The importance of maize and oilseed rape field margins for *Lepidoptera*

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ONDERZOEKSRAPPORT

The importance of maize and oilseed rape field margins for Lepidoptera

Cover photograph by Sergej Jansen: the Dusky Large Blue (*Phengaris nausithous*), a critically endangered butterfly in the Netherlands, with a substantial occurrence in maize field margins.

De Vlinderstichting

The importance of maize and oilseed rape field margins for Lepidoptera

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Agriculture, GMO, non-target organisms, Bt maize, field margins, biodiversity, Lepidoptera, butterflies, moths

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Preface

Larvae of insects consume host plant tissue and may be exposed to transgenic plant material when pollen of genetically modified (GM) maize is deposited on their host plants. To assess whether cultivation of an insect-resistant GM maize crop poses a risk to non-target Lepidoptera such as butterflies, EFSA uses a mathematical model that calculates the expected mortality for non-target Lepidoptera in maize field margins. Model simulations carried out for three GM Bt maize events predicted that in case of a theoretical highly sensitive non-target Lepidoptera species, the percentage of mortality exceeds the threshold set by EFSA. EFSA therefore recommended risk mitigation measures to protect non-target Lepidoptera.
In its advices on these three Bt maize events, COGEM pointed out that in order to pose a risk to a non-target Lepidoptera species the major part of the population, and consequently of its host plants, has to be present in or in close proximity to the fields of these Bt maize events. COGEM questioned whether such a Lepidopteran species exists.
To investigate whether there are non-target Lepidoptera species which rely on maize fields and their margins, COGEM commissioned a research project which was conducted by the Dutch Butterfly Conservation. The Dutch Butterfly Conservation conscientiously analysed and combined data from several sources to identify those Lepidoptera species which occur in maize fields and their margins more than can be expected by chance. They subsequently considered whether these species rely on maize fields and their margins. The resulting report provides an excellent source of information which can be used in future assessments of potential risks to non-target Lepidoptera.

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Summary

The use of transgenic insect-resistant agricultural crops, such as Bt maize, is increasing worldwide. Exposure of sensitive non-target species to produced Bt toxins might contribute to population declines and eventual extinction.
In order to prevent detrimental impacts, a careful risk assessment of a possible introduction of transgenic insect-resistant crops is required for non-target organisms, including flower-visiting insects, such as Lepidoptera (butterflies and moths). This requires an assessment of the species that are most likely to be potentially exposed. This report provides this information, by using extensive field observations from the Netherlands to identify Macrolepidoptera species that occur to a significant extent in fields and field margins of potential insect-resistant agricultural crops, in particular maize and oilseed rape.

Until now, data have been lacking to determine which non-target Lepidoptera occur in arable field margins and could thus be potentially affected by a possible introduction of transgenic insect-resistant crops. In the face of this knowledge gap, this report addresses the following questions:

1. Which species of Lepidoptera (butterflies and moths) depend to a significant extent on fields and field margin habitats, in particular those of two widely used insect-resistant crops, maize and oilseed rape, in the Netherlands?
2. Which of these species could potentially be exposed to Cry proteins during the flowering period of these crops?

We reviewed published evidence of European Lepidoptera in fields and field margins with their food resources. Using detailed geospatial data from the Netherlands, we then analysed the extent of occurrence of butterfly and macro-moth species in maize and oilseed rape fields and field margins. By combining this species selection with species food plants, we compiled a list of species that are potentially significantly exposed to transgenic pollen in the margins of maize and oilseed rape fields.

The literature review resulted in species lists of butterflies and macro-moths occurring in field margins of eight countries across Europe, including the Netherlands. For butterflies, information on 105 species was collected, with 38 species occurring in field margins of 50% or more of the countries, including the Netherlands. For moths, only British studies were available, listing 334 species, with 29 species observed in field margins in all studies. All but one of these moth species also occur in the Netherlands.

On the basis of three sources of plant species occurring in fields and field margins in the Netherlands – commercial seed mixtures, spontaneous vegetation and arable weeds – we compiled a list of 763 plant species. Combined with known host plant relations of butterflies and macro-moths frequently found in field margins, this resulted in a list of 198 plant species of fields and field margins serving as potential larval host plants and adult nectar plants for butterflies and moths. The complete plant species database has been supplied as separate supplementary information (see Supplementary File).

The relative occurrence of butterflies and macro-moths was assessed in maize and oilseed rape field margins in the Netherlands. This was achieved by combining detailed geospatial data of Lepidoptera and field locations. Data on oilseed rape fields were limited due to the small area of cultivation, but data from maize fields were sufficiently abundant to estimate relative population sizes of butterflies on

the basis of systematically collected abundance counts. This resulted in a selection of 10 butterfly species and 43 species of macro-moths that occur more than expected by chance in maize fields and field margins.

The final step, identification of potentially significantly exposed species for transgenic insect-resistant crops was limited to maize, because insufficient data were available for oilseed rape. The identification was based on criteria of species occurrence, larval host plant occurrence, phenology of larval development and, for Red List species, habitat use during dispersal. In addition to the 10 butterfly species occurring more than expected in maize field margins, a further 9 Red List butterfly species are potentially exposed during dispersal, when they may find suitable larval habitat in maize field margins. From the 43 species of macro-moths, 28 species have caterpillars that could potentially be exposed in the flower period of maize. Thus, 19 butterfly species and 28 macro-moth species can be considered as potentially exposed to a significant extent to the introduction of insect-resistant maize.

Because not a single species occurs for more than 50% of its distribution or population in fields or field margins, we conclude that in the Netherlands *none* of the examined butterfly and macro-moth species rely predominantly on maize fields or field margins. Nevertheless, the occurrence of the critically endangered butterfly Dusky Large Blue (*Phengaris nausithous*), listed on Annex II and IV of the European Habitats Directive, was substantial (37.8% of recent records in maize field margins).

Still, even a modest dependence of Lepidoptera on field margins does not imply that populations of potentially exposed species are safe from a deteriorating habitat quality in field margins. With 68% of butterfly species on the Red List for the Netherlands and an estimated 47% of macro-moths, any addition to the existing pressures from land use may contribute to further population declines that may lead to extinction. It is therefore essential to establish that the introduction of transgenic insect-resistant crops does not pose such a pressure. This can only be determined by a thorough risk assessment involving species that are likely to be exposed. In this assessment, a comparison should be included with the alternative of maintaining current pest management, which might affect non-target Lepidoptera to a comparable or even greater extent.

Finally, we have listed the pros and cons of using particular butterfly species as model species in future risk assessments. A widespread European occurrence in field margins, rapid development and rearing experience render three butterfly species suitable as potential candidates for lab and field experiments in future risk assessments: Queen of Spain Fritillary (*Issoria lathonia*), Wall Brown (*Lasiommata megera*) and Swallowtail (*Papilio machaon*). Should transgenic insect-resistant crops be allowed in the future, then, based on the precautionary principle, we recommend adequate population monitoring of resident species by established methods to detect unexpected deviating trends.



Three butterfly species with widespread occurrence in field margins: Queen of Spain fritillary, Wall brown and Swallowtail (photo's C. van Swaay)

Samenvatting

Het gebruik van transgene, insecten-resistente landbouwgewassen, zoals Bt mais, neemt wereldwijd toe. Blootstelling van gevoelige niet-doelsoorten aan geproduceerde Bt toxinen kan bijdragen tot afname van populaties en uiteindelijke extinctie. Om dergelijke invloeden te voorkomen, is een zorgvuldige risicobeoordeling nodig voor niet-doelsoorten, waaronder bloembezoekende insecten, zoals Lepidoptera (dag- en nachtvlinders). Dit vereist een vaststelling van de soorten die het meeste kans lopen om mogelijk blootgesteld te worden. Dit rapport voorziet in deze informatie door uitgebreide veldwaarnemingen te benutten om soorten Macrolepidoptera aan te wijzen die in aanzienlijke mate in akkers en akkerranden voorkomen van mogelijke insecten-resistente landbouwgewassen, in het bijzonder mais en koolzaad.

Tot nu toe ontbraken gegevens om vast te stellen welke niet-doelsoort Lepidoptera in akkerranden voorkomen en daarmee mogelijk beïnvloed kunnen worden door een eventuele invoering van transgene insecten-resistente gewassen. Met het oog op die kennislacune behandelt dit rapport de volgende vragen:

1. Welke soorten van Lepidoptera (dag- en nachtvlinders) zijn in aanzienlijke mate afhankelijk van akkers en akkerranden als habitat, met name die van twee veel gebruikte insecten-resistente gewassen, mais en koolzaad, in Nederland?
2. Welke van deze soorten zou potentieel blootgesteld kunnen worden gedurende de bloeitijd van deze gewassen?

Wij maakten een overzicht van gepubliceerde gegevens van Europese Lepidoptera in akkers en akkerranden met hun voedselbronnen. Door het gebruik van gedetailleerde verspreidingsgegevens uit Nederland, werd de mate van voorkomen van de soorten dagvlinders en macro-nachtvlinders in akkers en akkerranden van mais en koolzaad vastgesteld. Door deze soortenselectie te combineren met de benutte voedselplaten, kon een lijst van soorten worden opgesteld die potentieel blootgesteld kunnen worden aan transgeen stuifmeel in en langs de akkers van mais of koolzaad.

Het literatuuroverzicht mondde uit in soortenlijsten van dagvlinders en macro-nachtvlinders in akkerranden van acht landen verspreid door Europa, inclusief Nederland. Van dagvlinders werd informatie over 105 soorten verzameld, waarvan 38 soorten in akkerranden in de helft of meer van deze landen werden gemeld, inclusief Nederland. Voor nachtvlinders waren er alleen Britse studies beschikbaar, met 334 species, waarvan 29 soorten in alle studies werden vermeld. Al deze nachtvlindersoorten, op één na, komen ook in Nederland voor.

Op basis van drie bronnen van plantensoorten uit akkers en akkerranden in Nederland – commerciële zaadmengsels, spontane vegetatie en akkeronkruiden – werd een lijst van 763 plantensoorten opgesteld. Gecombineerd met bekende waardplantrelaties van dagvlinders en macro-nachtvlinders, resulteerde dit in een lijst van 198 plantensoorten uit akkers en akkerranden die als potentiële waardplanten van rupsen en nectarplanten voor vlinders dienst kunnen doen. De complete database van plantensoorten is als apart supplement beschikbaar gemaakt (zie Supplementary File).

Het relatieve voorkomen van dagvlinders en macro-nachtvlinders in mais en koolzaadvelden in Nederland werd vastgesteld door gedetailleerde verspreidingsgegevens van vlinders en akkers te combineren. Gegevens over koolzaadvelden waren beperkt door het geringe teeltareaal, maar voor maisvelden

waren voldoende gegevens beschikbaar voor een bepaling van de relatieve populatiegrootte op basis van systematisch verzamelde tellingen. Dit leidde tot een selectie van 10 soorten dagvlinders en 43 soorten nachtvlinders die meer dan verwacht op basis van toeval voorkwamen in en rond maisakkers.

De laatste stap, aanwijzing van potentieel in belangrijke mate aan transgene insecten-resistente gewassen blootgestelde soorten, was beperkt tot mais omdat er onvoldoende gegevens voor koolzaad beschikbaar waren. De selectie was gebaseerd op criteria van het voorkomen van soorten, het voorkomen van waardplanten voor rupsen, de fenologie van de ontwikkeling van rupsen en – voor Rode Lijst-soorten – het habitatgebruik tijdens dispersie. In aanvulling op de 10 soorten dagvlinders die meer dan verwacht in akkerranden voorkwamen, zijn een verdere 9 soorten dagvlinders van de Rode Lijst als potentieel blootgesteld beschouwd, omdat ze daar tijdens dispersie mogelijk geschikt rupsenhabitat kunnen vinden. Van de 43 soorten macro-nachtvlinders hebben er 28 soorten rupsen die potentieel blootgesteld zouden kunnen worden in de bloeitijd van mais. Uiteindelijk kunnen dus 19 soorten dagvlinders en 28 soorten macro-nachtvlinders worden beschouwd als potentieel in belangrijke mate blootgesteld bij een introductie van insecten-resistente mais.

Omdat geen enkele soort voor meer dan de helft van zijn verspreiding dan wel populatie in akkers of akkerranden voorkomt, concluderen wij dat *geen* van de onderzochte soorten dagvlinders en macro-nachtvlinders grotendeels afhankelijk is van akkers of akkerranden van mais. Desalniettemin was het voorkomen van de ernstig bedreigde dagvlinder Donker pimpernelblauwtje (*Phengaris nausithous*), opgenomen op Bijlagen II en IV van de Europese Habitatrichtlijn, er aanzienlijk (37.8% van recente waarnemingen in randen van maisakkers).

Donker pimpernelblauwtje: een ernstig bedreigde vlinder die voorkomt in randen van maisakkers.

Desalniettemin hoeft ook een bescheiden afhankelijkheid van akkerranden bij Lepidoptera niet te betekenen dat de populaties van potentieel blootgestelde soorten veilig zijn voor verslechtering van de habitatkwaliteit in akkerranden. Met 68% van de soorten dagvlinders op de Nederlandse Rode Lijst en een geschatte 47% van de macronachtvlinders, kan elke verzwaring van de bestaande drukfactoren van landgebruik op de populaties van Lepidoptera bijdragen tot verdere afname van populaties en uiteindelijke extinctie. Het is daarom van essentieel belang om vast te stellen dat de introductie van transgene insecten-resistente gewassen niet zo'n drukfactor vormt. Dit kan alleen worden vastgesteld door een grondige risicoanalyse op basis van soorten met een grote kans op mogelijke blootstelling. In een dergelijke risicoanalyse behoort een vergelijking opgenomen te worden met het alternatief om gangbare methoden van plaagbestrijding te handhaven, welke van een vergelijkbare of zelfs grotere invloed op niet-doelsoort Lepidoptera zouden kunnen zijn.

Tenslotte zijn voor's en tegens opgesteld van de keuze voor een vlindersoort als modelsoort voor toekomstige risicobeoordeling. Een wijd verbreid Europees voorkomen in akkerranden, snelle ontwikkeling en kweekervaring maken drie soorten dagvlinders geschikt als potentiële kandidaten voor lab- en veldexperimenten: Kleine parelmoervlinder (*Issoria lathonia*), Argusvlinder (*Lasiommata megera*) en Koninginnenpage (*Papilio machaon*). Mochten transgene insecten-resistente gewassen in de toekomst worden toegelaten, dan bevelen wij vanuit het voorzorgprincipe adequate populatiemonitoring van aanwezige standvlinders aan via beproefde methoden, teneinde onverwacht afwijkende trends te kunnen vaststellen.

1. Introduction

With the worldwide increase in the cultivation of genetically modified crops for agricultural production, there is an obvious need for a thorough risk assessment of possible impacts on non-target organisms. In the case of insect-resistant crops, this concerns, amongst others, flower-visiting insects, such as butterflies and moths. This report has been commissioned by COGEM, the Netherlands independent scientific advisory committee on genetic modification. It provides an overview of the occurrence of Lepidoptera species in field margins of two crops: maize and oilseed rape. The dependence of butterflies and moths on field margin habitat is assessed, using data from the Netherlands. The results should contribute to a scientific basis for future risk assessments concerning the use of genetically modified insect-resistant cultivars of maize and rapeseed.

1.1 Background

The cultivation of genetically modified crops with built-in insect resistance is increasing worldwide. The potential benefits are an increased crop production through reduced levels of insect herbivory as well as positive effects on environment and biodiversity as a result of reduced application of pesticide use. However, exposure to genetically modified (GM) plant material, for instance pollen which may be deposited on host plants in adjacent field margins, may pose a risk to non-target insects. Therefore, the European Union follows strict procedures in considering the possible authorisation of insect-resistant crops (e.g. EFSA, 2010; 2011; EFSA & COGEM, 2013; EFSA, 2015; Riedel *et al.,* 2016).

Bt-maize is the most widely used application of genetically acquired insect resistance in an agricultural crop. Its resistance follows from the expression of Cry proteins from the naturally widespread, soil-dwelling bacterium *Bacillus thuringiensis* (Bt). Cry proteins have been approved for application in insecticide sprays and are widely used as such, amongst others in organic farming (Sanchis & Bourguet, 2008; Sanchis, 2011). The Cry proteins are toxic to the larval stages of certain insect herbivores. Various protein types have been incorporated in GM crops to protect them from insect damage: Cry1 proteins are specific for Lepidoptera, such as the European corn borer (*Ostrinia nubilalis*; Crambidae) and Mediterranean corn borer (*Sesamia nonagrioides*; Noctuidae), Cry2 proteins are toxic to both Lepidoptera and Diptera and Cry3 proteins are toxic to Lepidoptera and Coleoptera (Scholte & Dicke, 2005). Transgenic Bt crops produce the insecticidal Cry protein in most of their plant tissues, but highest concentrations are found in fresh leaves (Nguyen & Jehle, 2007). The toxic proteins are biodegradable, but non-target Lepidoptera may be exposed through the consumption of maize pollen that can be drifted by wind onto host plants of butterfly larvae growing near the maize field (e.g., Lang et al., 2004; Perry *et al.,* 2012). Only those life stages that occur in synchrony with the crop flowering period are potentially at risk. Butterfly larvae can be adversely affected, either lethally or sub-lethally, when consuming this Bt maize pollen together with host plant tissue (Lang & Otto, 2010). In nectar-producing flowering crops, such as oilseed rape, flower-visiting Lepidoptera might also be exposed to Cry proteins through nectar feeding.

In Europe, one variety of Bt-maize has been approved for commercial cultivation, mainly in Spain, but decisions on the extension of this approval and approval of the possible introduction of other Bt varieties will be considered on a short term. It is of paramount importance to be able to assess the risks of negative effects on non-target insects before deciding on a market authorisation. Knowledge on the ecology of non-target insects that are potentially exposed, such as non-target Lepidoptera, is indispensable to assess potential risks.

