/~agexten/ipm/insects/ladybeetle.htm Accessed: 11-2006

Baker, R., Cannon, R., Bartlett, P. & Barker, I. 2005. Novel strategies for assessing and managing the risks posed by invasive alien species to global crop production and biodiversity. Annals of Applied Biology. 146, 177-191.

Baranowski, R. & Gärdenfors, U. 1974. Vinddrift av jordlöpare i sydöstra Skåne. Entomologen 3, 35-52.

Biström, O. 2004. Harpalus signaticornis (Duftschmid), a new carabid species from Estonia (Coleoptera: Carabidae). Sahlbergia 9, 129-130.

Brown, M. W. & Miller, S. S. 1998. Coccinellidae (Coleoptera) in apple orchards of eastern west Virginia and the impact of invasion by Harmonia axyridis. Entomological news. 109, 143-151.

Buckland P.I. & Buckland P.C. 2006. Bugs Coleopteran Ecology Package (Versions: BugsCEP v7.63; Bugsdata v7.11; BugsMCR v2.02; BugStats v1.22) [Downloaded/CDROM: 05-2007] www.bugscep.com Accessed: 05-2007.

Colunga-Garcia, M. & Gage, S. H. 1998. Arrival, establishment, and habitat use of the multicouloured Asian lady beetle (Coleoptera : Coccinellidae) in a Michigan landscape. Environmental entomology. 27, 1574-1580.

Coderre, D., Lucas, E. & Gagnè, E. 1995. The occurrence of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). Proceedings of the Entomological Society of Washington. 93, 630-635.

Cook, W.C. 1929. A bioclimatic zonation for studying the economic distribution of injurious insects. Ecology, 10, 282-293.

Day, W. H., Prokrym, D.R., Ellis, D.R. & Chianese, R.J. 1994. The known distribution of the predator Propylea quatuordecimpunctata (Coleoptera: Coccinellidae) in the United States, and thoughts on the origin of this species and five other exotic lady beetles in eastern North America. Entomological news. 105, 224–256.

de Almeida, L.M. & da Silva, V.B. 2002. First record of *Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae): a lady beetle native to the Palaearctic region. Revista Brasileira de Zoologia. 19, 941–944.

De Clercq, P. 2000. Predaceous Stinkbugs pp.737-789 in Schaefer, C.W. & Panizzi, A.R. 2000 (eds.). Heteroptera of economic importance. CRC Press, Boca Raton, Florida.

Disney, R.H.L. 1997. A new species of Phoridae (Diptera) that parasitises a wide-spread Asian ladybird beetle (Coleoptera: Coccinellidae). The Entomologist. 116, 163–168.

Ejbich, K. 2003. Producers in Ontario and northern U.S. bugged by bad odors in wine. Wine spectator. 16.

Elliot, N., Kieckhefer, R. & Kauffman, W. 1996. Effects of an invading coccinellid on native coccinellids in an agricultural landscape. Oecologia. 105, 537-544.

EPPO 2006. Sucessfully introduced classical biological control agents: Insecta, Coleoptera http://archives.eppo.org/EPPOStandards/biocontrol_web/classical/coleop_class.htm Accessed: 04 -2007

FAO. 2007. Glossary of phytosanitary terms. ISPM No. 05. https://www.ippc.int/servlet/CDSServlet?status=ND0xMzM5OSY2PWVuJjMzPSomMzc9a29z Accessed: 05-2007

Fauna Europaea 2006. http://www.faunaeur.org/ Accessed: 05-2007.

Ferran, A., Niknam, H., Kabiri, F., Picart, J.L., Herce, Cd., Brun, J., Iperti, G. & Lapchin, L. 1996. The use of *Harmonia axyridis* larvae (Coleoptera: Coccinellidae) against *Macrosiphum rosae* (Hemiptera: Sternorrhyncha: Aphididae) on rose bushes. European Journal of Entomology (České Budějovice). 93, 59–67.

Fischer, S. & Leger, A. 1997. Biological control of aphids on cucumbers grown in greenhouses using banker plants. Revue suisse de viticulture, arboriculture, horticulture. 29, 119–126.

Fisher, A. C. & Hanemann, W. M. 1986. Option value and the extinction of species. Advances in applied microeconomics. 4, 169-190.

Gederaas, L., Salvesen, I. & Viken, Å. (red.) 2007. 2007 Norwegian Black List – Ecological Risk Analysis of Alien Species. 152 pp. Artsdatabanken, Norway.

Gordon, R.D. 1985. The Coleoptera (Coccinellidae) of America north of Mexico. J.N.Y. Entomol. Soc. 93, 1–912.

Grill C.P., Moore, A.J. & Brodie, E.D. 1997. The genetics of phenotypic plasticity in a colonizing population of the ladybird beetle Harmonia axyridis. Heredity (Edinb., Print). 78, 261-269.

Hågvar, S. 2005. Altitudinal zonation of ants (Formicidae) in steep fjord landscape in Sogndal, Western Norway. Norw. J. Entomol. 52, 3-12.

Halstead, A.J. 1998. Two flea beetles feeding on Solanum crispum. Br. j. entomol. nat. hist. 11, 30.

Hammond, P.M. 1974. Changes in the British Coleopterous Fauna. Pp. 323-36 in Hawksworth, D.L. (ed.) The Changing Flora and Fauna of Britain. Systematics Association Special Volume No. 6, 9. Academic Press, London.

Harde, K.W. 1984. A field-guide in colour to beetles. 116 pp. London, Octopus Books.

Hesler, L.S., Keickhefer, R.W. & Beck, D.A. 2001. First record of Harmonia axyridis (Coleoptera: Coccinellidae) in South Dakota and notes on its activity there and in Minnesota. Entomological news. 112, 264–270.

Hodge, P. J. & Jones, R. A. 1995. New British Beetles: species not in Joy's practical handbook. Pp.175. British Entomological and Natural History Society.

Hodek, I. & Honek, A. 1996. Ecology of Coccinellidae. Kluwer Academic, Dordrecht.

Hodek, I. 1996. Food relationships. Pp. 143–238 in Hodek, I. & Honek, A. (eds.) Ecology of Coccinellidae. Kluwer Academic, Dordrecht.

Honek, A. 1996. Life history and development. Pp. 61–93. in Hodek, I. & Honek, A. (eds.) Ecology of Coccinellidae. Kluwer Academic, Dordrecht.