Oilseed rape (*Brassica napus*) is another crop where genetic modification to acquire insect resistance has been developed (Wang *et al.*, 2005). Hence, a careful risk assessment is also required for this crop. In GM varieties of other crops that are cultivated in the Netherlands, the transfer of transgenic proteins through pollen or nectar does not appear relevant, as these are not attracting flower-visiting insects, do not shed pollen or are harvested before flowering.

Amongst non-target insects, Lepidoptera are of special concern. In Europe, about a third (31%) of the 482 butterfly species has declining populations, while only 4% are increasing (Van Swaay *et al.*, 2010). Across 22 European countries, the abundance of grassland butterflies has declined by 30% from 1990 to 2015 (Van Swaay *et al.,* 2016). In northwestern Europe, where land use is most intensive, butterflies are at an even greater risk. In the Netherlands, 68% of the 71 indigenous butterfly species is listed on the Red List (Van Swaay, 2006) and the abundance of butterflies has declined significantly since 1992 for 41% of the species, against an increase in 28% of the species. In agricultural areas, the decline has been more severe, with an average 65% decline in the abundance of 14 butterfly species between 1992 and 2014 (CBS, PBL, Wageningen UR, 2015).
For moths, quantitative estimates are only available for Great Britain and the Netherlands, but these also indicate substantial losses in both abundance and species richness. Thus, a 31% loss in abundance has been reported for Great Britain over a 35-year period, with declining population trends for 66% of the 337 species studied (Fox, 2013). In the Netherlands, Groenendijk & Ellis (2011) found similar changes, with 71% of 733 Dutch macro-moth species decreasing in abundance and the total abundance of moths decreasing by one-third over the period 1980–2009. The provisional Red List for macro-moths (Ellis *et al.,* 2013) lists 47% of 841 species in the Netherlands as threatened to a variable degree.

Given the widespread declining trends in European Lepidoptera, any additional environmental pressures could have serious consequences on Lepidopteran diversity. This underlines the need of thorough risk assessments in determining the potential risks of introducing transgenic Bt crops.
Lang & Otto (2010) have reviewed laboratory and field studies on the effects of transgenic Bt maize on non-target Lepidoptera. Besides an overall lack of studies, they pointed out that laboratory studies were often carried out under conditions that were unrealistic from an ecological point of view, such as in Bt dosage, climatic conditions, food availability and larval health. Studies largely were carried out in North America and were restricted to a small number of 11 species, predominantly butterflies and amongst them especially the Monarch butterfly (*Danaus plexippus*). From the European non-target Lepidoptera, i.e. excluding *Pieris* spp. and *Plutella xylostella,* only the butterflies *Papilio machaon* and *Aglais io* were investigated in laboratory experiments. From the small number of field experiments, which provide opportunities to test realistic conditions of exposure, only one was carried out in Europe: Gathmann et al. (2006) carried out a field experiment in Germany to assess effects of Bt maize on larval abundance of the two most frequent and secondary pest species *Plutella xylostella* and *Pieris rapae.*

A modelling approach in risk assessments may assist in decision making by identifying the conditions under which the risks of cultivation can be considered acceptable. Recently, EFSA has applied the model developed by Perry *et al.* (2012) for risk assessment of non-target Lepidoptera (EFSA, 2015). This model uses theoretical model species with a given sensitivity to Cry proteins that occur to a substantial extent in the vicinity of field margins to evaluate the impacts of realistic levels of distance-dependent exposure on mortality. However, it remains unclear to which species this applies in practice. In particular, the extrapolation from a given mortality to population persistence remains to be established, because information on the occurrence of Lepidoptera in field margins and the importance of field margins for the persistence of their populations is lacking.

Some exploratory studies have been carried out to determine which resident butterflies occur in maize field margins and could, therefore, be potentially at risk. Schmitz *et al.* (2003) used a database on species phenology and habitat affinity to identify 96 species of Macrolepidoptera (butterflies and macro-moths) that typically occur in the German agricultural landscape and might get into contact with (Bt-) maize pollen. However, there were no field data to underpin this species selection.
Lang (2004) surveyed the butterflies in maize field margins in Bavaria, Germany. He recorded 33 species and determined that a sample size in the range of 75 to 150 field margins would be required to detect (with a power of 80%) effects larger than 15% in species richness and pooled butterfly abundance. Much greater sample sizes would be required to detect more subtle or detailed effects at species level. In an heterogeneous agricultural area in Switzerland, Lang *et al.* (2015) investigated the butterfly community of protected habitats and their potential exposure to possible cultivation of Bt maize. They recorded 49 butterfly species that showed an average temporal overlap of 50 ± 30% between the period of larval development and the shedding of maize pollen. Maize pollen predominantly fell within a 30 m buffer around the fields, but also drifted onto host plants as far as 500 m away. Still, the scale of the field studies has been limited so far and did not consider moths. Moreover, the importance of field margins relative to the distribution and population dynamics of the occurring species has not been addressed by these studies.
Furthermore, a database of bio-ecological information on non-target arthropod species has been established and updated by Riedel *et al.* (2016) to support the environmental risk assessment of genetically modified crops in the EU. The compiled database covers a large number of arthropod species, but the number of records on Lepidoptera rarely exceeds 20, which precludes a quantitative assessment.

Overall, the combination of the threatened status of many Lepidopterans in Europe and a weak knowledge base clearly warrant a more extensive review and a quantitative analysis of non-target Lepidoptera that are potentially exposed in Bt maize and oilseed rape field margins.

1.2 Objective

In order to facilitate a comprehensive risk assessment, it remains to be established which non-target Lepidoptera actually are likely to be potentially exposed to a significant extent by a possible introduction of transgenic insect-resistant crops.

The specific questions that need to be resolved are:

1. Which species of Lepidoptera (butterflies and moths) depend to a significant extent on fields and field margin habitats, in particular those of two widely used insect-resistant crops, maize and oilseed rape, in the Netherlands?
2. Which of these species could potentially be exposed to Cry proteins during the flowering period of these crops?

This study addresses both of these questions. In doing so, we review information from published studies and carry out an analysis of detailed data on the distribution and abundance of Lepidoptera and the occurrence of their host- and nectar plants in field margins. We adopt a functional habitat approach – including the availability of larval host plants, adult nectar plants and dispersal route – to translate the occurrence of species to an assessment of the field margin as adequate habitat.

The resulting list of ‘field margin Lepidopterans’ that are potentially at risk from transgenic Bt crops may then be used in follow-up research to determine the actual sensitivity of these species to the exposure to insect-resistant crops.

2. Methodology

We reviewed published evidence of European Lepidoptera in field margins with their food resources. Using detailed geospatial data from the Netherlands, we then analysed the extent of occurrence of butterfly and macro-moth species in maize and oilseed rape fields and field margins. By combining this species selection with species food plants, we compiled a list of species that are potentially exposed to significant quantities of GM pollen in the margins of maize and oilseed rape fields.

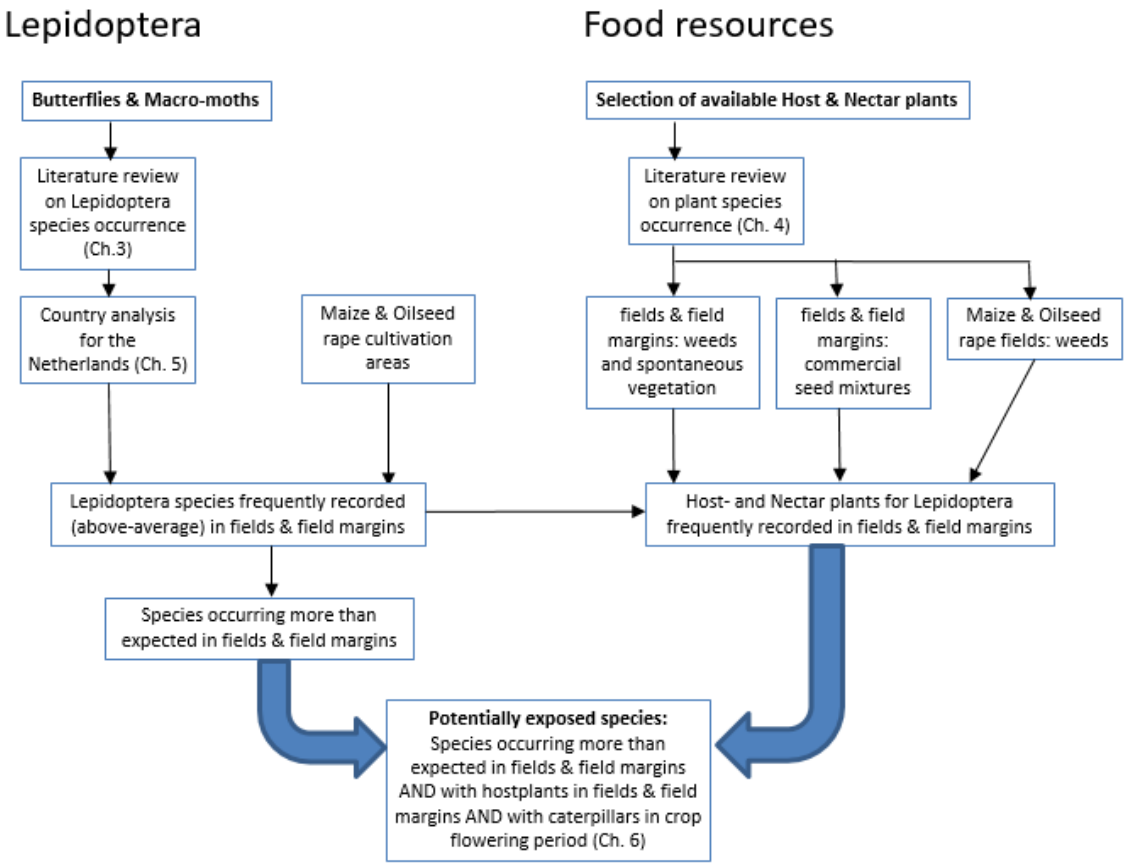

Figure 2.1: Structural outline of the study. The selection of host and nectar plants has been elaborated in Fig. 2.2, the analysis of Lepidoptera occurrence in Fig. 2.3 and Lepidoptera population size in Fig. 2.6.

2.1 General approach

To reach the central objective of determining which Lepidoptera species depend to a significant extent on fields and field margin habitats of maize and oilseed rape, we follow a series of steps (Figure 2.1).

In the first step, in Chapter 3, we review published studies on the occurrence of Lepidoptera species in field margins across Europe. This will yield a first overview of species that are likely to use field margins as a habitat. Because few studies have specifically targeted maize and oilseed rape field margins, we have adopted a broader perspective encompassing all field margins, regardless of crop species.

In the subsequent steps, we focus on field margin habitats in the Netherlands, where the field itself is being implicitly included. The species list from the European review is not included in the selection process of steps 2 to 4 (as explained below), but serves as a background in discussing the obtained species selection.

In the second step (Chapter 4), we compile a list of plant species that occur in field margins in the form of either spontaneous vegetation, in-field and field margin weeds or sown wildflower seed mixtures for margins. In combination with the selection of frequently occurring Lepidoptera in field margins (Chapter 5), this results in a list of widespread potential larval host plants and butterfly nectar plants in maize and oilseed rape fields and field margins.
With regard to the concept of field margins as a habitat, we adopt a 30 m buffer around the crop field, which has been taken by EFSA (2015) as the potential zone under influence of pollen drift from Bt maize which is of importance to sensitive Lepidopterans. Hence, this buffer zone often will include non-agricultural vegetation, including road verges, embankments, woodland edges and other semi-natural vegetation.

The third step (Chapter 5) consists of identifying Lepidoptera species with a significant occurrence in field margins of maize and oilseed rape. Here, we combine spatial information of Lepidoptera observations (2011-2016) with recent maps of maize and oilseed rape fields (2015). Especially maize is usually grown on the same field over a series of years. Therefore, we feel confident that the distribution of a single year offers a fair representation for the longer period from which the Lepidoptera observations were taken.
Two assessments are made: first, the relative frequency of occurrence of Lepidoptera species in maize and oilseed rape field margins and second, the relative abundance or population size of butterfly species in maize field margins (adequate data were not available for oilseed rape and for moths).
From the Lepidopterans, we explicitly consider only Macrolepidoptera, i.e. butterflies (Rhopalocera; c. 63 species in the Netherlands, including regular migrants but excluding incidental records; see Bos *et al.,* 2006) and macro-moths (Heterocera; c. 920 species; see Ellis *et al.,* 2013). We exclude the most species-rich group of Microlepidoptera (c. 1480 species in the Netherlands), because of a far less comprehensive knowledge on species ecology, Red List-status and detailed distribution. Species names are according to Fauna Europaea.

In the fourth step (Chapter 6), we follow a functional habitat approach (Dennis *et al.,* 2003) to arrive at a selection of butterfly and macro-moth species that are potentially at risk in maize and oilseed rape field margins, because of a significant occurrence in this habitat zone. This includes the availability of larval host plants, the availability of nectar plants as food resource and attractants for (egg-laying) adults, and the probability of especially Red-List species to encounter flowering maize or oilseed rape fields during dispersal.

Chapter 7 discusses the main findings of the study and their significance for future work on risk assessment of transgenic insect-resistant crops for non-target Lepidopterans. Chapter 8 then summarises the conclusions and main recommendations for the future.

2.2 Review: Lepidoptera in field margins

We reviewed peer-reviewed papers on Lepidoptera (butterflies and moths) in field margins by combining the preceding keywords and selecting papers from European sites that provided comprehensive species lists. In some cases, we approached the authors to supply species lists when these were not included with the paper or supplementary information.

2.3 Review: host and nectar plant species in field margins

The aim of this section is to investigate which potential host plants (including nectar plants) for butterflies and moths occur in field margins around and/or as weeds in crop fields of maize and oilseed rape in the Netherlands.

The survey was carried out with the following limitations:

- Focus on reports and data from the Netherlands (with a few exceptions, mentioned further onwards).
- Focus on reports and data concerning maize (*Zea mays*) and oilseed rape (*Brassica napus*) crops (for as far as possible).
- Focus on plant species that are indigenous, or since long established in the Netherlands, as their suitability as host or nectar plants is best known.
- Focus on herbaceous vegetation, as this is the more challenging to assess availability in field margins. The occurrence of shrubs and trees In field margins concerns a much smaller number of more widespread species and has been determined on the basis of expert knowledge.

This approach led to different types of vegetation to investigate, as explained below and in Figure 2.2:

1. Sown plant species from commercial seed mixtures sown in field margins of maize and oilseed rape crops. Depending on the seed company and on the type of mixture, these include both exotic and native plant species.
2. Spontaneous vegetation:
   a) Plant species from spontaneous vegetation in field margins or ditch embankments around maize or oilseed rape crops, native species.
   b) Arable weeds in maize and oilseed rape crops, (mostly) native species.

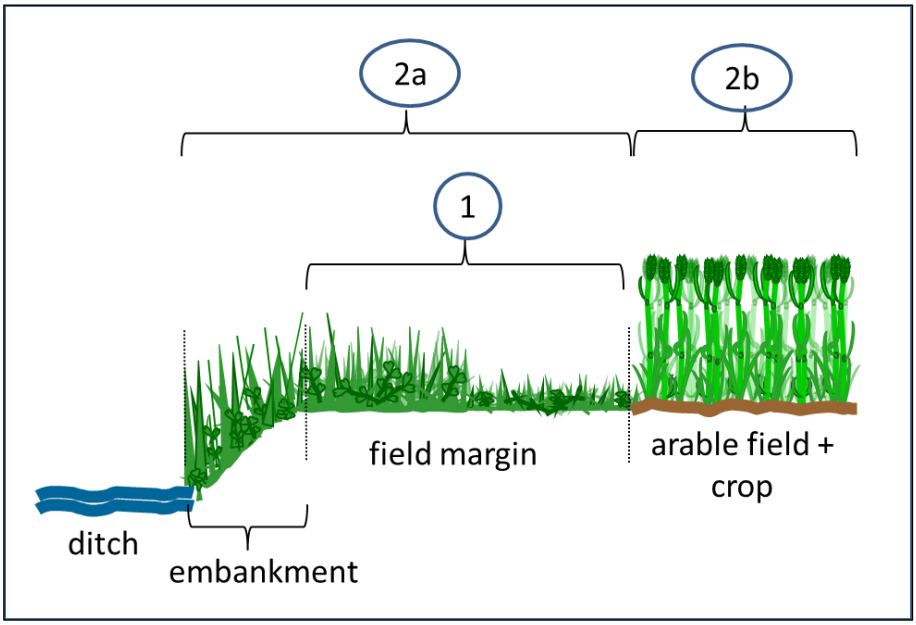

Figure 2.2: Schematic representation of the three types of vegetation investigated in this study: 1) Commercial seed mixtures, sown in the field margin, (partly exotic and partly) native species. 2a) Spontaneous vegetation in field margins and ditch embankments, (mostly) native species. 2b) Arable weeds in crops, (mostly) native species.

2.3.1 Plant species in commercial seed mixtures

Field margins for agri-environmental schemes (Dutch: “agrarisch natuurbeheer”), for natural pest control (Dutch: Functionele AgroBiodiversiteit, abbrev. FAB) and to stimulate pollinators and farmland birds have become rather popular in recent years. As a result, seed companies offer a range of seed mixtures for field margins.
In order to compile a list of potential nectar and host plants for butterflies and moths in field margins and crops, we selected a representative sample of seed mixtures for field margins and ditch embankments. For the first type of vegetation, the commercial seed mixtures for field margins, we selected four Dutch seed companies that are known to work exclusively or predominantly with indigenous plant species

for their field margin mixtures for arable farming (van Alebeek, 2012). From the websites of these seed companies, we selected a total of 30 commercial seed mixtures for field margins and road and ditch embankments. These websites (consulted in January 2017) are:

Biodivers http://biodivers.nl/pages/samenstellingen.php
Cruydthoeck www.cruydthoeck.nl/bloemenmengsels
Limagrain www.limagrain.nl/web/Gras-Veldbloemen/Veldbloemen.htm
Medigran www.medigran.nl

An overview of the 30 seed mixtures used in this study is given in Table 2.1. Information on the different seed mixtures can also be found on the websites of the seed companies. As a test of the robustness of this selection of 30 commercial seed mixtures, we tested what the effect would have been of adding another 3 new seed mixtures from 3 other seed companies, to check for significant changes in potential host plants.