Hironori, Y. & Katsuhiro, S. 1997. Cannibalism and interspecific predation in two predatory ladybirds in relation to prey abundance in the field. Entomophaga. 42, 153–163.

Hoogendoorn, M. & Heimpel, G.E. 2002. Indirect interactions between an introduced and a native ladybird beetle species mediated by a shared parasitoid. Biological control. 25, 224–230.

Hough-Goldstein, J.C.J., Armstrong, A. 1996. *Podisus maculiventris* (Hemiptera: Pentatomidae) predation on ladybird beetles (Coleoptera: Coccinellidae). Florida Entomologist. 79, 64–68.

Huelsman, M.F., Kovach, J., Jasinski, Young, J.C. & Eisley, B. 2002. Multicolored Asian lady beetle (Harmonia axyridis) as a nuisance pest in households in Ohio. Pp. 243-250. In Proceedings of the 4th International Conference on Urban Pests, 7-10 July 2002, Charleston, South Carolina. Pocahontas Press, Blacksburg, Virginia.

Iablokoff-Khnzorian, S.M. 1982. Les coccinelles Coléoptères-Coccinellidae: Tribu Coccinellini des régions Paléarctique et Orientale. 568pp. Société Nouvelle des Éditions Boubée, Paris.

Iperti, G. & Bertand, E. 2001. Hibernation of Harmonia axyridis (Coleoptera: Coccinellidae) in South-Eastern France. Acta Soc. Zool. Bohem. 65, 207–210.

Javahery, M. 1967. The biology of some Pentatomidae and their egg parasites. In Schaefer, C. W. & Panizzi, A.R. 2000 (eds.). Heteroptera of economic importance. CRC Press, Boca Raton, Florida.

Joy, N.H. 1932. A Practical Handbook of British Beetles. Pp. 622. Reprinted by E.W. Classey Ltd. Faringdon (1979).

Kålås, J.A., Viken, Å. & Bakken, T. (Eds.) 2006. Norsk Rødliste 2006 – 2006 Norwegian Red List. Artsdatabanken, Norway, pp 416.

Kalaskar, A. & Evans, E.W. 2001. Larval responses of aphidophagous lady beetles (Coleoptera: Coccinellidae) to weevil larvae versus aphids as prey. Ann. Entomol. Soc. Am. 94, 76–81.

Kangas, E. 1945. Ein Vertreter der sibirischen Coccinellidenfauna (Col.) in Finnland. Ann. entomol. Fenn. 11, 63-67.

Katsoyannos, P., Kontodimas, D.C., Stathas, G.J. & Tsartsalis, C.T. 1997. Establishment of *Harmonia axyridis* on citrus and some data on its phenology in Greece. Phytoparasitica. 25, 183–191.

Kidd, K.A., Nalepa, C.A., Day, E.R. & Waldvogel, M.G. 1995. Distribution of Harmonia axyridis (Pallas) (Coleoptera:Coccinellidae) in North Carolina and Virginia. Proceedings of the Entomological Society of Washington. 97, 729–731.

Koch, K. 1989. Ökologie 1. Die Käfer Mitteleuropas, Band E1. Pp. 440. Goecke & Evers, Krefeld.

Koch, K. 1992. Ökologie 3. Die Käfer Mitteleuropas, Band E3. Pp. 389. Goecke & Evers, Krefeld.

Koch R. L. & Hutchison W. D. 2003. Multicolored Asian lady beetle. Vegetable pest fact sheets, VegEdge Web site, Dept. of Entomology. University of Minnesota Extension Service St. Paul, MN

Koch, R.L. 2003. The multicolored Asian lady beetle, Harmonia axyridis: A review of its biology, uses in biological control, and non-target impacts. 16 pp. J. Insect Sci. 3, 32. Available online: http://insectscience.org/3.32 Accessed: 04-2007

Koch R. L., Burkness E. C., Wold Burkness S. J.& Hutchison W. D. 2004. Phytophagous preferences of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) to autumn ripening fruit. J. Econ. Entomol. 97, 539–544.

Koch, R.L., Carrillo, M.A., Venette, R.C., Cannon, C.A & Hutchison W.D. 2004. Cold hardiness of the multicolored Asian lady beetle (Coleoptera: Coccinellidae). Environmental entomology 33, 815-822.

Koch, R.L. & Hutchison, W.D. 2003. Phenology and blacklight trapping of the multicoloured Asian lady beetle (Coleoptera: Coccinellidae) in a Minnesota agricultural landscape. J. Entomol. Sci. 38, 477–480.

Koch, R.L., Hutchison, W.D., Venette, R.C. & Heimpel, G.E. 2003. Susceptibility of immature monarch butterfly, Danaus plexippus (Lepidoptera: Nymphalidae: Danainae), to predation by Harmonia axyridis (Coleoptera: Coccinellidae). Biological control (Print). 28, 265–270.

Koch, R., Venette, R.C. & Hutchison, W. D. 2006. Invasions by Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: Implications for South America. Neotrop. entomol. 35, 421-434.

Kovach, J. 2004. Impact of multicolored Asian lady beetles as a pest of fruit and people. Am. Entomol. 50, 159-161.

Labrie, G., Lucas, E. & Coderre, D. 2006. Can Developmental and Behavioral Characteristics of the Multicolored Asian Lady Beetle Harmonia Axyridis Explain its Invasive Success? Biological Invasions. 8, 743-754.

LaMana, M.L. & Miller, J.C. 1996. Field observation on Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae) in Oregon. Biological control. 6, 232–237.

LaMana, M.L. & Miller, J.C. 1998. Temperature-dependent development in an Oregon population of Harmonia axyridis (Coleoptera: Coccinellidae). Environmental entomology. 27, 1001–1005.

Lindroth, C. H. 1986. The Carabidae (Coleoptera) of Fennoscandia and Denmark. Vol. 15, part 2. 497pp. Fauna Entomologica Skandinavica, Leiden, Copenhagen.

Lovdata. 2000. Forskrift om planter og tiltak mot planteskadegjørere: http://www.lovdata.no/for/sf/ld/ld-20001201-1333.html Accessed: 05-2007.

Lucas, E., Coderre, D. & Vincent, C. 1997. Voracity and feeding preferences of two aphidophagous coccinellids on Aphis citricola and Tetranychus urticae. Entomologia experimentalis et applicata (Print). 85, 151–159.

Lundberg, S. 1984. Den brända skogens skallbaggsfauna I Sverige. Entomologisk Tidsskrift 105, 129-141.

Majerus, M., Strawson, V. & Roy, H. 2006. The potential impacts of the arrival of the harlequin ladybird, Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae), in Britain. Ecological entomology (Print) 31, 207–215.

McClure, M.S. 1986. Role of predators in regulation of endemic populations of *Matsucoccus matsumarae* (Homoptera: Margarodidae) in Japan. Environmental Entomology. 15, 976–983.

McCutcheon, T. W. & Scott, H.R. 2004. Observation of Cosmetic Damage on a House Caused by the Multicolored Asian Lady Beetle, Harmonia axyridis (Coleoptera: Coccinellidae). Unpublished Report. West Virginia University Extension Service. http://www.wvu.edu/~agexten/ipm/insects/beetle.pdf. Accessed: 05-2007.

Meats, A. 1989. Bioclimatic potential. World crop pests. Fruit Flies: Their Biology, Natural Enemies and Control (eds. Robinson, A.S. & Hooper, G.), pp. 241-252. Elsevier, Amsterdam.

Michaud, J.P. 2000. Development and reproduction of ladybeetles (Coleoptera: Coccinellidae) on the citrus aphids Aphis spiraecola Patch and Toxoptera citricida (Kirkaldy) (Homoptera: Aphidae). Biological control. 18, 287–297.

Mizell, R.F. 2001. Multicolored Asian Lady Beetle, Harmonia axyridis Pallas (Insecta: Coleoptera: Coccinellidae). Pp.4. EENY-04 (IN361), one of a series of Featured Creatures from the Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu/IN361.

Mooney, H.A. 2005. Invasive Alien Species: The nature of the Problem. In: Mooney, H.A., Mack, R.N., McNeely, J.A., Neville, L.E., Schei, P.J. & Waage, J.K. (Eds.): Invasive Alien Species – A New Synthesis. Island Press, Washington DC, USA. 1-15.

Moraes, M. C. B., Laumann, R.A., Cokl, A. & Borges, M. 2005. Vibratory signals of four Neotropical stink bug species. Physiological entomology (Print). 30, 175-188.

Nakata, T. 1995. Population fluctuations of aphids and their natural enemies on potato in Hokkaido. Applied entomology and zoology. 30, 129–138.

Nalepa, C.A., Kidd, K.A., Ahlstrom, K.R. 1996. Biology of Harmonia axyridis (Coleoptera: Coccinellidae) in winter aggregations. Annals of the Entomological Society of America. 89, 681–685.

Nalepa, C.A., Kidd, K.A. & Hopkins, D.I. 2000. The multicolored Asian ladybeetle (Coleoptera: Coccinellidae): Orientation to aggregation sites. Journal of entomological science. 35, 150–157.

Nalepa, C.A. & Kidd, K.A. 2002. Parasitism of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) by Strongygaster triangulifera (Diptera: Tachinidae) in North Carolina. Journal of entomological science. 37, 124–127.

Nash, T.A.M. 1933. A statistical analysis of the climatic factors influencing the density of tsetse flies, Glossina mortisans West. Journal of Animal Ecology, 2, 197-203.

NGF 2006. Norwegian Horticultural Growers Association, unpublished statistics.

Obata S. 1986a. Determination of hibernation site in the ladybird beetle, *Harmonia axyridis* Pallas (Coleoptra, Coccinellidae). Kontyu. 54:218–223.

Ødegaard, F. 2006. Impact factors and environmental status. Pp. 61-94 in Kålås, J.A., Viken, Å. & Bakken, T. (ed.) – 2006 Norwegian Red List. Artsdatabanken, Norway.

Palm, E. 1996. Nordeuropas snudebiller: 1. De kortsnudede arter (Coleoptera: Curculionidae) – med særligt henblik på den danske fauna. – Danmarks dyreliv 7, 356 pp. Apollo Books, Stenstrup.

Panizzi, A.R., McPherson, J.E., James, D.G., Javahery, M. and McPherson, R.M. Pp.421-474 in Schaefer and Panizzi (eds.) Heteroptera of Economic Importance. CRC Press. Boca Raton, Florida.

Pickering, G., J. Lin, R. Riesen, A. Reynolds, I. Brindel & G. Soleas. 2004. Influence of Harmonia axyridis on the sensory properties of white and red wine. American journal of enology and viticulture. 55, 153-159.

Pimentel, D., Lach, L., Zuniga, R. & Morrison, D. 1999. Environmental and economic costs associated with non-indigenous species in the United States. http://www.news.cornell.edu/releases/Jan99/species-costs.html. Accessed: 02.03.2006.

Rafoss, T. & Sæthre, M.-G. 2003. Spatial and temporal distribution of bioclimatic potential for the Codling moth and the Colorado potato beetle in Norway: model predictions versus climate and field data from the 1990s. Agricutural and Forest Entomology. 5, 75-85.

Roy, H.E., Brown, P. & Majerus, M. 2006 Harmonia axyridis: A successful biocontrol agent or an invasive threat? Pp.295-309 in Eilenberg, J. & Hokkanen, H. (eds.) An ecological and societal approach to biological control. Kluwer Academic Publishers, Netherlands.

Sæthre, M.-G. & Hofsvang, T. 2005. Diurnal flight activity of the codling moth, *Cydia pomonella*, (Lepidoptera: Tortricidae) males in relation to temparature and twilight. Norwegian Journal of Entomology. 52, 75-90.

Sæthre, M.-G., Hermansen, A. & Nærstad, R. 2006. Economic and Environmental impacts of the introduction of Western flower thrips (*Frankliniella occidentalis*) and Potato late blight (*Phytopthora infestans*) to Norway. Bioforsk Report, Vol. 1 No. 64 2006. pp 35 + appendix.

Sakurai, H., Kawai, T. & Takeda, S. 1992. Physiological changes related to diapause of the lady beetle, Harmonia axyridis (Coleoptera: Coccinellidae). Applied entomology and zoology. 27, 479–487.