Table 2.1: An overview of the 30 commercial seed mixtures for field margins and road and ditch embankments from 4 seed companies, used in this study.

Seed Firm	Code	Mixture name (in Dutch)	Remarks, description
Biodivers	B102	Biodivers 102 Margriet I mengsel	30 annual and perennial herbs and grasses for acidic, sandy and loamy soils
	B103	Biodivers 103 Margriet II mengsel	35 annual and perennial herbs and grasses for calcareous, sabulous clay
	B104	104 Walstro-Wilde peenmengsel	58 annual and perennial herbs and grasses for peat soils, marshes and ditch embankments
	B106	106 Dotter-koekoeks-bloemmengsel	31 perennial herbs and grasses for calcareous, sandy soils
	B111	111 Akkerkruiden-mengsel	20 annual and perennial arable weeds for different soil types
	B113	113 Mengsels van bloemrijke ruigten	23 perennial herbs for different soil types, to be mown only once per two years
	B115	B115 Oeverplanten-mengsel	30 perennial herbs for river banks and ditch embankments
	B144	B144 Slootkant-mengsel	A simple mixture of 12 perennial herbs for ditch embankments
	B119	B119 FAB mengsel (I) eenjarig	6 annual herbs, designed field margins to attract beneficial insects for natural pest control
	B120	B120 FAB mengsel (II) meerjarig	14 perennial herbs, designed for field margins to attract beneficial insects for natural pest control
Cruydt-Hoeck	A6	A6 - Mengsel éénjarige akkerbloemen	13 annual, arable weeds for different soil types
	G1	G1 - Bloemrijk graslandmengsel	25 annual and perennial herbs for meadows on different soil types
	G2	G2 - Bloemrijk graslandmengsel	15 perennial herbs for meadows and roadsides on eutrophic clay soils
	G3	G3 - Bloemen graslandmengsel	20 perennial herbs for marshes, humid meadows and ditch embankments
	M1	M1 - bloemrijk graslandmengsel	A simple mixture of 10 perennial herbs for meadows and roadsides
Limagrain	1	Akkerrand Bloemrijk 1	17 annual herbs, designed for flower rich field margins on different soil types
	2	Akkerrand Bloemrijk 2	11 perennial herbs, designed for flower rich field margins on different soil types
	--	Grutto-weidevogelmengsel	9 perennial herbs and grasses, designed to support meadow bird populations
	2a	2a voor voedselrijke gronden	17 perennial herbs for meadows and roadsides on eutrophic clay soils
	3a	3a nat en voedselrijk	23 perennial herbs for meadows and marshes on humid sandy or peaty soils
	13	13 voor voedselrijke zavel-, klei- en leem	23 perennial herbs for meadows and roadsides on eutrophic loamy, sabulous or clay soils
	1a	1a algemeen	24 perennial herbs for meadows on different

Seed Firm	Code	Mixture name (in Dutch)	Remarks, description
			soils (not humid and no too eutrophic)
	1b	1b algemeen, lager	10 perennial herbs for meadows on different soils (not humid and no too eutrophic)
	47	47 op lichte humeuze zandgrond	20 perennial herbs for light, sandy soils
Medigran	RN-17	Ruigteflora RN – 17 vochtig	13 perennial herbs for humid, sandy soils
	RN-18	Ruigteflora RN – 18	12 perennial herbs for humid, sandy soils
	NRN-10	NRN 10 Nectarhoudend Ruigteflora	14 perennial herbs for river banks and ditch embankments on eutrophic soils
	GN-27	Graslandflora GN – 27	19 perennial herbs and grasses for meadows on humid, eutrophic soils
	GN-28	Graslandflora GN – 28	16 perennial herbs and grasses for meadows on humid, eutrophic soils
	GBT-48	GBT 48 Graslandflora Berm - Talud	18 annual and perennial herbs and grasses for meadows and roadsides on eutrophic soils

2.3.2 Plant species in spontaneous vegetation in field margins and ditch embankments

For the second type of vegetation, i.e. (2a) the spontaneous plant species in field margins and ditch embankments, we scanned the scientific literature (Wageningen Digital Library, Scopus) and "grey" literature (such as handbooks on arable weeds, growers guides, research reports from applied plant research, etc.) for lists of plant species in or around maize and oilseed rape crops in the Netherlands.
It soon became apparent that very few research reports and publications could be found that described (in detail) the composition of the vegetation of field margins and ditch embankments around maize and oilseed rape fields in the Netherlands. In reports or articles that deal specifically with maize or oilseed rape, often, only just a few of the most important weeds were mentioned. Reports with more detailed information probably do exist, but in the amount of time available, few detailed inventories of natural vegetation around maize fields or oilseed rape crops in the Netherlands could be found.
Thus, we relied on the few studies and articles available that described arable weeds communities in general (regardless of the crops involved) and field margins composition (again, regardless of the neighbouring crops) in arable farming in the Netherlands. Even within this selection, very few reports and articles were found that contained complete plant species lists (Table 2.2). Still, we are confident that these give a fairly representative overview of the relevant plant species.

Table 2.2: Overview of information sources on arable weeds and natural vegetation in field margins in the Netherlands, used in this study.

	Information source	Text
1	*Beeldenbank Onkruiden, Groen Kennisnet* https://wiki.groenkennisnet.nl/display/BEEL/Onkruiden+op+alfabet	Multi-lingual
2	*IRS Onkruidherkenning* http://www.int-koop.de/unkraut/mod_liz_unkraut_bestimmung/partner/irs/lang/nl/index.html	Multi-lingual
3	Glas, H. (1981). *Handleiding voor het herkennen van akkeronkruiden en hun kiemplanten: een overzicht van 55 veel voorkomende akkeronkruiden in Nederland*. Misset.	NL
4	Glas, H. (1995). *Weide-onkruiden. Kiemplanten en bijzonderheden*. Misset.	NL
5	Oomen, P.A., P.F.J. Oostelbos, R.J.J. Botden en H.A.. Duindam (redactie) (2003). *Gewas-beschermingsgids 2003. Gids voor de gewasbescherming in de land- en tuinbouw en het openbaar en particulier groen*. 17e geheel herziene druk. Plantenziektenkundige Dienst Wageningen.	NL
6	Kleijn, D. (1997). *Species richness and weed abundance in the vegetation of arable field boundaries.* PhD Thesis. Wageningen University, Wageningen	UK
7	Noordijk J., C.J.M. Musters, J. Dijk & G.R. de Snoo (2011). Vegetation development in sown field margins and on adjacent ditch banks. *Plant Ecology* 212, 157–167.	UK

	Information source	Text
8	Clevering, O.A., G.K. Hopster, A.J.C.M. van Beek, J. Spruijt, A.J. Visser (2005). *Natuurontwikkeling langs akkers. Evaluatie van zes jaar onderzoek naar het beheer van akkerranden en slootkanten op proefbedrijven.* Wageningen UR, Praktijkonderzoek Plant & Omgeving, Lelystad.	NL
9	Marseille, M., 2012. *Bloeiende Akkerranden* (2012). Verslag van monitoring van flora en fauna. Agrarische natuur- en milieuvereniging Vallei Horstee, Leusden.	NL
10	Meyer, S., E. Bergmeier, T. Becker, K. Wesche, B. Krause & C. Leuschner (2015). Detecting long-term losses at the plant community level – arable fields in Germany revisited. *Applied Vegetation Science* 18, 432–442.	UK

2.3.3 Plant species as weeds in maize and oilseed rape in the Netherlands

For the third type of vegetation, i.e. (2b) the arable weeds in maize and oilseed rape crops, we scanned the scientific literature (Wageningen Digital Library, Scopus) and "grey" literature (such as handbooks on arable weeds, growers guides, research reports from applied plant research, etc.) for lists of plant species in maize and oilseed rape crops in the Netherlands.
Here, we encountered the same problem as before that very few research reports and publications could be found that described (in detail) the composition of weeds in maize or oilseed rape crops in the Netherlands. In reports or articles that deal specifically with maize or oilseed rape, often, just a few of the most important weeds were mentioned. We did retrieve various information sources which provided short lists of the main weeds in maize and oilseed rape (Table 2.3). These should cover the main weed species that are likely to be encountered.

Table 2.3: An overview of information sources on arable weeds in maize and in oilseed rape, relating to the Netherlands, used in this study.

	Crop	Information source	Text
1	Maize	Schooten, H. van, B. Philipsen & J. Groten (2016). *Handboek Snijmais. Hoofdstuk 8. Onkruidbestrijding*. http://www.wur.nl/upload_mm/a/2/c/2755184c-1dc0-4c42-b0e5-6be576fb790a_Handboek%20Snijmais%20december%202016%20onkruidbestrijding.pdf	NL
2	Maize	KWS-Maïsmanager*, onkruidherkenning*. http://www.kws-maismanager.nl/tools/onkruidherkenning	NL
3	Maize	Landbouwcentrum voor Voedergewassen vzw (B), *Onkruidwijzer Mais* (2015): http://www.lcvvzw.be/publicaties/?kw=onkruid Onkruidwijzer mais LCV	NL
4	Maize	Meissle, M., P. Mouron, T. Musa, F. Bigler, X. Pons, V. P. Vasileiadis, S. Otto, D. Antichi, J. Kiss, Z. Pálinkás, Z. Dorner, R. van der Weide, J. Groten, E. Czembo7, J. Adamczyk, J.-B. Thibord, B. Melander, G. Cordsen Nielsen, R. T. Poulsen, O. Zimmermann, A. Verschwele & E. Oldenburg (2010). Pests, pesticide use and alternative options in European maize. production: current status and future prospects. *J. Appl. Entomol.* 134, 357–375	Eng
5	Oilseed rape	Van Zeeland, M. (2007). *Toelatingsmogelijkheden voor Herbiciden in koolzaad.* Kennisakker. http://www.kennisakker.nl/kenniscentrum/document/toelatingsmogelijkheden-voor-herbiciden-koolzaad	NL
6	Oilseed rape	van 't Westeinde, J. (2011). *Belchim grassenbestrijding in koolzaad*. SPNA Rapport nr 56. http://www.spna.nl/downloads/catalogus/269%20rapport.pdf	NL
7	Oilseed rape	De Visser, C.L.M (1985). *Chemische onkruidbestrijding in de teelt van winterkoolzaad*. Proefstation voor de akkerbouw en de groenteteelt in de vollegrond, verslag nr. 46. http://library.wur.nl/WebQuery/wurpubs/fulltext/350180	NL

2.3.4 Potential host plants for selected Lepidoptera species

The three sources of potential host plants were combined with the selection of species of butterflies and moths that occur frequently, i.e. above-average, in field margins in the Netherlands (see. 2.4) to arrive at a selection of widespread larval host plants and nectar plants that suit this selection of Lepidoptera.
In this selection process, we used the known nectar plants and hosts for these

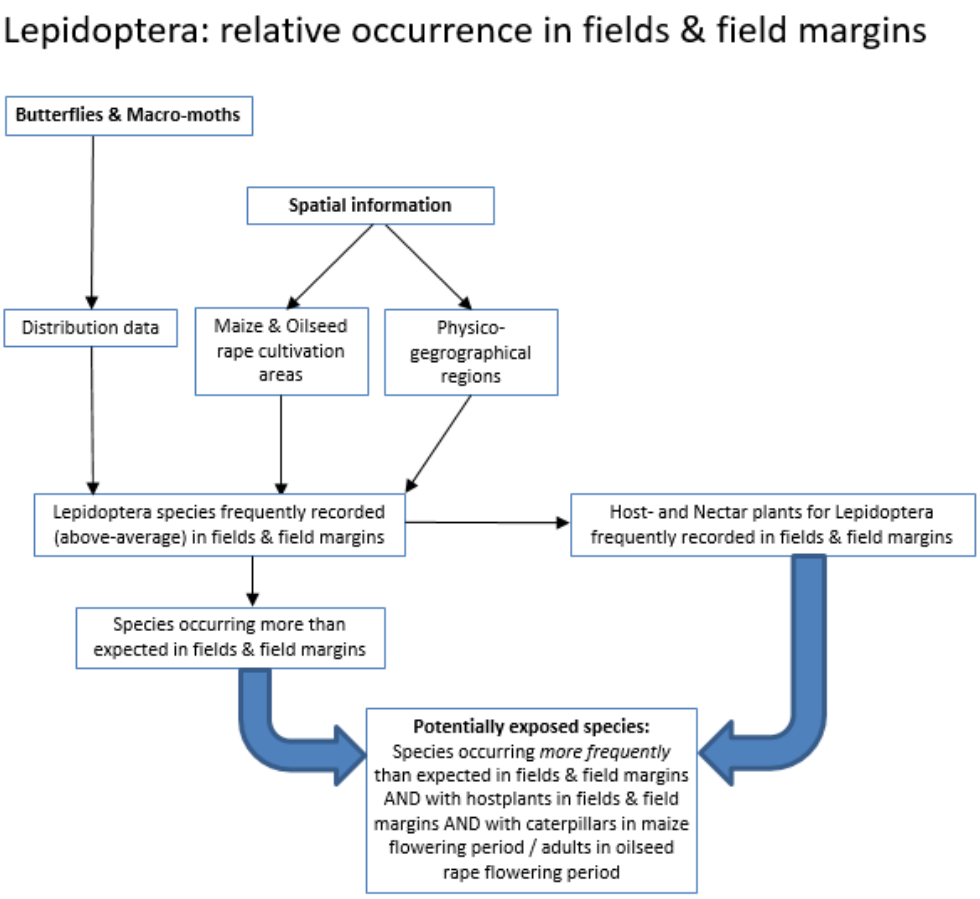

Figure 2.3: Flow diagram of the steps leading to the assessment of the relative occurrence of butterfly and macro-moth species in maize and oilseed rape fields and field margins.

selected species, based on Tax (1989), Bos *et al.* (2006) for butterflies and Ellis *et al.* (2013) and the database from De Vlinderstichting) for moths. Regarding nectar plants, the information was limited to butterflies, but it was assumed that this will be reasonably representative for moths as well. This assumption clearly does not account for existing species-specific nectar plant relations, but should give a reasonable indication for overall nectar availability to butterflies and moths. In any case, larval host plant availability, not nectar plant availability, should be regarded here as the primary factor determining potential exposure of Lepidoptera to transgenic insect-resistant crops.

2.4 Analysis of relative occurrence of Lepidoptera from distribution data

The relative frequency of occurrence in field margins was determined for butterfly and macro-moth species in both maize and oilseed rape fields. This was achieved by combining geospatial data of Lepidoptera, maize and oilseed rape fields and – to correct for differences between soil types – physico-geographical regions (Figure 2.3).

2.4.1 Lepidoptera data

Lepidoptera distribution data were obtained for butterflies and macro-moths from the National Database on Flora and Fauna (www.ndff.nl). Only recent data from the period 2011-2016 at fine spatial resolution (<50 m accuracy) were used. This resulted in a dataset of 1.76 million records for 63 species of butterflies and 0.8 million records of 778 macro-moth species.

It should be noted that these data are not corrected for sampling effort and therefore can – and indeed very likely do – contain an unknown bias in sampling effort between habitat types.

2.4.2 Maize and oilseed rape distribution

Shapes of recent (2015) maize and oilseed rape fields were obtained from Statistics Netherlands (CBS). Buffers of 30 m were added around the fields to determine the area of fields and field margins; see figure 2.4 for an example.

N.B. Throughout the report field margins are typically meant also to include the fields themselves, although these rarely provide suitable habitat for Lepidoptera compared to the margins.

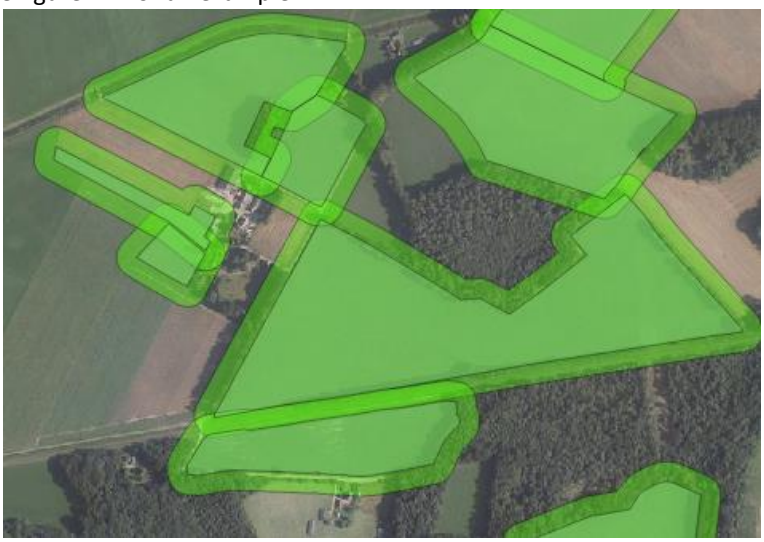

Figure 2.4: Example of maize fields with the 30 m buffer considered as field margin in the context of this study.

2.4.3 Physico-geographical regions

Shapes of the physico-geographical regions were also obtained from Statistics Netherlands (CBS). The following seven regions were distinguished: Coastal dunes, Calcareous loamy soils, Pleistocene sands, Lowland peat, Riverine clays, Marine clays and Urban areas (Figure 2.5).