Schaefer, P.W., Dysart, R.J., Specht, H.B. 1987. North-American distribution of Coccinella septempunctata and its mass appearance in coastal Delaware. Environmental Entomology 16, 368-373.

Schaefer, C.W., Panizzi, A.R. 2000. Heteroptera of Economic Importance. 828 pp. CRC Press. Boca Raton, Florida,

Schanderl, H., Ferran, A., Larroque, M. 1985. Les besoins trophiques et thermiques des larves de la coccinelle Harmonia axyridis Pallas. Agronomie 5, 417-421.

Scudder, G.G.E. & Eyles, A. C. 2003. Heterogaster urticae (Hemiptera: Heterogastridae), a new alien species and family to New Zealand. Weta (Up. Hutt). 25, 8-13.

Settle, W. H., and L. T. Wilson. 1990. Invasion by the variegated leafhopper and biotic interactions: parasitism, competition, and apparent competition. Ecology. 71, 1461-1470.

Shel'deshova, G.G. 1967. Ecological factors determining distribution of the codling moth Laspeyresia pomonella L. (Lepidoptera, Tortricidae) in the northern and southern hemispheres. Entomologal Review. 46, 349-359.

Silfverberg, H. 2004. Enumeratio nova Coleopterorum Fennoscandiae, Daniae et Baltiae / Dokumentet er del av serien Sahlbergia. 9,1. 111 pp. Helsinki : Luonnontieteellinen keskusmuseo.

Sivertsen, T.H. 2000. Weather information, site information and a system for dissemination of information on the Worldwide Web from a network of 52 automatic agrometeorological stations. Bull. OEPP/EPPO Bull. 30, 77-81.

Soares, A.O., D. Coderre & H. Schanderl. 2003. Effect of temperature and intraspecific allometry on predation by two phenotypes of *Harmonia axyridis* Pallas (Coleptera: Coccinellidae) Environmental entomology. 32: 939-944

Southwood, T.R.E. & Leston, D. 1959. Land and Water Bugs of the British Isles. 436 pp. Warne, London. CD-ROM.

Statens landbrukstilsyn. 2001. Vurdering av *Harmonia axyridis*. Seksjon plantevernmidler. Internt arbeidsdokument.

Staverløkk, A., 2006. Occurrence of alien species and other unwanted stowaways in imported horticultural plants. M.Sc. thesis, pp. 111. Department of Ecology and Natural Resources Management (INA), University of Life Sceinces (UMB), Norway.

Stichel, W. 1958. Illustrierte Bestimmungstabellen der Wanzen. II. Europa (Hemiptera-Heteroptera Europae). Stichel, Berlin. Hermsdorf. 4, 129-160.

Stuart, R.J., Michaud, J.P., Olsen, L., McCoy, C.W. 2002. Lady beetles as potential predators of the root weevil *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in Florida citrus. Florida Entomologist. 85, 409–416.

Sutherst, R.W. Maywaki, G.F. and Skarratt, D.B. 1995. Predicting insect distributions in a changed climate. *Insects in a changing Environment.* (ed. By Harrington, R. & Stork, N.E.) pp. 59-91. Academic Press, London.

Sutherst, R.W. Maywald, G.F., Bottomley, W. & Bourne, A. 2004. CLIMEX v2, User's Guide.CSIRO 2004, Hearne Scientific Software Pty Ltd, Melbourne, Australia. pp 100.

Takahashi, K. 1987. Differences in oviposition initiation and sites of lady beetle, Coccinella septempunctata bruckii Mulsant and Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae) in the field. Japanese Journal of Applied Entomology and Zoology 31, 253-254.

Tedders, W.L. & Schaefer, P.W. 1994. Release and establishment of Harmonia axyridis (Coleoptera: Coccinellidae) in the southeastern United States. Entomological news. 105, 228–243.

Tempere, G. 1979. Will the australian lathridian coleoptera Aridius bifasciatus invade Europe? Entomologiste (Paris). 35, 67-69.

The UK Ladybird Survey. http://www.ladybird-survey.org/ Accessed: 04-2007

Toccafondi, P., Covassi, M. & Pennacchio, F. (1991). Study on the predator complex of Matsucoccus cock. Occurring in Italy. Bio-ethological notes on Rhyzobius chrysomeloides (Herbst) in pine woods of Liguria (Coleoptera, Coccinellidae). Redia (Firenze). 74, 599-620.

Tolsgaard, S. 2001. Status of Danish shieldbugs, squashbugs and firebugs. (Heteroptera: Pentatomidea, Coreoidea & Pyrrhocoridea). Entomologiske meddelelser. 69, 3-46.

Tourniaire, R., Ferran, A., Gambier, J., Giuge, L., Bouffault, F. 1999. Locomotor behavior of flightless Harmonia axyridis Pallas (Col., Coccinellidae). Journal of insect behavior. 12, 545–558.

Trouve, C., Ledee, S., Ferran, A., Brun, J. 1997. Biological control of the damson-hop aphid, Phorodon humuli (Homoptera :Aphididae), using the ladybeetle Harmonia axyridis (Coleoptera.: Coccinellidae). Entomophaga (Paris). 42, 57–62.

van Lenteren, J.C., Babendreier, D., Bigler, F., Burgio G., Hokkanen, H.M.T., Kuske, S., Loomans A.J.M., Menzler-Hokkanen, I., van Rijn, P.C.J., Thomas, M.B., Tommasini, M.G. & Zeng, Q.-Q. 2003.

Environmental risk assessment of exotic natural enemies used in inundative biological control. BioControl (Dordr.). 48, 3-38.

Watanabe, M. 2002. Cold tolerance and myo-inositol accumulation in overwintering adults of a lady beetle, Harmonia axyridis (Coleoptera: Coccinellidae). European Journal of Entomology (Čes. Budějovice). 99, 5–9.

Watt, J. C. 1969. Keys to genera and some species of New Zealand Lathrididae (Coleoptera). New Zealand Entomologist. 4, 49-67.

Wells, M.L. & McPherson, R. M. 1999. Population dynamics of three coccinellids in flue-cured tobacco and functional response of *Hippodamia convergens* (Coleoptera: Coccinellidae) feeding on tobacco aphids (Homoptera: Aphididae). Environmental Entomology. 28, 768–773.