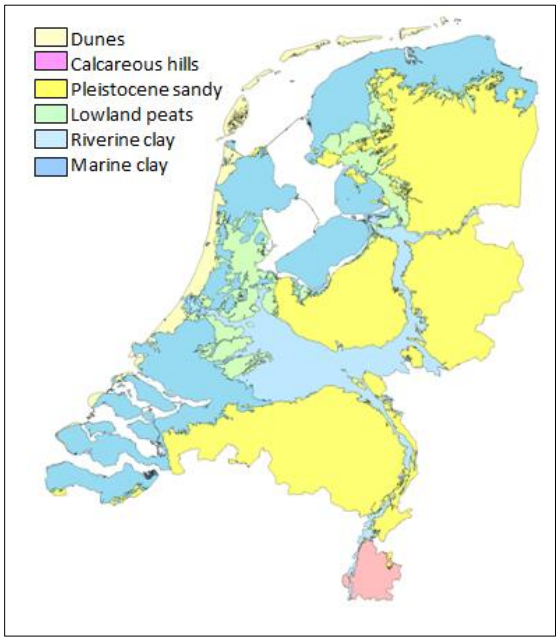

Figure 2.5: Physico-geographical regions of the Netherlands considered in this study (note that, to avoid an overcrowded picture, urban areas have not been represented on this map).

2.4.4 Data analysis

We used QGIS 2.8.1 and R 3.3.1 to assign Lepidoptera records as inside or outside the area of fields + field margin, within specific physico-geographical regions. As, especially maize is grown largely on Pleistocene sandy soils, we ran the analysis at a national scale and for Pleistocene sandy soils separately. For each Lepidoptera species, we determined the relative proportion of records in fields + field margins.

- Proportions higher than the overall proportion of species occupancy in fields + field margins were regarded as 'above-average occurrences' in field margins *in comparison to other species* and the species concerned were analysed for larval host plant preference and, in the case of butterflies, for nectar plant preference.
- Proportions higher than the proportion by field + field margin area were considered to indicate a substantial occurrence of a species in field margin habitats *in comparison to the available area*.

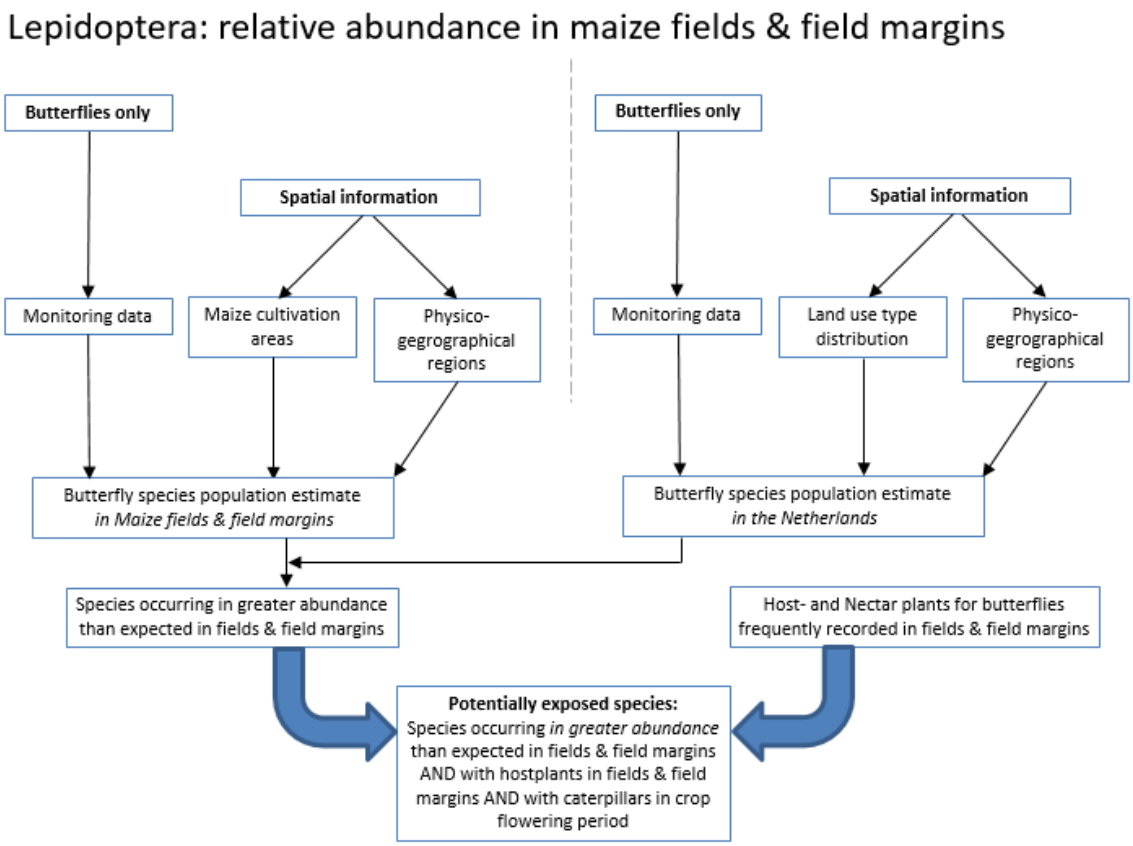

Figure 2.6: Flow diagram of the steps leading to the assessment of the relative population size (abundance) of butterfly species in maize fields and field margins.

2.5 Analysis of relative population size of butterflies from monitoring data

An assessment of relative population size of Lepidoptera species in field margins is preferable over an estimate of relative frequency of occurrence obtained from opportunistic distribution data. First, such an estimate takes into account the differences in abundance between habitat types. Second, when using systematic monitoring data, biases due to differences in sampling effort can be accounted for. Unfortunately, such systematic count data are only available for butterflies as yet. Furthermore, monitoring data from oilseed rape field margins were not available, so that the analysis has been restricted to maize field margins.

The analysis combined two assessments, both on the basis of monitoring transect data (Figure 2.6): 1) population size of species on transects in maize field margins (left side of figure) and 2) population size of species on transects at a national scale (right side of figure). The relative population size in maize field margins was the proportion of the population in maize fields relative to the national population size.

2.5.1 Butterfly monitoring data

We used data from the Dutch butterfly monitoring scheme for the period 2010-2015 (Van Swaay *et al.,* 2016). For each transect section of 50 x 5 m, species abundances were averaged over the years and converted to densities per hectare from summed weekly counts (with interpolation for missing data). For species with multiple generations, data were selected for the first generation, which gives less variable results between years.

2.5.2 Spatial information

Transect sections were assigned to maize field margins, physico-geographical region and land use type (Figure 2.7). Shapes with detailed locations were obtained from Statistics Netherlands (CBS). Distinguished land use types were: agricultural area, woodland, dry semi-natural area, wet semi-natural area and urban area

Figure 2.7: Example of the assignment of sections of butterfly monitoring transect to a maize field margin.

2.5.3 Population estimates

Population sizes were obtained as weighted estimates according to the habitat strata:

- Maize field margin population size: summed values of species densities per physico-geographical region multiplied by the area of each region
- National population size: summed values of species densities per land use type within each physico-geographical region multiplied by the area of each land use type x region combination

The estimated population sizes are likely to be biased towards higher values, because the transects of the monitoring scheme are probably representing locations where butterflies are typically more abundant. However, the main objective here is to determine the proportion of the national population found in maize fields margins and, as we have no reason to believe that the bias differs between maize field margins and other regions, we can argue that the estimated proportion of the population found in maize field margins is an unbiased estimate. In any case, it is the best estimate that can be provided.

As in 2.4, proportions higher than the proportion by maize field + field margin area were considered to indicate a substantial occurrence of a species in field margin habitats.

2.6 Assessment of potential exposure of species in field margins

The analyses described in 2.4 and 2.5 yielded estimates of substantial occurrences of butterfly and macro-moth species in field margins of maize and oilseed rape on the basis of distribution data, and, for butterflies in maize field margins, on the basis of population estimates.

In order to estimate a significant dependence on the presence and quality, i.e. the availability of host and nectar plants, of field margin habitats, a further assessment of the functional role of this habitat is required. We have assessed this function by determining the likely presence of host plants for larval development and the presence of nectar plants for adult stages (where information on nectar plant use is only available from butterflies). Both form a prerequisite for a suitable habitat.

The next step then is to determine potential species exposure to transgenic Bt crops. We consider that species are potentially exposed if their larval development takes place during the flowering period of the crop, i.e. when pollen may drift onto larval host plants. For maize this period lies between July and mid-September and for oilseed rape between mid-April and mid-May.

A further risk concerns Red List species that may not use field margins to a substantial extent, but may still depend on or are affected by their presence during dispersal, especially when host and nectar plants are present. Indeed, dispersal routes between partial habitats or between local populations from a larger metapopulation should also be considered as part of the habitat (see Dennis *et al.,* 2003; Vanreusel & Van Dyck*,* 2007).

Thus, we arrive at the following decision criteria to determine which species potentially are exposed to a significant extent to transgenic Bt maize or oilseed rape in the Netherlands:

- Species occurs more than expected in maize / rapeseed field margins
- Larval food plants also occur in maize / rapeseed field margins (for butterflies, nectar plants provide additional indication of habitat suitability)
- Larval development takes place in the flowering period of maize (July to mid-September) or oilseed rape (mid-April to mid-May)

- In case of Red List species, there is a potential risk if there is a high probability of encountering maize or oilseed rape fields during dispersal between partial habitats or different reproduction sites within a larger metapopulation. This criterion has only been assessed in a qualitative matter for butterflies on the basis of the distribution of current populations in the Netherlands.

3. Review of Lepidoptera in field margins

We compiled species lists of butterflies and macro-moths occurring in field margins across Europe, using published studies. For butterflies, information on 105 species was collected, with 38 species occurring in 50% or more of the countries. For moths, only British studies were available, listing 334 species, with 29 species observed in all studies.

3.1 Butterflies

We found published studies on butterflies in field margins for 8 countries (Finland, France, Germany, Italy, the Netherlands, Sweden, Switzerland and United Kingdom). These listed 105 species in total, with the number of species ranging between 14 for the Netherlands and 57 in France. Ten species were recorded in all countries and 38 in at least half of the countries, which was considered as an indication of a widespread occurrence. All 38 species also occur in the Netherlands, although *Melanargia galathea* is not a stable resident species and *Cupido argiades* has only established recently.
Among the rarer occurrences, mentioned in less than half of the countries (Annex 1), were 4 species listed on the European Red List (RL) and/or protected under the European Habitats Directive (HD): *Euphydryas aurinia* (HD; recorded in Switzerland and France), *Euphydryas maturna* (HD, RL-Vulnerable; recorded in Finland), *Lycaena dispar* (HD; recorded in France and Italy) and *Thymelicus acteon* (RL-Near threatened; recorded in France).

Two studies, Lang (2004) in Germany and Lang *et al.* (2015 in Switzerland, focussed more specifically on maize field margins. Other studies did not target specific crops and partly also involved grassland fields. The specific circumstances of the source studies per country can be summarised as follows:

- CH – Switzerland (no data on occupancy):
  - Aviron *et al.* (2009) collected monitoring data in 1998, 2000 and 2002 in three agricultural regions in several habitat types including low-input and conventional meadows, hedgerows, orchards, flower strips and crop fields. Species and individuals of adult butterflies were counted during five 10 min. observation periods between May and August, across an area of 0.25 ha in the middle of fields or along hedges.
  - Lang *et al.* (2015) collected data on the butterfly community in the Reuss valley, an area that includes 21 protected and species-rich nature reserves but also has a predominance of agricultural land (56-70% of the area, depending on the community), with 39% of the cropland consisting of maize fields.
- D – Germany (% occupancy from Lang, 2004; presence from Börschig *et al.,* 2013):
  - Lang (2004) collected butterfly monitoring data from 20 maize field margins in Bavaria.
  - Börschig *et al.* (2013) conducted butterfly transect surveys in 137 grassland sites across a gradient of land use intensity in three regions of Germany.
- F – France (% occupancy in linear elements):
  - Van Halder *et al.* (2017) carried out butterfly transect counts in 142 linear elements, mostly along cropland, in three agricultural regions in France: Burgundy, Aquitaine and Gascony.
- GB - United Kingdom (only presence):
  - Feber *et al.* (1996): butterfly transect counts in arable field margins at the University of Oxford's farm.

  - Dover & Sparks (2000): review of British butterfly species recorded along hedgerows.
  - Dover et al. (2000): green lanes were surveyed for butterflies in 1997 on lowland arable farmland on the Trafford/north Cheshire border (Warburton) and on upland grassland in the Yorkshire Dales (Ribble Valley).
  - Meek *et al.* (2002): butterfly transect counts in a replicated study of five different field margin types along winter wheat and barley fields in North Yorkshire.
- I – Italy : (% occupancy in field margins):
  - Dainese *et al.* (2015) conducted butterfly transect counts at 90 field margin sites (with maize, wheat and soybean as dominant crops) bordering on either grassland or hedgerows in the Venetian-Friulian Plain in northeastern Italy.
- NL – Netherlands (only presence):
  - De Snoo et al. (1998) surveyed butterfly transects along winter wheat and potato crops in two different years (6 transects in 1990 and 8 in 1992) in the Haarlemmermeerpolder, an arable region on marine clay in the west of the Netherlands.
- S – Sweden (% occupancy in 16 field margins):
  - Rundlöf *et al.* (2008) carried out butterfly transect counts in 8 pairs of organically and conventionally managed cereal fields (mainly spring-sown wheat and barley) in different landscapes in southern Skåne, the southernmost part of Sweden.
- SF – Finland (only presence):
  - Saarinen (2002) collected butterfly transect count data over 3 years (1997-1999) in field margin habitats at four sites in Karelia (along cereal fields and grasslands) and in Joutseno, South Karelia (dry verges between arable field and pine forest, moist verges between arable field and aspen forest and mesic verges between adjoining fields); grazed and mown grasslands were also studied, but were not included in Table 3.1.

The EFSA database on non-target arthropods (Riedel *et al.,* 2016) listed no butterfly species for maize and only two pest species for oilseed rape, *Pieris rapae* (5 records) and *P. brassicae* (3 records).

3.2 Moths

The occurrence of moths in field margins has only been investigated more extensively in the United Kingdom. Among day-active moths, burnet moths (Zygaenidae) were investigated in France and Sweden.
The British studies of moths in field margins yielded 334 species of macro-moths, with 29 species recorded in all studies and 133 species in two out of three studies (Table 3.2; Annex 2). Only the study by Merckx *et al.* (2012) covered the whole flight season from May till October. All listed species do occur in the Netherlands, with the exception of *Photedes captiuncula* found by Fuentes-Montemayor *et al.* (2011).

The specific circumstances of the source studies per country can be summarised as follows:

- Merckx *et al.* (2012) investigated macro-moth abundance during four consecutive years (2006–2009; 240 trap nights; 1920 trap events) using 6 W Heath light traps with 48 fixed sampling sites, which were spread over 16 predominantly arable farms in Oxfordshire, England. The fields were characterized by having both standard and extended-width grass margins, hedgerows and a variable number of hedgerow trees. Each farm was sampled 40 times between 2006 and 2009, in discrete fortnightly periods from mid-May to mid-October.

- Alison *et al.* (2016) surveyed 96 arable field margins with and without agri-environment scheme interventions across a range of connectivity to chalk grasslands in four study landscapes within north-west Hampshire, England. Field crops were primarily wheat and barley. Moths were caught during one trapping night at each location in June 2014 with Heath light traps.
- Fuentes-Montemayor *et al.* (2011) surveyed 18 pairs of agri-environment scheme interventions and conventionally-managed farms in central Scotland. Adjacent fields were either pastoral or arable. Moths were caught during one trapping night at each location in 2008, using portable 6 W Heath light traps powered with 12 V batteries.

Day-active Zygaenidae were observed by Van Halder *et al.* (2017) in a French field margin study (see 3.1). They recorded the following 4 species in 1 to 4% of the field margins: *Zygaena filipendulae, Z. lonicerae, Z. loti, Z. trifolii.*
In Sweden, Rundlöf *et al.* (2008) also observed *Zygaena loti* (19% of field margins) and further recorded *Adscita statices* (12%).

Fuentes-Montemayor *et al.* (2011) also caught 25 species of Microlepidoptera in numbers varying between 5 and 115: *Agapeta hamana, Agriphila straminella, A. tristella, Blastobasis adustella, B. lacticolella, Catoptria falsella, Celypha lacunana, Chrysoteuchia culmella, Cnephasia asseclana, C. incertana, C. stephensiana, Dipleurina lacustrata, Eana osseana, Epiblema roborana, Eucosma cana, E. hohenwartiana, Hepialus fusconebulosa, Hofmannophila pseudospretella, Pandemis heparana, Pleuroptya ruralis, Scoparia ambigualis, S. pyralella, Trachycera advenella, Udea lutealis, U. prunalis.*

For maize fields, the EFSA database on non-target arthropods (Riedel *et al.,* 2016) listed 1 abundant species of micro-moth, the pest species *Ostrinia nubilalis* (European corn borer; Crambidae; 496 records) and 6 pest species of macro-moths (all Noctuidae): *Sesamia nonagrioides* (Mediterranean corn borer; 106 records), *Agrotis segetum* (Turnip moth, 27 records), *Helicoverpa armigera* (Cotton bollworm; 20 records, migrant species), *Agrotis ipsilon* (Dark sword-grass or Black cutworm; 11 records, migrant species), *Agrotis exclamationis* (Heart and Dart; 8 records)*, Autographa gamma* (Silver-Y moth; 8 records, migrant species).
For oilseed rape, only the micro-moth pest species *Plutella xylostella* (Diamondback moth; Plutellidae; 4 records) was listed.