Wells, M.L., McPherson, R.M., Ruberson, J.R., Herzog, G.A. 2001. Coccinelids in cotton: population response to pesticide application and feeding response to cotton aphids (Homoptera: Aphididae). Environmental Entomology. 30, 785–793.

With, K.A., Pavuk, D.M., Worchuck, J.L., Oates, R.K., Fisher, J.L. 2002. Threshold effects of landscape structure on biological control in agroecosystems. Ecological applications. 12, 52–65.

Wittenberg, R. & Cock, M.J.W. (eds.) 2001. Invasive Alien species: A toolkit of Best Prevention and Managemnt Practices. CAB International, Wallingford, Oxon, UK, pp 228.

Yasuda, H., Kikuchi, T., Kindlmann, P., Sato, S. 2001. Relationships between attack and escape rates, cannibalism, and intraguild predation in larvae of two predatory ladybirds. J Journal of insect behavior. 14, 373–384.

Yarbrough, J.A., Armstrong, J.L., Blumberg, M.Z., Phillips, A.E., McGahee, E. & Dolen, W.K. 1999. Allergic rhinoconjunctivitis caused by Harmonia axyridis (Asian lady beetle, Japanese lady beetle, or lady bug). Journal of Allergy and Clinical Immunology, 104, 705.

Zachariassen, K.E. 1985. Physiology of cold tolerance in insects. Physiology Reviews 65, 799-832.

8. Appendix

Summary over appendix

No	Subject
1	List of species found travelling as stowaways on imported horticultural plants.
2	Arboreal hosts (trees and shrubs) and associated preys utilized by *Harmonia axyridis* Pallas 1773 *(modified after Koch et al. 2006)*.
3	Ecoclimatic index (EI) for *Harmonia axyridis* Pallas 1773 for 47 locations in the Norwegian agrometeorological network under current climate and greenhouse climate scenarios.

Funn	Familie	U. familie	*Slekt*	*Art*
Collembola (127)	Entomobryidae			*Orchesella cincta* (L. 1758)
	Entomobryidae			*Entomobrya multifasciata* (Tullberg 1871)
	Entomobryidae			*Entomobrya nivalis* (L. 1858)
	Entomobryidae			*Orchesella quinquefasciata* (Bourlet 1843)
	Hypogastruridae			*Ceratophysella engadinensis* (Gisin 1949)
	Isotomidae			*Isotoma caerulea* (Bourlet 1839)
	Isotomidae			*Isotomurus palustris* (Müller 1776)
	Isotomidae			*Isotoma viridis* (Bourlet 1839)
	Tomoceridae			*Tomocerus vulgaris* (Tullberg 1871)
	Sminthuridae			Sminthuridae viridis (L. 1758)
	Onychiuridae		*Protaphorura*	sp.
Coleoptera (424)	Apionidae			*Apion carduorum* (Kirby 1808)
	Apionidae			*Apion flavipes* (Paykull 1792)
	Carabidae			*Acupalpus parvulus* (Sturm 1825)
	Carabidae			*Amara familiaris* (Duftschmid 1812)
	Carabidae			*Amara aenea* (Degeer 1774)
	Carabidae			*Amara plebeja* (Gyllenhal 1810)
	Carabidae			*Bembidion lampros* (Herbst 1784)
	Carabidae			*Calathus mollis* (Marsham 1802)
	Carabidae			*Clivina fossor* (L. 1758)
	Carabidae			*Dromius quadrimaculatus* (L. 1758)
	Carabidae			*Harpalus affinis* (Schrank 1781)
	Carabidae			*Harpalus rufipes* (Degeer 1774)
	Carabidae			*Semiophonus signaticornis* (Duftschmid 1812)
	Carabidae			*Harpalus tardus* (Panzer 1797)
	Carabidae			*Pterostichus cupreus* (L. 1758)
	Chrysomelidae			*Altica oleracea* (L. 1758)
	Chrysomelidae			*Epitrix pubescens* (Koch 1803)
	Coccinellidae			*Coccinella septempunctata* (L. 1758)
	Coccinellidae			*Coccinella undecimpunctata* (L. 1758)
	Coccinellidae			*Exochomus quadripustulatus* (L. 1758)
	Coccinellidae			*Harmonia axyridis* (Pallas 1773)
	Coccinellidae			*Propylea 14-punctata* (L. 1758)
	Coccinellidae			*Rhyzobius chrysomeloides* (Herbst 1792)
	Cryptophagidae			*Atomaria fuscicollis* (Mannerheim 1852)
	Cryptophagidae			*Atomaria lewisi* (Reitter 1877)
	Cryptophagidae			*Atomaria ruficornis* (Marsham 1802)
*	Curculionidae	Arammichnus		*Otiorhynchus* cf. *setosulus (Stierlin 1861)*
	Curculionidae			*Otiorhynchus ovatus* (L. 1758)
	Curculionidae			*Rhinoncus pericarpius* (L. 1758)
	Curculionidae			*Tychius picirostris* (Fabricius 1787)
	Elateridae			*Agriotes obscurus* (L. 1758)
	Elateridae			*Dalopius marginatus* (L. 1758)
	Histeridae			*Margarinotus brunneus* (Fabricius 1775)
	Hydrophilidae			*Cercyon impressus* (Sturm 1807)
	Hydrophilidae			*Cryptopleurum minutum* (Fabricius 1775)
	Hydrophilidae			*Megasternum concinnum* (Marsham 1802)
	Latridiidae			*Cartodere (Aridius) bifasciatus* (Reitter 1877)
	Latridiidae			*Corticarina similata* (Gyllenhal 1827)