*Table 3.1: Butterfly species frequently occurring in field margins in Europe (at least 4 out of 8 countries; for remaining species, see Annex 1). Where available, the occurrence has been expressed as a percentage occupancy; otherwise presence has been denoted as 'x' or between parentheses when only 1 individual was recorded. Species shown in **bold** are included in the Red List for the Netherlands.*

Species name	N countries	CH	D	F	GB	I	NL	S	SF
Aglais io	8	x	60	8	x	6	x	100	x
Aglais urticae	7	x	75	15	x		x	100	x
Anthocharis cardamines	6	x	25	(1)	x			19	x
Aphantopus hyperantus	5	x	30		x			100	x
Araschnia levana	5	x	15	(1)				37	x
Argynnis aglaja	5		x	1	(x)			12	x
Argynnis paphia	6	x	5		(x)	2		(6)	x
Aricia agestis	6	x	x	44	(x)	17	x		
Boloria selene	4		5		(x)			12	x
Celastrina argiolus	6	x	x	2	x	57			x
Coenonympha pamphilus	8	x	70	29	x	42	x	56	x
Colias croceus	5	x	x	20	x	43			
Cupido argiades	4	x		5		2			x
Cyaniris semiargus	4	x	x	2					x
Erynnis tages	4	x	x	3	(x)				
Favonius quercus	4	x	(5)		(x)			(6)	
Gonepteryx rhamni	6	x	25		x	8		(6)	x
Issoria lathonia	6	x	40	4		4	x	75	
Lasiommata megera	7	x	10	18	x	16	x	19	
Leptidea sinapis complex	5	x	10	3		8			x
Lycaena phlaeas	7	x	10	6	x	26		50	x
Lycaena tityrus	4	x	x	5		(1)			
Maniola jurtina	8	x	45	73	x	26	x	94	(x)
Melanargia galathea	5	x	25	56	x	3			
Melitaea athalia	4		x			7		12	x
Ochlodes sylvanus	7	x	15	4	x	32		19	x
Papilio machaon	5	x	40	4		9			x
Pararge aegeria	6	x	5	11	x	21			(x)
Pieris brassicae	8	x	20	43	x	52	x	94	x
Pieris napi	8	x	80	8	x	48	x	100	x
Pieris rapae	8	x	95	39	x	98	x	100	x
Polygonia c-album	6	x	15	(1)	x	13			x
Polyommatus icarus	8	x	35	46	x	45	x	44	x
Pyrgus malvae	5	x	x	6	(x)				x
Thymelicus lineola	7	x	30	25	x		x	94	x
Thymelicus sylvestris	4	x	15	5	x				
Vanessa atalanta	8	x	55	7	x	22	x	56	x
Vanessa cardui	8	x	45	4	x	57	x	12	x
N species	**105**	**53**	**44**	**57**	**39**	**42**	**14**	**27**	**56**

*Table 3.2: Macro-moth species occurring in field margins in all 3 studies in the United Kingdom (for remaining species, see Annex 2). Presence has been denoted as 'x' when species were caught incidentally (Merckx) or as single individuals in field centres (Alison) Species shown in **bold** are included as endangered in the provisional Red List for the Netherlands.*

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2016) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Amphipyra tragopoginis	4	30	38
Apamea crenata	4	100	x
Apamea lithoxylaea	x	30	19
Apamea monoglypha	47	40	144
Arctia caja	x	77	8
Autographa gamma	12	33	8
Caradrina morpheus	6	48	5
Campaea margaritaria	x	33	10
Diachrysia chrysitis	51	44	44
Diarsia mendica	x	40	8
Diarsia rubi	16	41	22
Epirrhoe alternata	71	50	16
Hydriomena furcata	2	100	5
Hypena proboscidalis	27	100	35
Luperina testacea	39	100	11
Mythimna conigera	47	29	6
Mythimna ferrago	20	29	9
Mythimna impura	49	47	415
Mythimna pallens	100	56	151
Noctua comes	18	57	58
Noctua pronuba	61	25	189
Oligia fasciuncula	2	30	5
Phlogophora meticulosa	47	11	x
Ptilodon capucina	x	100	x
Rhodometra sacraria	x	100	x
Scotopteryx chenopodiata	20	100	94
Spilosoma lubricipeda	2	44	5
Xanthorhoe montanata	8	50	49
Xestia triangulum	x	40	27
N species	**299**	**180**	**72**

4. Review of host and nectar plants in field margins

On the basis of three sources of plant species occurring in field margins in the Netherlands – commercial seed mixtures, spontaneous vegetation and arable weeds – we compiled a list of 763 plant species. Combined with known host plant relations of butterflies and macro-moths frequently found in field margins, this resulted in a list of 198 plant species of fields and field margins serving as potential larval host plants and adult nectar plants for butterflies and moths. The complete plant species database has been supplied as separate supplementary information (see Supplementary File)

4.1 Plant species in field margins and arable fields

4.1.1 Plant species in commercial seed mixtures

The compilation of all plant species from the 30 selected seed mixtures resulted in a total of 231 plant species. From these, 111 species were mentioned only once in one of the 30 seed mixtures. A total of 120 plant species occurred in two or more seeds mixtures.

The results of the test for the robustness of our selection method are summarized in Table 4.1. The addition of a "new" seed mixture (with 15 – 17 plant species) would have resulted in the addition of 1 or 2 extra plant species to our list of 231 potential host plants. We thus decided that the 30 seed mixtures were sufficient to cover the botanical composition of the commercial seed mixtures available in the Netherlands.

Table 4.1: Test with 3 additional seed mixtures from 3 seed firms

Seed Firm	Mixture name (in Dutch)	Number of species	Additions to host plant list
Neutkens BV	Neutkens meerjarig vlindermengsel	17	2
Van Dijke Zaden	Meerjarig FAB mengsel (2012)	15	1
PVM	Meerjarig akkerrandenmengsel vlinders nr 2	17	1

4.1.2 Plant species of spontaneous vegetation in field margins and embankments

As mentioned in par. 2.3, detailed lists of weed species and field margin vegetation around maize or oilseed rape crops in the Netherlands were not found. Therefore, we had to rely on information sources on arable weeds in general, and inventories of (semi)natural vegetation in field margins irrespective of the accompanying crops (see Table 2.2). Ten such information sources were found, two of which (IRS Onkruidherkenning and Meyer *et al.*, 2015) also include a number of species not occurring in the Netherlands. In total, this produced a sub-list of 673 plant species, of which 312 species occurred in one information source only and 361 occurred more frequently. This only concerns herbaceous plant species, excluding shrubs and trees.

4.1.3 Plant species as weeds in maize and oilseed rape in the Netherlands

The limited amount of information sources on weeds in maize and oilseed rape resulted in a list of 96 weed species, of which 22 were 'specific' for maize (in this limited inventory) and 24 species were characteristic for oilseed rape.

4.1.4 Potential nectar and host plants for butterflies and moths in field margins

The combination of the three subsets of vegetation (1 - seed mixtures, 2a - natural vegetation in field margins and 2b - weeds in maize and oilseed rape) resulted in a total list of 762 different plant species (Table 4.2). Of these, 317 plant species were mentioned in one information source (and thus in one subset) only. From the more frequently mentioned species, a total of 203 plant species occurred in 2 of the vegetation subsets, and a small number of just 17 plant species occurred in all 3 subsets of vegetation. Given the different nature of these botanical selections (especially regarding seed mixtures and weeds), this is not surprising, however.

Table 4.2: Total number of plant species in the different subsets of vegetation types and in the combined list of potential nectar and host plants for butterflies and moths

Vegetation subsets:	Per subset	Single-mention species*	in 1 subset only	in 2 subsets			in 3 subsets
Commercial seed mixtures	230	42	29	–	0	142	17
Field margins and ditch embankments	673	264	189	61	–	142	17
Weeds in maize and oilseed rape crops	96	11	7	61	0	–	17
Combined plant list	**762**	**317**	**225**	**203**			**17**

* = occurring only once in one information source of the vegetation subsets

4.2 Host and nectar plants of butterflies and moths frequently occurring in field margins of maize and oilseed rape

The distribution analysis of butterflies and moths in Chapter 5 produced a list of Lepidoptera species frequently recorded (above-average) in field margins. For these Lepidoptera, the known nectar plants and host plants were selected. This resulted in a list of 125 plant species and 45 plant genera (as host plant use is often specific to a plant genus rather than a plant species).

Table 4.3: Numbers of known nectar and host plant species or genera of butterflies and moths occurring more than average in field margins of maize and oilseed rape.

Category	Total	in 1 subset only	in 2 subsets			in 3 subsets
Nectar plants	52	17	6	–	21	8
Butterfly host plants	58	35	6	9	–	8
Moth host plants	112	74	–	9	21	8
Combined plant list	**170**	**126**		**36**		**8**

4.3 Availability of host and nectar plants for field-margin Lepidoptera

We checked whether the known nectar and host plants of the selected species of butterflies and moths (occurring more than average in field margins of maize and oilseed rape) actually do occur in seed mixtures, field margins, ditch embankments or weed communities of maize and oilseed rape. For this purpose, the overlap between all the plant lists was tabulated.

This resulted in a total plant list of 788 plant species and/or plant genera, of which 490 species are not a nectar or host plant for the butterflies and moths occurring more than average in field margins. A further 26 host plant species did not occur in any source of field margin vegetation, leaving 788 – 490 – 26 = 272 host plant and nectar plant species available in field margins, with 256 species of larval host plants and 16 species of nectar plants (i.e. not serving as important host plants).

In order to exclude rare plants, i.e. represented by a single literature source (and pooling some taxonomical redundancy), we discarded a further 74 species to arrive

at the final selection of 198 herbaceous plant species that may frequently occur in field margins and are known to serve as larval host plants or nectar plants to butterfly and macro-moth species with above-average occurrence in field margins.

The distribution of the remaining 198 plant genera and species over the different categories is given in Table 4.4:

- 15 plant species are butterfly nectar plants but do not serve as larval host plants
- 123 plant species serve as moth larval host plants only
- 36 plant species serve as butterfly larval host plants only
- 24 plant species serve as larval host plants for both butterflies and moths

The full plant species list is included in Table 4.5; it includes some crop species (*Brassica* species, *Solanum tuberosum*) that may also grow in field margins.

Table 4.4: Number of plant species frequently occurring in field margins and serving as larval host plants or nectar plants for butterflies and moths recorded above-average in field margins.

Plant category	Butterfly Nectar plants		Total
	Yes	No	
Non-host plants	**15**	**–**	**15**
Host plants moths only	**22**	**101**	**123**
Host plants butterflies only	**6**	**30**	**36**
Host plants butterflies & moths	**15**	**9**	**24**
Host plants moths total	37	101	138
Host plants butterflies total	21	39	60
Total	**58**	**140**	**198**

Table 4.5: List of plant species frequently occurring in field margins and serving as larval host plants or nectar plants for butterflies and moths recorded above-average in field margins. Indicated is the total number of Lepidoptera species (N spp) using the plant species and the number of sources (refs) where the plant species is mentioned.

Plant species name	N spp Host plant butterflies	N spp Host plant moths	N spp Nectar plant butterflies	N seed mixtures	N refs in spontaneous vegetation	N refs in weeds	Total Frequency
Larval Host Plants							
Achillea millefolium		3	4	13	8	0	21
Agrostis capillaris	1			5	4	0	9
Agrostis stolonifera	2			0	5	0	5
Alliaria petiolata	4		2	2	2	0	4
Alopecurus pratensis	5			1	4	0	5
Angelica sylvestris	1	1	3	5	1	0	6
Arctium lappa	1			1	1	0	2
Arctium minus	1			0	2	0	2
Arrhenatherum elatius	1	1		3	6	0	9
Artemisia vulgaris		4		0	8	1	9
Atriplex patula		2		0	8	2	10
Atriplex prostata		2		0	6	0	6
Atriplex sp.		2		0	1	2	3
Barbarea vulgaris	2			6	1	0	7
Brassica napus	3	2	4	0	4	0	4
Brassica nigra	3	2	4	0	2	0	2
Brassica oleracea	3	2	4	0	2	0	2

Plant species name	N spp Host plant butterflies	N spp Host plant moths	N spp Nectar plant butterflies	N seed mixtures	N refs in spontaneous vegetation	N refs in weeds	Total Frequency
Brassica rapa	3	2	4	0	3	0	3
Calluna vulgaris		6	8	0	2	0	2
Cardamine pratensis	3		4	3	4	0	7
Carduus crispus	1			0	3	0	3
Centaurea jacea		1	6	8	2	0	10
Cerastium arvense		1		1	6	0	7
Cerastium fontanum		1		2	4	0	6
Cerastium glomeratum		1		0	2	0	2
Chamerion angustifolium		3	2	1	2	0	3
Chenopodium album		2		0	10	3	13
Chenopodium glaucum		2		0	4	0	4
Chenopodium hybridum		2		0	2	0	2
Chenopodium polyspermum		2		0	5	0	5
Chenopodium rubrum		2		0	3	0	3
Chenopodium species		2		0	1	3	4
Cirsium arvense	1	1	15	0	10	3	13
Cirsium vulgare	1		6	0	7	0	7
Convolvulus arvensis		1		0	8	2	10
Convolvulus sepium		1		0	8	4	12
Crepis biennis		1	2	5	1	0	6
Crepis capillaris		1	2	2	5	0	7
Cynosurus cristatus	3			2	1	0	3
Dactylis glomerata	6	4		0	5	0	5
Daucus carota	1		2	8	7	0	15
Deschampsia cespitosa	3	4		0	3	0	3
Deschampsia flexuosa		3		2	3	0	5
Digitalis purpurea		1		1	2	0	3
Dipsacus fullonum		1		0	2	0	2
Elytrigia repens	6	3		0	9	3	12
Epilobium palustre		1		0	2	0	2
Epilobium parviflorum		1		0	3	0	3
Epilobium tetragonum		1		0	2	0	2
Eupatorium cannabinum		2	12	5	0	0	5
Euphorbia esula		1		1	2	0	3
Festuca arundinacea	1	1		1	6	0	7
Festuca pratense	4			2	3	0	5
Festuca rubra	3			0	5	0	5
Filipendula ulmaria		2		8	3	0	11
Foeniculum vulgare	1			2	0	0	2
Galeopsis tetrahit		1	3	1	7	2	10
Galium aparine		11		0	9	6	15
Galium mollugo		11		6	3	0	9
Galium palustre		11		2	0	0	2
Galium tricornutum		11		0	2	0	2
Galium verum		11		2	2	0	4
Glechoma hederacea		1		0	7	0	7
Heracleum sphondylium		2	4	3	5	0	8
Hieracium laevigatum		1	10	3	0	0	3
Hieracium pilosella		1	1	0	5	0	5
Hieracium umbellatum		1	8	2	1	0	3

Plant species name	N spp Host plant butterflies	N spp Host plant moths	N spp Nectar plant butterflies	N seed mixtures	N refs in spontaneous vegetation	N refs in weeds	Total Frequency
Holcus lanatus	2			3	6	0	9
Hypericum perforatum		1		2	4	0	6
Iris pseudacorus		2		6	3	0	9
Jacobaea vulgaris		3	6	0	6	0	6
Lactuca serriola		1		0	4	0	4
Lamium album		10		0	6	0	6
Lamium amplexicaule		10		0	6	1	7
Lamium purpureum		10		0	8	4	12
Linaria vulgaris		1		1	6	0	7
Lolium perenne	2			1	7	1	9
Lotus corniculatus	1	3	1	8	6	0	14
Lotus pedunculatus	1	1	4	9	4	0	13
Luzula campestris		1		4	2	0	6
Luzula multiflora		1		0	2	0	2
Luzula pilosa		1		0	2	0	2
Lysimachia vulgaris		1		5	2	0	7
Lythrum salicaria		2	12	9	2	0	11
Malva neglecta	1			0	4	0	4
Malva sylvestris	1			3	3	0	6
Matricaria chamomilla		2		2	9	1	12
Matricaria discoidea		2		0	8	0	8
Medicago lupulina	2	1	8	2	2	0	4
Medicago sativa	2	1	8	1	4	0	5
Melilotus albus		1	1	1	2	0	3
Melilotus altissimus		1	1	1	1	0	2
Mentha aquatica		1	1	5	1	0	6
Molinia caerulea	2	8		0	2	0	2
Oenothera biennis		2		2	0	0	2
Oenothera erythrosepala		2		0	3	0	3
Oenothera biennis		2		0	2	0	2
Origanum vulgare		1	1	3	2	0	5
Pastinaca sativa	1			6	4	0	10
Persicaria amphibia		1		0	7	2	9
Persicaria hydropiper		1		0	6	2	8
Persicaria lapathifolia		1		0	6	1	7
Persicaria lapathifolia subsp. pallida		1		0	4	1	5
Persicaria maculosa		1		0	9	5	14
Peucedanum palustre	1			2	0	0	2
Phalaris arundinacea		3		0	5	0	5
Phleum pratense	4			0	5	0	5
Phragmites australis		1		0	6	1	7
Pimpinella saxifraga	1			2	0	0	2
Plantago lanceolata		9		11	7	0	18
Plantago major subsp. major		9		0	8	0	8
Plantago media		9		2	1	0	3
Poa annua		1		0	9	5	14
Poa pratense	4	2		1	5	0	6
Poa trivialis	4	2		0	6	0	6
Polygonum aviculare		2		0	9	6	15
Potentilla reptans		1		0	3	0	3

Plant species name	N spp Host plant butterflies	N spp Host plant moths	N spp Nectar plant butterflies	N seed mixtures	N refs in spontaneous vegetation	N refs in weeds	Total Frequency
Pteridium aquilinum		1		0	4	0	4
Ranunculus arvensis		2		0	3	0	3
Ranunculus auricomus		2		0	2	0	2
Ranunculus bulbosus		2		2	2	0	4
Ranunculus ficaria		2		0	3	0	3
Ranunculus flammula		2		1	1	0	2
Ranunculus lingua		2		1	1	0	2
Ranunculus sardous		2		0	2	0	2
Ranunculus sceleratus		2		0	4	0	4
Raphanus raphanistrum	1			0	4	2	6
Raphanus sativus	1			0	2	0	2
Reseda lutea	1			0	2	0	2
Rorippa nasturtium-aquaticum	3			0	2	0	2
Rorippa palustris	3			0	5	0	5
Rorippa sylvestris	3			0	5	0	5
Rubus fruticosus agg.		7	13	0	6	0	6
Rubus idaeus		2		0	3	0	3
Rumex acetosa		2		5	9	0	14
Rumex acetosella		2		1	6	0	7
Rumex conglomeratus		20		0	3	0	3
Rumex crispus		20		0	5	0	5
Rumex obtusifolius		20		0	8	0	8
Rumex thyrsiflorus		20		2	0	0	2
Salix alba		3		0	2	0	2
Sanguisorba officinalis	1		1	1	1	0	2
Scrophularia nodosa		1		1	2	0	3
Scrophularia umbrosa		1		1	1	0	2
Senecio sylvaticus		1		0	3	0	3
Senecio viscosus		1		0	2	0	2
Senecio vulgaris		1		0	7	2	9
Silene dioica		3		1	3	0	4
Silene latifolia subsp. alba		4		3	4	0	7
Silene noctiflora		4		1	1	0	2
Silene vulgaris		4		0	2	0	2
Sinapis alba	2			0	3	0	3
Sinapis arvensis	2			0	10	2	12
Sisymbrium officinale	2			0	7	0	7
Solanum tuberosum		1		0	5	3	8
Sonchus arvensis		1	1	0	9	1	10
Stachys arvensis		1		0	2	0	2
Stachys sylvatica		1		0	2	0	2
Stellaria graminea		4		1	3	0	4
Stellaria media		4		0	9	3	12
Stellaria sp.		4		0	0	3	3
Symphytum officinale		1		1	8	0	9
Tanacetum vulgare		2	7	4	7	0	11
Taraxacum officinale agg.		6	8	1	9	0	9
Thlaspi arvense	3			1	6	2	9
Trifolium arvense	1	8	1	4	2	0	6
Trifolium campestre	1	8	1	1	2	0	3

Plant species name	N spp Host plant butterflies	N spp Host plant moths	N spp Nectar plant butterflies	N seed mixtures	N refs in spontaneous vegetation	N refs in weeds	Total Frequency
Trifolium dubium	1	8	1	2	2	0	4
Trifolium pratense	3		10	8	7	0	15
Trifolium resupinatum	1	8	1	1	2	0	3
Urtica dioica	3	15		0	8	1	9
Urtica urens	3			0	6	5	11
Verbascum densiflorum		1		1	1	0	2
Verbascum nigrum		1		2	0	0	2
Vicia cracca	1	1	4	5	7	0	12
Vicia hirsuta		1		1	4	0	5
Vicia sativa		1		2	7	0	9
Vicia sativa subsp. nigra		1		2	0	0	2
Vicia sepium		1		0	3	0	3
Vicia tetrasperma		1		1	3	0	4
Vicia villosa		1		0	3	0	3
Viola arvensis		2		1	8	4	13
Viola tricolor		2		0	4	0	4
Butterfly Nectar plants but not Larval Host plants							
Anthriscus sylvestris			1	4	8	0	12
Cirsium palustre			11	5	1	0	6
Echium vulgare			2	3	2	0	5
Epilobium hirsutum			1	3	4	0	7
Hypochaeris radicata			5	6	5	0	11
Jasione montana			1	2	3	0	5
Knautia arvensis			2	4	1	0	5
Leontodon autumnalis			7	8	6	0	14
Lychnis flos-cuculi			3	7	1	0	8
Ranunculus acris			2	15	6	0	21
Ranunculus repens			5	2	8	0	10
Saponaria officinalis			1	3	0	0	3
Solidago virgaurea			1	2	0	0	2
Trifolium repens			3	5	8	0	13
Valeriana officinalis			2	8	3	0	11

5. Lepidoptera in maize and oilseed rape field margins in the Netherlands

The relative occurrence of butterflies and macro-moths was assessed in maize and oilseed rape field margins in the Netherlands. This was achieved by combining detailed geospatial data. Data on oilseed rape fields were limited due to the small area of cultivation, but for maize fields data were sufficiently abundant to estimate relative population sizes of butterflies on the basis of abundance data. This resulted in a selection of 10 butterfly species and 43 species of macro-moths that occur more than expected in maize field margins.

5.1 Maize and oilseed rape area

5.1.1 Maize area

In 2015, the area under maize cultivation in the Netherlands amounted to 240,861 ha (Table 5.1), at an average field size of 2.5 ha (median 1.9). Including a 30 m buffer around these fields augmented the area by 87%, i.e. 216,564 ha.
At a the scale of the Netherlands, with a terrestrial surface of 3,470,269 ha (34,703 km^2), the proportion of maize fields covered 7.1 % of the national land surface and 13.4 % including the 30 m field margin (i.e. 6.2% for maize field margins only).
The largest proportion of maize cultivation (70.7%) takes place on Pleistocene sandy soils, where they represented 10.7% of land cover and 20.3% including the 30 m field margin buffer (i.e. 9.5% for maize field margins only).
The area of maize cultivation is also substantial on riverine and marine clays, but much less on lowland peat, coastal dunes, calcareous loamy soils and urban areas. As the total area of calcareous loamy soils is small, the proportion of maize fields in this region (8.1%) still lies above the national average.

5.1.2 Oilseed rape area

The current area of oilseed rape cultivated in the Netherlands is small: only 2539 ha in 2015, at an average field size of 5.0 ha (median 3.5 ha). More than half of the area is cultivated on marine clay soils (especially in the province of Groningen; Luijten & de Jong, 2010) and a further 27% on Pleistocene sands. The total area including field margins amounted to 4061 ha. This area was not sufficient for an extensive quantitative analysis. Therefore, only an indicative overview of Lepidoptera occurrence in oilseed rape fields is given in par. 5.4.

Table 5.1: Extent of maize and oilseed rape cultivation in the Netherlands in 2015 (source: CBS).

	Maize				Oilseed rape	
Region	N fields	Area (ha)	% Area fields	% Area fields + margins	N fields	Area (ha)
Coastal dunes	241	761	0.8	1.4	1	1
Calcareous soils	2014	4138	8.1	15.7	11	40
Pleistocene sands	73049	175446	10.7	20.3	189	692
Lowland peat	2428	7180	2.8	5.6	27	176
Urban	241	572	0.5	0.9	1	5
Riverine clay	12192	31390	8.7	16.2	82	257
Marine clay	7709	28575	3.0	5.2	192	1368
Total	**97874**	**248061**	**7.1**	**13.4**	**503**	**2539**

5.2 Butterflies in maize field margins

Proportions of butterfly occurrence higher than the area proportion covered by maize field margins, i.e. 6.2% for the Netherlands and 9.5% within the physico-geographical region with Pleistocene sands, were considered as an indication of a higher occurrence in maize field margins than expected by chance, i.e. a significant extent.
In total, based on both distribution and population analysis, nine species were found to occur to a significant extent in maize field margins and one additional species almost met the threshold criterion.

5.2.1 Butterfly distribution analysis

There were 62,884 records of 56 butterfly species in maize field margins (i.e. 3.6% from a total of 1.76 million records of 63 species); 20 species occurred above the overall proportion of 3.6% for all butterfly records in field margins (Table 5.2). Most of these were also frequently recorded in the European review (Chapter 3). Five species were not at all recorded in earlier field margin studies, but except for *Phengaris nausithous* this concerned species that, as expected, were only rarely recorded in Dutch maize field margins.
Frequently recorded species that were not or rarely recorded in the European review were *Apatura iris* (Red List Critically Endangered)*, Carterocephalus palaemon* (Red List Vulnerable)*, Colias hyale* (a migrant)*, Phengaris nausithous* (Red List Critically Endangered) and *Pyronia tithonus.*
The 6.2% threshold of occurrence, i.e. the national proportion by area of maize field margins, was exceeded by five species (in order of decreasing percentages): *Phengaris nausithous* (Red List Critically Endangered)*, Cupido argiades, Pyronia tithonus, Carterocephalus palaemon* (Red List Vulnerable) and *Aphantopus hyperantus.*
For *Phengaris nausithous,* the proportion of records in maize field margins was remarkably high: 37.8%. Only one population of this species, listed on the Habitats Directive occurs in the Netherlands in an area where maize covers a substantial area (Figure 5.1). *Cupido argiades* is a newly colonising species that has established a few populations in the southern part of the Netherlands.

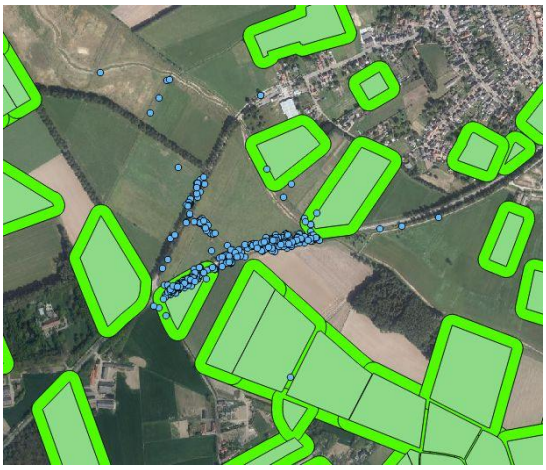

Figure 5.1: Distribution of Phengaris nausithous *in an area with abundant maize field margins.*

For some species, high frequencies of occurrence in maize field margins were not apparent at a national scale, but only within the physico-geographical region with Pleistocene sands, where most maize fields are grown. This concerned especially *Colias croceus* (a migrant)*, Issoria lathonia, Papilio machaon, Colias hyale* (a migrant) and *Lasiommata megera,* but only the first three exceeded the 9.5% threshold of field margin cover in the Pleistocene sands region*. L. megera* has strongly declined in this region over the last decade.

Figure 5.2: Distribution of monitoring transects with sections in maize field margins.

5.2.2 Butterfly population analysis

The population analysis was carried out with a set of 558 monitoring transect sections in maize field margins (Figure 5.2) on a total of 7131 sections. These were used to estimate the proportion of the population occurring in maize field margins, accounting for physico-geographical

region and land use type. This was possible for 23 species, with records in at least 10 sections in maize field margins.
For ten out of these 23 species, the proportion of the population in maize field margins exceeded the average proportion of 3.3% over all species records (Table 5.2). Four species also met the 6.2% threshold of national cover of maize field margins (in decreasing order of percentages): *Carterocephalus palaemon* (Red List Vulnerable), *Pyronia tithonus, Callophrys rubi, Aphantopus hyperantus*.
No additional species exceeded the 9.5% threshold in the Pleistocene sands region.

Table 5.2: Percentage of records and of population size of butterfly species in maize field margins for the Netherlands and within the region of Pleistocene sands where 71% of maize fields are situated. Percentages printed in bold exceed the proportion by area of maize field margins. Species printed in bold are on the Red List of the Netherlands (HD = species listed on the European Habitats Directive). The right column gives the number of European countries from which the species was recorded in field margins (see Ch. 3).

Species	NL		Pleistocene sands		Europe
	% Records	% Population	% Records	% Population	(Ch. 3)
Aglais io	3.4	3.3	5.7	4.8	8
Aglais urticae	3.9	2.4	7.0	4.8	7
Anthocharis cardamines	3.7	3.1	5.1	3.4	5
Apatura iris	4.0		5.7		3
Aphantopus hyperantus	**6.8**	**6.6**	8.5	6.9	5
Araschnia levana	4.4	2.7	6.3	3.2	5
Argynnis aglaja	0.2		0.2		5
Argynnis niobe	0.0		0.0		0
Argynnis paphia	1.1		5.3		6
Aricia agestis	1.6		4.9		6
Boloria selene	0.0		0.0		4
Callophrys rubi	1.1	**7.3**	1.4	8.0	3
Carcharodus alceae	0.1		0.0		2
Carterocephalus palaemon	**7.7**	**8.5**	7.8	8.5	2
Celastrina argiolus	2.1	1.7	3.0	2.6	6
Coenonympha pamphilus	2.5	1.6	4.6	2.9	8
Colias croceus	5.0		**10.3**		5
Colias hyale	4.6		9.2		3
Cupido argiades	**10.6**		**35.3**		4
Cyaniris semiargus	4.4		0.0		4
Favonius quercus	2.5		3.4		4
Gonepteryx rhamni	3.5	4.5	4.5	5.3	6
Hesperia comma	0.0		0.0		1
Heteropterus morpheus	1.2		1.2		0
Hipparchia semele	0.1		0.2		2
Issoria lathonia	1.0		**10.0**		6
Lasiommata megera	2.9		8.7		7
Leptidea sinapis	0.0		0.0		5
Limenitis camilla	1.9		1.9		2
Lycaena phlaeas	2.7	2.0	4.8	2.7	7
Lycaena tityrus	1.2		1.2		4
Maniola jurtina	2.4	1.7	3.9	2.4	8
Melitaea athalia	0.1		0.1		4
Melitaea cinxia	0.3		0.6		1
Nymphalis polychloros	3.3		7.2		3
Ochlodes sylvanus	4.6	5.7	5.2	6.8	7
Papilio machaon	5.7		**9.8**		5
Pararge aegeria	4.4	2.9	7.0	4.6	6
Phengaris alcon	0.2		0.2		1
Phengaris nausithous[HD]	**37.8**		**37.8**		0
Phengaris teleius[HD]	0.4		0.4		0

Species	NL		Pleistocene sands		Europe
	% Records	% Population	% Records	% Population	(Ch. 3)
Pieris brassicae	3.6	4.1	6.1	7.2	8
Pieris napi	4.4	2.1	6.9	3.1	8
Pieris rapae	4.5	2.3	8.0	4.6	8
Plebejus argus	0.4		0.5		3
Polygonia c-album	2.5	2.8	4.2	4.8	6
Polyommatus icarus	2.4	0.8	5.3	1.4	8
Pyrgus malvae	0.0		0.0		5
Pyronia tithonus	**8.0**	**7.8**	**10.5**	**9.6**	3
Satyrium ilicis	0.3		1.8		0
Satyrium w-album	0.7		2.4		1
Thecla betulae	2.7		3.2		2
Thymelicus lineola	5.8	2.1	7.8	2.9	7
Thymelicus sylvestris	1.3		1.7		4
Vanessa atalanta	3.4	3.2	6.2	6.2	8
Vanessa cardui	3.7	4.6	7.2	7.6	8

5.3 Moths in maize field margins

Out of the total of 0.8 million records of 778 macro-moth species, 15,812 records of 542 species were located in maize field margins; 250 species occurred above the average proportion of 2.0 % (Annex 3).
Threshold proportions were estimated on the basis of the distribution of well-investigated sites (where at least 15 species were recorded): 3.8% of these were located in maize field margins for the whole of the Netherlands and 6.6% for the Pleistocene sands regions. Proportions of moth occurrence higher than these values were considered as an indication of a higher occurrence in maize field margins than expected by chance.

In total, 43 species were recorded more than expected in maize field margins, including 5 species that have been listed as Endangered on the provisional Red List for the Netherlands (Table 5.3); 21 of these were also mentioned in other field margin studies (Chapter 3). 26 species were recorded above the threshold value for the Netherlands as a whole and 17 were occurring above the threshold value only in the Pleistocene sands region.

The species with the highest occurrence in maize field margins was *Theria rupicapraria* (NT) with 12 % of the records in field margins, but only in the riverine landscape. *Cucullia chamomillae* (EN) ranked second with 9.5 % of the records in field margins. Within the Pleistocene sands region *Mythimna pallens* had 14.8 % of records in field margins.

Table 5.3: Percentage of records of macro-moth species in maize field margins for the Netherlands and within the region of Pleistocene sands where 71% of maize fields are situated. Percentages printed in bold exceed the proportion of well-investigated sites in maize field margins. Species printed in bold are on the Red List of the Netherlands. The right column indicates a qualitative indication of the presence of species in British studies (see Annex 2).