	Latridiidae			*Cortinicara gibbosa* (Herbst 1793)
Funn	**Familie**	***U. familie***	***Slekt***	***Art***
	Nitidulidae			*Meligethes aeneus* (Fabricius 1775)
	Phalacridae			*Olibrus norvegicus* (Munster 1901)
	Phalacridae			*Stilbus testaceus* (Panzer 1797)
	Scarabaeidae			*Aphodius niger* (Panzer 1797)
	Scarabaeidae			*Aphodius prodromus* (Brahm 1790)
	Scirtidae			*Cyphon variabilis* (Thunberg 1787)
	Staphylinidae			*Aleochara lanuginosa* (Gravenhorst 1802)
	Staphylinidae			*Amischa analis* (Gravenhorst 1802)
	Staphylinidae			*Amischa decipiens* (Sharp 1869)
	Staphylinidae			*Anotylus complanatus* (Erichson 1839)
	Staphylinidae			*Anotylus tetracarinatus* (Block 1799)
	Staphylinidae			*Anthobium unicolor* (Marsham 1802)
	Staphylinidae			*Atheta atramentaria* (Gyllenhal 1810)
	Staphylinidae			*Atheta debilis* (Erichson 1837)
	Staphylinidae			*Atheta elongatula* (Gravenhorst 1802)
	Staphylinidae			*Atheta fungi* (Gravenhorst 1806)
	Staphylinidae			*Atheta longicornis* (Gravenhorst 1802)
	Staphylinidae			*Atheta pertyi auct. nec* (Heer 1839)
	Staphylinidae			*Bledius fracticornis* (Paykull 1776)
	Staphylinidae			*Carpelimus bilineatus* (Stephens 1834)
	Staphylinidae			*Carpelimus corticinus* (Gravenhorst 1806)
	Staphylinidae			*Lesteva longoelytrata* (Goeze 1777)
	Staphylinidae			*Megarthrus denticollis* (Beck 1817)
	Staphylinidae			*Omalium rivulare* (Paykull 1789)
	Staphylinidae			*Omalium rugatum* (Mulsant et Rey 1880)
	Staphylinidae			*Philonthus carbonarius* (Gravenhorst 1802)
	Staphylinidae			*Philonthus cognatus* (Stephens 1832)
	Staphylinidae			*Platystethus cornutus* (Gravenhorst 1802)
	Staphylinidae			*Quedius scintillans* (Gravenhorst 1806)
	Staphylinidae			*Rugilus orbiculatus* (Paykull 1789)
	Staphylinidae			*Scopaeus laevigatus* (Gyllenhal 1827)
	Staphylinidae			*Stenus clavicornis* (Scopoli 1763)
	Staphylinidae			*Stenus impressus* (Germar 1824)
	Staphylinidae			*Tachinus laticollis* (Gravenhorst 1802)
	Staphylinidae			*Tachinus signatus* (Gravenhorst 1802)
	Staphylinidae			*Tachyporus hypnorum* (Fabricius 1775)
	Staphylinidae			*Tachyporus nitidulus* (Fabricius 1781)
	Staphylinidae			*Tachyporus pulchellus* (Mannerheim 1843)
	Staphylinidae			*Tinotus morion* (Gravenhorst 1802)
	Staphylinidae			*Xantholinus longiventris* (Heer 1839)
	Staphylinidae		*Gabrius*	sp.
Dermaptera (3)				*Forficula auricularia* (L. 1758)
Diptera (204)	Camillidae		*Camilla*	*sp.*
	Chironomidae			*Smittia cf. edwardsi* (Goetghebuer 1932)
	Diastatidae (?)			
	Diastatidae (?)		*Diastata (?)*	sp.
	Ephydridae		*Pelina*	sp.
	Lonchopteridae		*Lonchoptera*	sp.

Orden	Familie	U. familie	Slekt	Art
	Muscidae		*Coenosia*	sp. nr. *strigipes* Stein
Orden	**Familie**	***U. familie***	***Slekt***	***Art***
	Phoridae			
	Psychodidae			
	Sciaridae			*Chaetosciara estlandica* (Lengersdor 1929)
	Sciaridae		*Scatopsciara*	sp.
	Sciaridae		*Sciara*	sp.
	Sciaridae		*Corynoptera*	sp.
	Sphaeroceridae		*Ischiolepta*	sp.
	Sphaeroceridae		*Sphaerocera*	sp.
	Sepsidae			*Sepsis orthocnemis* (Frey 1908)
	Tipulidae		*Nephrotoma*	sp.
	Tipulidae			*Tipula oleraceea* (L. 1758)
Hemiptera (35)	Nabidae			*Nabis rugosus* (L. 1758) *hann*
				Cymus claviculus (Fallén 1807) *hunn*
				Cyphostethus tristriatus (Fabricius 1787)
	Lygaeidae			*Heterogaster urticae* (Fabricius 1775) *hunn*
				Kleidocerys resedae (Panzer 1797) *hunn*
				Lygus pratensis (L. 1758) *hann*
				Lygus wagneri (Remane 1955)
				Nabis ferus (L. 1758) *hann*
				Nysius thymi (Wolff 1804)
				Palomena prasina (L. 1761)
	Pentatomidae			*Piezodorus lituratus* (Fabricius 1794)
				Scolopostethus affinis (Schilling 1829)
				Scolopostethus decoratus (Hahn 1833)
				Stenodema calcarata (Fallén 1807)
				Stygnocoris sabulosus (Schilling 1829)
	Cicadoidea			sp.
Hymenoptera (31)	Braconidae	Alysiinae		
	Braconidae		*Panerema*	sp.
	Diapriidae		*Diapria*	sp.
	Eulophidae			
	Encyrtidae			
	Formicidae	Myrmicinae		*Temnothorax crassispinus* (Karavaiev 1926)
	Formicidae			*Lasius niger* (L. 1758)
	Formicidae			*Lasius platythorax* (Seifert 1991)
	Formicidae			*Myrmica rubra* (L. 1758)
	Formicidae	Myrmicinae		*Temnothorax unifasciatus* (Latreille 1798)
	Ichneumonidae		*Astiphomma*	sp.
	Ichneumonidae		*Enicospilus*	sp.
	Ichneumonidae		*Mesochorui*	sp.
	Perilampidae			
	Pteromalidae		*Cleonymus*	sp.
	Pteromalidae			
	Scelionidae		*Trissolcus*	sp.
	Vespidae			*Vespa germanica* (Fabricius 1793)
Lepidoptera (14)	Oecophoridae	Chimabachinae		*Diurnea fagella* (Denis & Schiffermüller 1775)