Family	Species	NL % Records	Pleistocene sands % Records	UK studies (Ch. 3)
Cossidae	*Cossus cossus*	3.2	**6.9**	
Erebidae	*Amata phegea*	**4.2**	4.3	
	Diaphora mendica	**3.9**	5.7	Present
	Euclidia glyphica	**5.1**	**9.3**	
	Hypena rostralis	**4.0**	6.2	
	Orgyia antiqua	**4.2**	4.5	Present
Geometridae	*Apocheima hispidaria*	**4.0**	5.4	

Family	Species	NL % Records	Pleistocene sands % Records	UK studies (Ch. 3)
	Biston strataria	**3.8**	5.8	
	Chiasmia clathrata	2.6	**8.3**	
	Ennomos autumnaria	**6.7**	**13.6**	
	Ennomos erosaria	**4.6**	4.9	Present
	Gandaritis pyraliata	2.9	**7.5**	Abundant
	Lycia hirtaria	**5.2**	**8.9**	
	Siona lineata	3.3	**12.3**	
	Thera britannica	**4.8**	**7.2**	Present
	Theria rupicapraria	**11.8**	0.0	
	Timandra comae	**4.1**	6.3	
Limacodidae	*Apoda limacodes*	**4.5**	5.8	Frequent
Noctuidae	*Acronicta aceris*	3.4	**7.3**	Present
	Agrochola lunosa	2.6	**10.1**	Frequent
	*Agrotis segetum**	3.3	**7.3**	Abundant
	Atethmia centrago	1.6	**11.1**	Present
	Caradrina morpheus	2.4	**8.7**	Frequent
	Cosmia pyralina	2.6	**6.6**	Present
	Cucullia chamomillae	**9.5**	**11.3**	
	Cucullia scrophulariae	**5.2**	5.5	
	Diarsia mendica	2.5	**6.9**	Occasional
	Diarsia rubi	2.5	**6.7**	Frequent
	Dryobotodes eremita	**5.8**	**7.1**	Occasional
	Hecatera bicolorata	3.7	**7.0**	Present
	Hoplodrina octogenaria	2.9	**7.3**	Occasional
	Ipimorpha subtusa	3.4	**11.7**	Present
	Macdunnoughia confusa	**4.5**	**7.7**	
	Mesapamea secalis	2.9	**9.9**	Frequent
	Mythimna l-album	**4.2**	**11.0**	
	Mythimna pallens	**4.2**	**14.8**	Abundant
Nolidae	*Bena bicolorana*	**5.1**	**7.3**	
Notodontidae	***Drymonia dodonaea***	**6.1**	**6.6**	
	Thaumetopoea processionea	**4.6**	**7.0**	
Sesiidae	*Synanthedon tipuliformis*	**7.9**	0.0	
Sphingidae	*Agrius convolvuli*	**3.9**	**7.3**	
	Laothoe populi	2.5	**7.3**	Frequent

5.4 Lepidoptera in oilseed rape

5.4.1 Butterflies in oilseed rape field margins

Data on butterfly occurrence in oilseed rape fields and field margins included only 284 butterfly records from 26 species. The average proportion of records in oilseed rape field margins was 0.02%, with 14 species occurring at an above-average proportion (Table 5.4). The other 12 recorded species were (number of records between brackets): *Anthocharis cardamines* (5), *Celastrina argiolus* (3), *Coenonympha pamphilus* (5), *Colias croceus* (2), *Gonepteryx rhamni* (6), *Lasiommata megera* (1), *Lycaena phlaeas* (4), *Maniola jurtina* (19), *Pararge aegeria* (14), *Polygonia c-album* (1), *Polyommatus icarus* (8) and *Pyronia tithonus* (2).

None of the recorded species is included on the Red List for the Netherlands.

Table 5.4: Butterfly species with above-average occurrence in field margins of oilseed rape, with the number of records per species and proportion relative to the total number of national records.

Species	N records	% records
Aglais io	25	0.03
Aglais urticae	35	0.03
Aphantopus hyperantus	13	0.03
Araschnia levana	6	0.02
Nymphalis polychloros	1	0.22
Ochlodes sylvanus	11	0.03
Pieris brassicae	11	0.02
Pieris napi	34	0.02
Pieris rapae	36	0.02
Satyrium w-album	3	0.67
Thymelicus lineola	7	0.02
Thymelicus sylvestris	1	0.04
Vanessa atalanta	19	0.02
Vanessa cardui	12	0.04
Total	**284**	**0.02**

5.4.2 Moths in oilseed rape field margins

For macro-moths, 73 records from 40 species were collected from oilseed rape field margins in the period 2011-2016. This concerned 0.009% of all national records. The following species were observed, with a maximum of 4 records per species:
Autographa gamma, Cabera pusaria, Calliteara pudibunda, Chiasmia clathrata, Chloroclysta siterata, Cossus cossus, Cucullia chamomillae, Deilephila elpenor, Deltote bankiana, Epirrhoe alternata, Eupithecia abbreviata, Euplagia quadripunctaria, Hypena proboscidalis, Hypena rostralis, Idaea aversata, Macroglossum stellatarum, Mesoligia furuncula, Mormo maura, Mythimna pallens Nola cucullatella, Opisthograptis luteolata, Orthosia cerasi, Panolis flammea, Peridea anceps, Pheosia tremula, Phragmatobia fuliginosa, Plagodis pulveraria, Pterostoma palpina, Rivula sericealis, Scoliopteryx libatrix, Selenia dentaria, Stegania trimaculata, Timandra comae, Tyria jacobaeae, Watsonalla binaria, W. cultraria, Xanthorhoe ferrugata, X. montanata, Xestia xanthographa, Zygaena filipendulae.

Among these species, three are included as endangered on the provisional Red List for the Netherlands: *Cucullia chamomillae, Nola cucullatella* and *Plagodis pulveraria*. Furthermore, *Euplagia quadripunctaria* (1 record) is a protected species according to the European Habitats Directive.

6. Potentially significantly exposed species

The identification of species potentially exposed to a significant extent to transgenic insect-resistant crops was limited to maize, because insufficient data were available for oilseed rape. The identification was based on criteria of species occurrence, larval host plant occurrence, phenology of larval development and, for Red List species, habitat use during dispersal. It resulted in 19 butterfly species and 28 macro-moth species that can be considered as potentially significantly exposed to the introduction of insect-resistant maize.

6.1 Butterflies

Ten butterfly species were considered as potentially exposed to a significant extent in maize field margins on the basis of a higher occurrence than expected (Table 6.1; also see par. 5.3). *Lasiommata megera* did not fully meet the criteria, but was included because the review in Chapter 3 indicates that it is one of the most widespread field margin species. In the Netherlands, the species has strongly declined during the last decade, especially on Pleistocene sands (Klop *et al.,* 2015). Therefore, data to accurately estimate its occurrence in field margins were limited, and we considered that the 8.7% was sufficiently near the threshold of 9.5% to allow it to be considered in the selection process.

The next decision criterion following the species frequency of occurrence concerns habitat suitability. The combination of data on species occurrence with the availability of larval host plants and main nectar plants in field margins (Chapter 4) indicated that suitable habitat is potentially available for all 10 species frequently recorded in maize field margins (Table 6.1). It should be noted that the nectar plant criterion is based on the frequent of occurrence of important nectar plant species in field margins. This does not imply, however, that nectar availability is sufficient if the criterion is met, because actual nectar abundance will depend largely on local conditions and on field margin management (e.g., fertilisation rate, cutting and herbicide application). Thus, nectar availability may often be limited in practice, but Table 6.1 indicates that the presence of nectar sources should potentially be sufficient for the listed species.
The final decision criterion consists of determining whether larval development takes place during the flowering period, when pollen could be deposited onto host plants. All species have caterpillars in the flower period of maize.
Thus, the 10 butterfly species that are found most frequently in field maize margins can all be considered as potentially exposed to a significant extent.

Table 6.1: Assessment of potentially significant exposure of butterfly species in maize field margins in the Netherlands (x = meets criterion). Red List Status: LC = Least Concern, VU = Vulnerable, CR = Critically Endangered.

Family	Species	Dutch name	Red List Status	Host plant present?	Nectar plants present?	Caterpillar July-August?	Potentially exposed?
Hesperiidae	*Carterocephalus palaemon*	bont dikkopje	VU	x	x	x	x
Papilionidae	*Papilio machaon*	koninginnenpage	LC	x	x	x	x
Pieridae	*Colias croceus*	oranje luzernevlinder	Migrant	x	x	x	x
Lycaenidae	*Callophrys rubi*	Groentje	LC	x	x	x	x
	Cupido argiades	Staartblauwtje	New	x	x	x	x
	Phengaris nausithous	donker pimpernelblauwtje	CR	x	x	x	x
Nymphalidae	*Aphantopus hyperantus*	Koevinkje	LC	x	x	x	x
	Issoria lathonia	kleine parelmoervlinder	VU	x	x	x	x
	Lasiommata megera	Argusvlinder	LC	x	x	x	x
	Pyronia tithonus	oranje zandoogje	LC	x	x	x	x

A complementary criterion consists of considering whether threatened species are likely to encounter field margins during dispersal and find larval host plants there that may host larvae during the maize flowering period. This was assessed semi-quantitatively on the basis of the distribution of known local populations in relation to the distribution of maize fields that lie between them (Figure 6.1).
For 12 species, including 3 already listed in Table 6.1, we arrive at a potential exposure during dispersal: *Aricia agestis, Carterocephalus palaemon* (see Table 6.1), *Cyaniris semiargus, Hesperia comma, Heteropterus morpheus, Hipparchia semele, Issoria lathonia* (see Table 6.1), *Lycaena tityrus* (see Figure 6.1)*, Phengaris nausithous* (see Table 6.1), *Melitaea cinxia, Ochlodes sylvanus* and *Pyrgus malvae.*

Thus, the total list of potentially significantly exposed butterfly species numbers 19 species, i.e. ten potentially exposed species with a significant occurrence in maize field margins and nine species potentially exposed during dispersal (see Annex 4 for species characteristics).

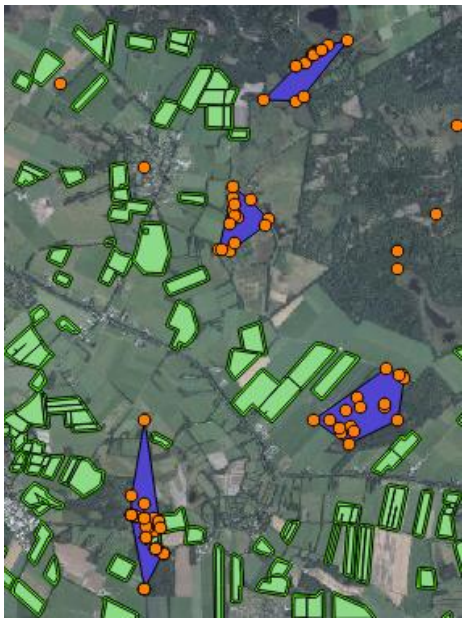

Figure 6.1: Example of the distribution of local populations of the Red List species Lycaena tityrus *in relation to interspersed maize field margins: dispersing butterflies are likely to encounter maize fields with larval host plants in their margins.*

6.2 Moths

Maize
For all 43 species recorded more frequently than expected in maize field margins (Table 6.2; also see par. 5.4) larval host plants are frequently found in such field margins, although 21 of the moth species have woody host plants. Trees and shrubs have not been explicitly considered in Chapter 4, but moth larvae often use several host plant species and the species listed all have a widespread occurrence, which extends to the woodland margins, tree lanes and hedgerows along field margins. Therefore, potentially suitable larval habitat appears available for all species. Nectar dependence and availability is less well known for moths than for butterflies and was not considered as a separate factor. However, as the potential availability of nectar plants did not appear limiting for butterflies (Table 6.1), we do not deem it an important limitation for moths either, given that field margin management is adequate.

Out of the 43 species, 14 species do not have caterpillars in the flower period of maize and one species lives under bark, which keeps it from exposure to maize pollen. The remaining 28 species, however, can be considered as potentially exposed to a significant extent; 10 of these have woody host plants and 18 have herbaceous host plants (see Annex 4 for species characteristics).
Five of these potentially significantly exposed species are listed as Endangered on the provisional Red list for the Netherlands: *Ennomos autumnaria, Ennomos erosaria, Cucullia chamomillae, Cucullia scrophulariae, Drymonia dodonaea*.

For moths, the knowledge about metapopulation ecology and distribution of populations is as yet insufficient to determine whether threatened species run an additional potential risk to encounter maize field margins during dispersal.

Table 6.2: Assessment of potentially significant exposure of macro-moth species in maize field margins in the Netherlands (x = meets criterion). Red List Status: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Family	Species	Dutch name	Status	Host plant	Caterpillar Jul-Aug	Potentially exposed?
Cossidae	*Cossus cossus*	wilgenhoutrups	LC	trees	lives under bark	
Erebidae	*Amata phegea*	phegeavlinder	LC	x	x	x
	Diaphora mendica	mendicabeer	LC	x	x	x
	Euclidia glyphica	bruine daguil	LC	x	x	x
	Hypena rostralis	hopsnuituil	LC	x	x	x
	Orgyia antiqua	witvlakvlinder	LC	trees	x	x
Geometridae	*Apocheima hispidaria*	voorjaarsspanner	LC	trees		
	Biston strataria	vroege spanner	VU	trees		
	Chiasmia clathrata	klaverspanner	LC	x	x	x
	Ennomos autumnaria	iepentakvlinder	EN	trees	x	x
	Ennomos erosaria	gehakkelde spanner	EN	trees	x	x
	Gandaritis pyraliata	gele agaatspanner	LC	x		
	Lycia hirtaria	dunvlerkspanner	EN	trees		
	Siona lineata	vals witje	LC	x	x	x
	Thera britannica	schijn-sparspanner	VU	trees	x	x
	Theria rupicapraria	late meidoornspanner	NT	shrubs		
	Timandra comae	lieveling	LC	x	x	x
Limacodidae	*Apoda limacodes*	slakrups	LC	trees	x	x
Noctuidae	*Acronicta aceris*	bont schaapje	VU	trees	x	x
	Agrochola lunosa	maansikkeluil	LC	x		
	Agrotis segetum	gewone velduil	LC	x	x	x
	Atethmia centrago	essengouduil	LC	trees		
	Caradrina morpheus	morpheusstofuil	LC	x		
	Cosmia pyralina	maanuiltje	VU	shrubs		
	Cucullia chamomillae	kamillevlinder	EN	x	x	x
	Cucullia scrophulariae	helmkruidvlinder	EN	x	x	x
	Diarsia mendica	variabele breedvleugeluil	VU	x	x	x
	Diarsia rubi	gewone breedvleugeluil	NT	x	x	x
	Dryobotodes eremita	eikenuiltje	LC	trees		
	Hecatera bicolorata	tweekleurige uil	VU	x	x	x
	Hoplodrina octogenaria	gewone stofuil	LC	x	x	x
	Ipimorpha subtusa	tweekleurige heremietuil	VU	trees		
	Macdunnoughia confusa	getekende gamma-uil	NT	x	x	x
	Mesapamea secalis	halmrupsvlinder	LC	x		
	Mythimna l-album	witte-l-uil	LC	x	x	x
	Mythimna pallens	bleke grasuil	LC	x	x	x
	Parastichtis suspecta	populierenuil	VU	trees		
Nolidae	*Bena bicolorana*	grote groenuil	VU	trees	x	x
Notodontidae	*Drymonia dodonaea*	gestreepte tandvlinder	EN	trees	x	x
	Thaumetopoea processionea	eikenprocessierups	LC	trees		
Sesiidae	*Synanthedon tipuliformis*	bessenglasvlinder	LC	shrubs	x	X
Sphingidae	*Agrius convolvuli*	windepijlstaart	Migrant	x	x	X
	Laothoe populi	populierenpijlstaart	LC	trees	x	x

Oilseed rape

Data were too scarce to allow an assessment of a potentially significant exposure of Lepidoptera in oilseed rape field margins. Still, it should be noted that three macro-moth species that are listed as Endangered on the provisional Red List for the Netherlands have been found in oilseed rape field margins. Two of these could be considered as potentially exposed, because larvae are found in the flowering period of oilseed rape:

- *Cucullia chamomillae* (young larvae May–July)
- *Nola cucullatella* (larvae Aug–June)

This also applies to the following species that is listed on the Habitats Directive: *Euplagia quadripunctaria* (larvae Sept-June)

7. Discussion

In order to facilitate the risk assessment for the introduction of transgenic insect-resistant crops, notably maize and oilseed rape, we compiled a list of non-target Lepidoptera species that are potentially exposed to a significant extent. We reviewed the occurrence of butterflies and macro-moths in field margins and subsequently carried out a quantitative analysis of the occurrence of these Lepidopterans in field margins of maize and oilseed rape in the Netherlands. In combination with an assessment of habitat suitability in terms of host and nectar plant availability as well as the probability of dispersing Red List species to encounter suitable habitat in field margins, this resulted in a list of species that are potentially exposed to a significant extent.

7.1 Main findings

In the literature review, we focused on the frequency of occurrence of species in different studies across European countries. We found evidence for 105 species of butterflies occurring in field margins in Europe, with 38 species occurring in 50% or more of the eight countries studied. For moths, only British studies were available, listing 334 species, with 29 species observed in all studies.

In the analysis of Macrolepidoptera from the Netherlands, we examined both species occurrence and habitat conditions for frequently occurring species. We compiled a list of 763 plant species that can be found in field margins, including plants from indigenous seed mixtures, weeds and spontaneous vegetation bordering field margins. Combined with known host plant relations of butterflies and macro-moths frequently found in field margins of maize and oilseed rape, this resulted in a list of 198 plant species of fields and field margins serving as potential larval host plants and adult nectar plants.

In the quantitative analysis, we used recent data from the Netherlands to determine the Lepidopterans occurring within a 30 m field margin buffer around the fields of maize and oilseed rape. Maize fields cover a substantial area of the country (248,061 ha in 2015): when including the 30 m buffer advised by EFSA (2015), this amounts to 13.4% of the land surface. Oilseed rape was only cultivated over 2539 ha, which precluded an extensive analysis for that crop.
For both butterflies and macro-moths, we estimated the proportion of records within the 30 m field margin buffer relative to their national occurrence. Because this analysis was based on opportunistically collected data, no correction for sampling effort could be made, but the large volume of available data gave confidence in the results. For butterflies, we were also able to use monitoring data that allowed the use of species abundances based on a standard counting protocol. However, the sample size of this dataset was much smaller, enabling estimation for 23 species. The agreement of the estimates between the two methods was generally satisfactory with a deviation of 0.1 to 2.3 % for 21 species. Only two species showed a substantial deviation: *Thymelicus lineola* (3.7%) and *Callophrys rubi* (6.2%). For the grassland species *T. lineola,* the deviation could be attributed to differences in abundance between field margins and other sites, with lower abundance in field margins. For *C. rubi,* a species of open woodland and heathland, the deviation was rather due to a difference in sampling distribution leading to a higher presence in field margins on the monitoring sites than in the distribution records.

From the total of 56 butterfly species and 542 macro-moth species, we arrived at a selection of 10 butterfly species and 43 species of macro-moths that occur more than expected in maize field margins. One butterfly species had an exceptionally

high occurrence in maize field margins, with 37.8% of recent records: *Phengaris nausithous*. This is significant, as the species is critically endangered at a national scale, near threatened at a European scale and it is protected under Annexes II and IV of the European Habitats Directive. In the Netherlands, *P. nausithous* used to occur more widespread on moderately fertilised damp meadows in the southern parts of the country. Only one population is currently remaining in the Netherlands in the Roer river valley (Boeren *et al.,* 2011), an area where maize cultivation is frequent.