Funn	Familie	U. familie	Slekt	Art
Neuroptera (3)	Chrysopidae		*Chrysoperla*	sp.
Thysanoptera (20)	Thripidae			*Dendrothrips ornatus* (Jablonowski 1894)
Aranea (210)	Araneidae			*Agelenatea redii* (Scopoli 1763)
	Araneidae			*Araneus cornutus* (Clerck 1757)
	Argiopidae		*Argiope*	*juv.*
	Clubionidae			*Clubiona trivialis* (C.L.Kock 1843)
	Dictynidae			*Lathys humilis* (Blackwall 1855)
	Linyphidae			*Neriene montana* (Clerck 1757)
	Linyphidae			*Tenuiphantes tenuis* (Blackwall 1852)
	Linyphiidae			*Bathyphantes gracilis* (Blackwall 1841)
	Linyphiidae			*Erigone arctica* (White 1852)
	Linyphiidae			*Erigone atra* (Blackwall 1833)
	Linyphiidae			*Erigone dentipalpis* (Wider 1834)
	Linyphiidae			*Microlinyphia pusilla* (Sundevall 1830)
	Linyphiidae			*Neriene montana* (Clerck 1757)
	Linyphiidae			*Oedothorax apicatus* (Blackwall 1850)
	Linyphiidae			*Ostearius melanophygius* (O.P.-Cambridge 1879)
	Lycosidae		*Pardosa*	*juv.*
	Lycosidae			*Pirata piraticus* (Clerck 1758)
	Mimetidae			*Ero cambridgei* (Kulczynski 1911)
	Mimetidae			*Ero furcata* (Villers 1789)
	Pisauraidae			*Pisaura mirabilis* (Clerck 1758)
	Salticidae			*juv.*
	Tetragnathidae		*Tetragnatha*	*juv.*
	Tetragnathidae			*Pachygnatha clercki* (Sundevall 1823)
	Theridiidae			*Paidiscura pallens* (Blackwall 1834)
	Thomisidae		*Xysticus*	*juv.*
	Philodromidae			*Tibellus oblongus* (Walckenaer 1802)
	Zoridae			*Zora spinimana* (Sundevall 1833)
Diplopoda (12)				*Craspedosoma rawlinsii* (Leach 1815)
				Brachyiulus pusillus (Leach 1815)
				Cylindroiulus britannicus (Verhoeff 1891)
				Cylindroiulus punctatus (Leach 1815)
Isopoda (38)				*Philoscia muscorum* (Scoploli 1763)
				Porcellio scaber (Latreille 1804)
Gastropoda (49)				*Cepaea nemoralis* (L. 1758)
				Cernuella cf. *virgata* (da Costa 1778)
				Cornu aspersum (Müller 1774)
				Deroceras reticulatum (Müller 1774)
				Galba sp. (ikke truncatula)
	Ancylidae			*Oxyloma elegans* (Risso 1826)
	Gastrodontidae			*Zonitoides nitidus* (Müller 1774)
				cf. *Zonitoides arboreus* (Say 1819)
	Succineidae			*Succinea elegans* (Risso 1826)

	Succineidae			*Succinea putris* (L.1758)
Opiliones (1)				
Funn	**Familie**	***U. familie***	***Slekt***	***Art***
Pseudoscorpionida(1)				
Psocoptera (10)	Ectopsocidae			*Ectopsocus petersi* (Smithers 1978)
Midd (6)	Gamasidae		*Ambliseius*	sp.
	Gamasidae		cf. *Parasitus*	sp.
Haplotaxida (6)	Lumbricidae			

Arboreal hosts (trees and shrubs) and associated preys utilized by *Harmonia axyridis* **Pallas 1773** *(modified after Koch et al. 2006)***.**

Host	Reported prey	Reference
Abies procera Rehder, noble fir	*Cinara* sp. (Aphididae)	LaMana & Miller 1996
Acacia spp., acacia	*Psylla uncatoides* (Ferris & Klyver) (Psyllidae)	Leeper & Beardsley 1974
Acer negundo L., boxelder	*Perihpyllus negundinis* (Thomas) (Aphididae)	Koch & Hutchison 2003
Acer saccharum Marsh., sugar maple	*Periphyllus testudinaceae* (Fernie), *Drepanaphis idahoensis* Smith & Dilley, *Drepanosiphum platanoides* (Schrank) (Aphididae)	LaMana & Miller 1996
Betula pendula Roth, European whitebirch	*Callipterinella calipterus* (Hartig), *Euceraphis betulae* (Kalterbach) (Aphididae)	LaMana & Miller 1996
Carya illinoinensis (Wangenh.) K. Koch, pecan	*Monellia caryella* (Fitch.), *Monelliopsis pecanis* Bissell (Aphididae), *Melanocallis caryaefoliae* (Davis)	Tedders & Schaefer 1994
Carya sp.	*Monellia caryella* (Fitch.)	Saini 2004
Castanea crenata Sieb. & Zucc., chestnut	*Diaspidiotus* (=*Comstockaspis*) *Macroporanus* (Takagi) (Diaspididae)	Choi et al. 1995a
Citrus spp., citrus	*Diaphorina citri* Kuwayama (Psyllidae) *Toxoptera citricida* (Kirkaldy) (Aphididae)	Michaud 1999, 2002a
Fagus sylvatica L., European beech	*Phyllaphis fagi* (L.) (Aphididae)	LaMana & Miller 1996
Hibiscus syridis L., hibiscus	*Aphis gossypii* Glover (Aphididae)	Kindlmann *et al.* 2000
Juglans regia L., English walnut	*Chromaphis juglandicola* (Kaltenbach)(Aphididae)	Li 1992
Lagerstroemia indica L.	*Tinocallis kahawaluokalani*	

	(Kirkaldy)(Aphididae)	Almeida & Silva 2002
Lagerstroemia sp., crape myrtle	*Tinocallis kahawaluokalani* (Kirkaldy)(Aphididae)	Chapin & Brou 1991
Liriodendron tulipifera L., tuliptree	*Illinoia liriodendri* Monell (Aphididae)	LaMana & Miller 1996
Magnolia macrophylla Michaux, magnolia	Not specified	Tedders & Schaefer 1994
Malus sp., apple	*Aphis spiraecola* Patch (Aphididae)	Brown & Miller 1998
Malus sp., dwarf apple	*Aphis pomi* DeGeer (Aphididae)	Coderre *et al.* 1995
Malus sp., crab apple	*Aphis spiraecola* Patch (Aphididae)	Chapin & Brou 1991
Pinus densiflora Siebold & Zucc., Japanese red pine	*Thecodiplosis japonensis* Uchida & Intuye (Cecidomyiidae),	Miura *et al.* 1986
	Matsucoccus matsumurae (Margarodidae)	McClure 1986b
Pinus massonia Lamb., Chinese red pine	*Matsucoccus matsumurae* (Kuwana) (Margarodidae)	Chai 1999
Pinus resinosa Ait., red pine (Margarodidae)	*Matsucoccus resinosae* Bean & Goodwin McClure 1986a, 1987	
Pinus taeda L., loblolly pine	*Eulachnus agilis* (Kaltenbach) (Aphididae)	Tedders & Schaefer 1994
Pinus thunbergiana Franco, Japanese black pine	*Matsucoccus thunbergianae* Miller & Park *Matsucoccus matsumurae* (Margarodidae)	Choi *et al.* 1995b, McClure 1986b
Pinus spp.	*Eulachnus agilis* (Kaltenbach) (Aphididae)	Tedders & Schaefer 1994
	Cinara atlantica (Wilson),	

	Cinara pinovora (Wilson) (Aphididae)	Almeida & Silva 2002
Podocarpus sp.	*Neophyllaphis podocarpi* Takahashi (Aphididae)	Tedders & Schaefer 1994
Prunus persica (L.) Batsch, peach	*Hyalopterus pruni* (Geoffroy), *Myzus varians* Davidson (Aphididae)	Osawa 2000
Prunus sp., plum	*Hyalopterus pruni* (Geoffrey) (Aphididae)	LaMana & Miller 1996
Quercus rubra L., northern red oak	*Myzocallus occultus* Richards (Aphididae)	LaMana & Miller 1996
Rhamnus sp., buckthorn	*Aphis glycines* Matsumura (Aphididae)	Hesler *et al.* 2004
Salix sieboldiana Blume, willow	*Aphis farinosa yanagicola* Matsumura *Tuberolachnus salignus* (Gmellin) (Aphididae)	Osawa 2000
Salix koriyanagi Kimura, willow	*Chaitophorus horii* Takashashi, *Tuberolachnus salignus* (Gmelin) (Aphididae)	Osawa 2000
Salix sp., willow	*Tuberolachnus salignus* (Gmelin) (Aphididae)	LaMana & Miller 1996
Sambucus sieboldiana Blume, Japanese Elderberry	*Aulacorthum magnoliae* (Essig & Kuwana) (Aphididae)	Osawa 2000
Spirea thunbergii Sieb. ex Bl.	*Aphis spiraecola* Patch (Aphididae)	Osawa 2000
Spirea blumei G. Don	*Aphis spiraecola* Patch (Aphididae)	Osawa 2000
Tilia americana L.American basswood	*Eucalypterus tiliae* (L.) (Aphididae)	LaMana & Miller 1996
Tsuga spp., hemlock	*Adelges tsugae* Annand (Adelgidae)	Wallace & Hain 2000
Ulmus americana L., American elm	*Tinocallis ulmifolii* (Monell) (Aphididae)	Hesler 2003
Zanthoxylum bungeanum Maxim Bunge prickly-ash	*Phenacoccus azaleae* Kuwana (Pseudococcidae)	Xie *et al.* 2004

Ecoclimatic index (EI) for *Harmonia axyridis* for 47 locations in the Norwegian agrometeorological network under current climate (CU) and greenhouse (GR) climate scenarios. Climate response parameters for two populations of *H. axyridis* (one from France and one from Oregon (USA)) are used. Climate data for a period of 10 years (1997 to 2006). Latitude (ºN), longitude (ºE) and altitude above sea level (Asl) are given for each location.

				French population		Oregon population	
Location	°N	°E	Asl	CU	GR (+1ºC)	CU	GR (+1ºC)
Ås	59.6	10.8	89	0	0	0	0
Alvdal	62.1	10.6	485	0	0	0	0
Apelsvoll	60.7	10.9	255	0	0	0	0
Balestrand	61.2	6.5	15	11	18	13	22
Bø	59.4	9.0	100	0	0	0	0
Etne	59.6	6.0	15	0	4	0	5
Fåvang	61.4	10.7	195	0	0	0	0
Frosta	63.5	10.7	100	0	0	0	0
Fureneset	61.2	5.0	7	9	15	10	18
Gausdal	61.2	10.3	369	0	0	0	0
Gjerpen	59.2	9.6	41	0	0	0	0
Gran	60.3	10.6	240	0	0	0	0
Gvarv	59.3	9.2	46	0	0	0	0
Hjelmeland	59.2	6.1	60	3	12	3	15
Hoenefoss	60.1	10.3	126	0	0	0	0
Hokksund	59.7	9.9	15	0	0	0	0
Holt	69.6	18.9	20	0	0	0	0
Ilseng	60.8	11.2	177	0	0	0	0
Kise	60.7	10.8	118	0	0	0	0
Kvam	60.3	6.2	13	9	18	11	22
Kvithamar	63.4	10.9	40	0	0	0	0
Landvik	58.3	8.5	5	0	0	0	0
Lier	59.7	10.3	60	0	0	0	0
Linge	62.2	7.2	35	9	18	11	22
Løken	58.1	9.1	521	0	0	0	0
Lyngdal	61.1	7.1	5	0	9	0	11
Mære	63.9	11.4	56	0	0	0	0
Njøs	61.1	6.9	35	4	13	4	15
Pasvik	69.4	30.0	27	0	0	0	0
Rakkestad	59.3	11.3	100	0	0	0	0
Ramnes	59.3	10.2	30	0	0	0	0
Rissa	63.5	9.9	18	0	0	0	0
Roverud	60.2	12.0	150	0	0	0	0
Rygge	59.3	10.7	29	0	0	0	0
Særheim	58.7	5.6	87	10	17	12	19
Sande	59.6	10.2	55	0	0	0	0
Skjetlein	63.3	10.2	80	0	0	0	0
Skogmo	64.5	12.0	35	0	0	0	0
Sortland	68.7	15.2	40	0	0	0	0
Surnadal	62.9	8.6	10	0	0	0	0
Svelvik	59.6	10.4	10	0	0	0	0
Tingvoll	62.9	8.1	20	0	4	0	5
Tjølling	59.0	10.1	5	0	0	0	0
Tjøtta	65.8	12.4	10	0	7	0	7
Tomb	59.3	10.8	20	0	0	0	0
Ullensvang	60.3	6.6	13	7	17	8	20
Vågønes	67.2	14.4	40	0	0	0	0

Appendix 3