We subsequently identified a list of species that can be considered as potentially exposed to a significant extent to the introduction of insect-resistant maize, based on criteria of species occurrence, larval host plant occurrence, phenology of larval development and, for Red List species, habitat use during dispersal. The list consists of 19 butterfly species and 28 species of macro-moths. The set of butterfly species includes the aforementioned 10 species frequently occurring in field margins and 9 Red List-species that are likely to encounter maize fields during dispersal between local populations, find larval host plants there and have caterpillars developing during the flower period of maize, when pollen may be deposited onto larval host plants.

As none of the Macrolepidoptera species occurs for more than 50% of its known distribution or population in field margins, we can conclude that *none* of the examined butterfly and macro-moth species rely predominantly on maize fields and field margins. Here, suitable habitat is almost exclusively restricted to the field margins. The fields themselves are suitable only for species that can successfully exploit annual plants for larval development. This greatly restricts the number of species to common Lepidoptera, such as *Pieris* species. The Red List species *Issoria lathonia* does frequently use the widespread annual *Viola arvensis.,* but only in field margins where microclimatic conditions are sufficiently warm. Field centres are therefore unsuitable for its larval development. Hence, even within the potentially suitable Pleistocene sands region, the proportion of records for this species in maize field margins does not exceed 10%.

Still, even a modest dependence of Lepidoptera on field margins does not imply that populations of potentially exposed species are safe from a deteriorating habitat quality in field margins. With 68% of butterfly species on the Red List for the Netherlands and an estimated 47% of macro-moths, any addition to the existing pressures from land use may contribute to declining population trends that, ultimately, may result in extinction. It is imperative, therefore, to view the vulnerability of Lepidopteran populations in the broader context of habitat quality in agricultural environments.

7.2 Lepidoptera in agricultural environments

The concern for Lepidoptera as non-target organisms is justified by the strong declines that are being recorded, both in butterflies (Van Swaay *et al*., 2010; 2016) and macro-moths (Groenendijk & Ellis, 2011; Fox, 2013). Even common species are seen to decline (Van Dyck, *et al.,* 2009). There is increasing evidence that habitat loss and degradation resulting from agricultural land-use intensification is a main driver of decline in Lepidoptera (Van Swaay *et al.,* 2006; Fox *et al.,* 2014; Van Halder *et al.,* 2017). The processes underlying the impacts of land-use intensification are complex, involving not only direct habitat destruction and loss of connectivity, but also less clearly evident aspects of deterioration of habitat quality. Thus, species declines have been linked to excessive levels of nitrogen deposition (Fox et al., 2014; WallisDeVries & Van Swaay, 2017), declines of nectar plants (WallisDeVries *et al.,* 2012; Dicks *et al.,* 2015) and pesticides (Roy *et al.,* 2003; Geiger *et al.,* 2010; Pisa *et al.,* 2015; Gilburn *et al.,* 2015), with likely interactions between these different pressures.

Overall, the evidence clearly indicates that, because of these multiple pressures, intensively used agricultural landscapes offer a hostile environment to the vast majority of butterflies and moths. This is a serious problem for the long-term preservation of Lepidopteran populations, because agricultural land-use dominates the landscape in most of lowland Europe; in the Netherlands the proportion of agricultural land area is 64%, with a 29% cover of cropland (CBS Statline). A sufficient basic quality of agricultural landscapes is then crucial to maintain the ecological infrastructure required for the long-term preservation of non-target insect diversity (Gámez-Virués *et al.,* 2015; Kovács-Hostyánszki *et al.,* 2017). Additional pressures, even of a minor magnitude, may lead to a fatal loss of population viability. It is therefore essential to establish that the introduction of transgenic insect-resistant crops does not pose such a pressure. This can only be determined by a thorough risk assessment involving species that are likely to be exposed.
In policy development, it should be important to weigh the risks of introducing transgenic insect-resistant crops against the risks of not doing so, which would probably result in a continuation of the widespread application of insecticides – possibly even an increase, in view of the expected rise of insect herbivore damage to cultivated crops in temperate climates under climatic warming; see Olesen *et al.,* 2011). Recent research (Hahn *et al.,* 2015) has provided further evidence of the negative effects of such agro-chemicals on Lepidoptera in field margins. It could turn out that Bt-maize pollen grains drifting onto host plants for Lepidoptera lead to a lesser exposure to toxic substances than current insecticide sprays. In that case GM crops, maize included, could prove beneficial to Lepidoptera populations.

7.3 Implications for risk assessments of transgenic insect-resistant crops

Prior to the introduction of transgenic crops potential risks to non-target organisms, including non-target Lepidoptera, are assessed using data from laboratory experiments as well as field experiments. Laboratory experiments on the impacts of Bt pollen on larval development of Lepidoptera have so far been conducted on a small number of species and in a limited number of studies. This prevents a comprehensive risk assessment (Lang & Otto, 2010). Still, in their review they found indications that a longer experimental exposure time was more often associated with the detection of adverse effects.
Results from (semi-)field experiments under more realistic conditions are even more scarce than from laboratory experiments (Lang & Otto, 2010). A number of studies has been carried out to assess the magnitude and distance of maize pollen drift. Pollen may spread over long distances of hundreds of metres. This finding led Lang *et al.* (2015) to suggest buffer zones of at least 50-100 m width, and case-specific risk assessments for distances above 100 m, which is a far greater buffer than considered in this study. A similar recommendation was reached by Hoffmann *et al.* (2016), who measured considerably higher maize pollen densities around maize fields than previously reported. Schuppener *et al.* (2012) conducted a combination of laboratory bioassays and field studies to assess the impacts of Bt maize on the common butterfly *Aglais urticae,* from which they concluded that the risk of adverse effects was negligible. However, given the influence of landscape configuration and variation in species sensitivities (as reported in Lang & Otto, 2010), we can conclude that a comprehensive risk assessment will require a substantial effort to arrive at scientifically robust recommendations.

One of the knowledge gaps concerns the scant attention for non-target Lepidoptera that may potentially be exposed in the field. This study provides a first identification of the species concerned, based on the situation for Macrolepidoptera (butterflies and macro-moths) in the Netherlands. A total of 19 species of butterflies (10 species occurring more than expected in maize field margins and 9 additional Red List species that are likely to encounter potential

habitat in field margins during dispersal) and 28 species of macro-moths have been identified as potentially exposed to a significant extent.
These potentially significantly exposed species could serve as model species in future risk assessments. Their actual suitability as model species also depends on a variety of species characteristics. The most relevant characteristics of the 19 butterfly and 28 macro-moth species have been summarised in Annex 4. Besides larval and adult phenology, these include their conservation status, main habitat, host plant use and voltinism.

- Main habitat and host plant use are obvious indicators of species occurrence in agricultural landscapes, especially field margins.
- Voltinism is relevant in relation to the suitability of species for rearing experiments, which can be more productive in bi- or multivoltine species.
- Species mobility is a further factor that should be taken into account in the interpretation of field experiments at a larger scale, where highly mobile species are less likely to give meaningful results about the effects of local conditions. However, this applies largely to butterflies where both fairly good mobility estimates and standardised monitoring methodologies are available.
- Rearing experience is an important criterion for the feasibility of laboratory as well as field experiments. This information has not been included in Annex 4, but has been taken into consideration in the weighing of pros and cons in Table 7.1. In general, most species have been reared, but only published experiments have been taken into account here.
- Conservation status may be regarded as important in the light of biodiversity policy targets, with a higher priority for endangered species. For moths, this status is only provisional as an official Red List remains to be established.

On the basis of species characteristics, we have listed the pros and cons of using particular butterfly species as model species in future risk assessments, considering both laboratory and field experiments (Table 7.1). Because the evidence base for butterflies is more extensive than for moths, we have restricted this evaluation to butterflies. In this evaluation, we have included a widespread occurrence in field margin habitats throughout Europe (Table 3.1) as an advantage for generalisation of eventual research output.

Table 7.1: Pros and cons for the suitability of potentially significantly exposed butterfly species in future risk assessments of transgenic insect-resistant crops. Red List Status in the Netherlands after Van Swaay (2006; Not threatened is equivalent to Least Concern and Sensitive to Near Threatened).

Butterfly species	Red List Status	Pros	Cons
Aphantopus hyperantus	*Not threatened*	*Abundant and widespread; common hostplants*	*Slow reproduction*
Aricia agestis	*Sensitive*	*Widespread; fast reproduction; common hostplants*	*Not frequent in field margins*
Callophrys rubi	*Not threatened*		*Slow reproduction; not typical for field margins in many regions; woody hostplants*
Carterocephalus palaemon	*Vulnerable*	*Relevant for conservation in NW Europe*	
Colias croceus	*Migrant*	*Widespread; fast reproduction; common hostplants*	*No permanent populations in temperate climates; high mobility and low density*
Cupido argiades	*Occasional resident*	*Fast reproduction; common hostplants*	*Erratic occurrence in many regions; high mobility*
Cyaniris semiargus	*Extinct (re-colonising)*	*Widespread; fast reproduction; common hostplants; relevant for conservation in NW Europe*	*Often rare and not abundant*
Hesperia comma	*Endangered*	*Relevant for conservation in NW Europe; well-studied species*	*Slow reproduction; not frequent in field margins*

Butterfly species	Red List Status	Pros	Cons
Heteropterus morpheus	*Critically endangered*		*Not widespread; Slow reproduction; not frequent in field margins*
Hipparchia semele	*Sensitive*		*Slow reproduction; not frequent in field margins*
Issoria lathonia	*Vulnerable*	*Widespread; fast reproduction; common hostplants; rearing experience*	*Inherent variability in larval growth rate; high mobility*
Lasiommata megera	*Not threatened*	*Widespread; fast reproduction; common hostplants; rearing experience*	*Strong recent decline in agricultural areas*
Lycaena tityrus	*Vulnerable*	*Fast reproduction; common hostplants; rearing experience*	*Not frequent in field margins*
Melitaea cinxia	*Critically endangered*	*Relevant for conservation in NW Europe; well-studied species; rearing experience*	*Slow reproduction*
Ochlodes sylvanus	*Sensitive*	*Widespread and abundant species; common hostplants*	*Slow reproduction*
Papilio machaon	*Not threatened*	*Widespread; fast reproduction; common hostplants; rearing experience*	*Not abundant; large population fluctuations between years (sensitive to cold); high mobility*
Phengaris nausithous	*Critically endangered / HD*	*Highly policy-relevant throughout Europe*	*Rare species; rare hostplant; Slow reproduction; complex life cycle*
Pyrgus malvae	*Endangered*	*Widespread species; common hostplants; policy-relevant in NW Europe*	*Not abundant in field margins; Slow reproduction*
Pyronia tithonus	*Not threatened*	*Regionally abundant species; common hostplants*	*Slow reproduction; not widespread in Europe*

When focussing on a combination of a fairly widespread occurrence in field margin habitats, habitat use, rapid life cycle and rearing experience, there are three species that emerge as potential candidates for lab and field experiments in future risk assessments: *Issoria lathonia* (host plants *Viola* species, including *V. arvensis* and *V. tricolor*), *Lasiommata megera* (host plants: miscellaneous grasses), and *Papilio machaon* (host plants Apiaceae, including *Daucus, Pastinaca, Foeniculum*). A different weighing of pros and cons might of course lead to a different choice, as would considering the merits of other species. Thus, *Aglais io* and *A. urticae* also meet the above-mentioned criteria, but these species are less dependent on field margin habitats than the species examined in Table 7.1 (see Table 5.2 for data on the occurrence of the two species in field margins).
Although we do not foresee systematically different outcomes between butterflies and moths, it may be advisable to also include a moth species in these risk assessments. Along the same lines of reasoning, *Chiasmia clathrata* and *Euclidia glyphica* (see Annex 4) might then be proposed.

Should the introduction of transgenic insect-resistant crops be approved in the future, then, based on based on the precautionary principle, it will be important to provide for a sufficient monitoring effort to detect unforeseen negative effects or confirm the expected neutral or even beneficial effects of the new cultivars on Lepidoptera populations. Butterfly Monitoring Schemes (Van Swaay *et al.,* 2008), similar to the monitoring scheme in the Netherlands, may be used to this effect. However, Lang (2004) cautions that a substantial sample size (at least 75-150 transects) is required to obtain sufficient power to detect meaningful trends.

8 Conclusion

The introduction of transgenic insect-resistant crops necessitates a careful risk assessment of possible adverse effects on non-target organisms, such as butterflies and moths. However, information on the species that are potentially exposed has been lacking. This report focussed on Macrolepidoptera species (butterflies and macro-moths) in fields and field margins of maize and oilseed rape. It contributes to fill this knowledge gap by identifying species that are most likely to be significantly exposed. A selection of these species can be considered as model species in future risk assessments.

A literature review offered a general overview of 105 species of butterflies occurring in field margins in Europe, with 38 species occurring in 50% or more of the eight countries studied. For moths, only British studies were available, listing 334 species, with 29 species observed in all studies and also occurring in the Netherlands.

For the Netherlands, the analysis yielded the following main outcomes:

- we identified 10 butterfly species and 28 macro-moth species that occur more frequently in maize field margins than expected by chance and are thus potentially exposed to a significant extent;
- a further 9 Red List butterfly species are potentially exposed to a significant extent during dispersal, when they may find suitable habitat in maize field margins;
- we found no species that are predominantly occurring in maize field margins, although the occurrence of the critically endangered butterfly *Phengaris nausithous* was substantial (37.8% of recent records in maize field margins)

For oilseed rape, the evidence was too scant to allow a quantitative analysis and only a preliminary overview was therefore compiled for this crop.

Although we did not find species that are fully dependent on maize field margins in the sense that their populations are restricted to this habitat, this finding should *not* lead to the conclusion that the identified species are safe from possible adverse effects. Many Macrolepidoptera species are facing declines across Europe and agricultural intensification has been identified as a major driver of decline. Any additional pressures may then lead to a cascade of population extinctions.
We therefore recommend a thorough procedure of risk assessments on the introduction of transgenic insect-resistant crops. This assessment should also weigh the (possibly greater) risks from the alternative decision of not introducing such crops, which will most likely involve a continued application of insecticides that are harmful to non-target Lepidoptera.

We propose three butterfly species that – on the basis of their widespread occurrence in field margin habitats, rapid life cycle and rearing experience – may considered suitable as model species in experimental studies for future risk assessments: *Issoria lathonia, Lasiommata megera* and *Papilio machaon.* Upon an eventual introduction of transgenic insect-resistant, we recommend adequate population monitoring out of the precautionary principle to enable detection of possible deviations from the expected neutral trend.

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References

Alison, J., Duffield, S.J., van Noordwijk, C.G.E., Morecroft, M.D., Marrs, R.H., Saccheri, I.J. & Hodgson, J.A. (2016). Spatial targeting of habitat creation has the potential to improve agri-environment scheme outcomes for macro-moths. *Journal of Applied Ecology* 53, 1814–1822.

Boeren, J., Eckelboom, R. & Wynhoff, I. (2011). Het donker pimpernelblauwtje in het Nederlandse en Duitse Roerdal. *Natuurhistorisch Maandblad* 100 (10), 189-198.

Börschig, C., Klein, A.M., von Wehrden, H. & Krauss, J. (2013). Traits of butterfly communities change from specialist to generalist characteristics with increasing land-use intensity. *Basic and Applied Ecology* 14 (7), 547–554.

Bos, F. G., M. A. Bosveld, D. G. Groenendijk, C. A. M. Van Swaay & I. Wynhoff (2006). *De dagvlinders van Nederland - verspreiding en bescherming.* Nederlandse Fauna 7. Nationaal Natuurhistorisch Museum Naturalis, KNNV Uitgeverij & EIS-Nederland, Leiden.

CBS, PBL, Wageningen UR (2015). *Trend vogels, zoogdieren en dagvlinders agrarisch gebied, 1990-2014 (indicator 1580, versie 01, 29 oktober 2015)*. www.compendiumvoordeleefomgeving.nl. CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven en Wageningen UR, Wageningen.

De Snoo, G.R., van der Poll, R.J. & Bertels, J. (1998). Butterflies in sprayed and unsprayed field margins. *Journal of Applied Entomology* 122, 157-161.

Dennis, R.L.H., Shreeve, T.G. & Van Dyck, H. (2003). Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. *Oikos* 102 (2), 417-426.

Dainese, M., Inclán Luna, D., Sitzia, T. & Marini, L. (2015). Testing scale-dependent effects of seminatural habitats on farmland biodiversity. *Ecological Applications* 25, 1681–1690.

Dicks, L.V., Baude, M., Roberts, S.P.M., Phillips, J., Green, M. & Carvell, C. (2015). How much flower-rich habitat is enough for wild pollinators? Answering a key policy question with incomplete knowledge. *Ecological Entomology* 40, 22–35.

Dover, J., Sparks, T., Clarke, S., Gobbett, K. & Glossop, S. (2000). Linear features and butterflies : the importance of green lanes. *Agriculture, Ecosystems and Environment* 80, 227-242

Dover, J. & Sparks, T. (2000). A review of the ecology of butterflies in British hedgerows. *Journal of Environmental Management* 60, 51-63.

EFSA (2010). Guidance on the environmental risk assessment of genetically modified plants. *EFSA Journal* 8(11):1879.

EFSA (2011). Guidance on the risk assessment of genetically modified microorganisms and their products intended for food and feed use. *EFSA Journa*l 9(6):2193.

EFSA (2015). Updating risk management recommendations to limit exposure of non-target Lepidoptera of conservation concern in protected habitats to Bt-maize pollen. *EFSA Journal* 13(7):4127.

EFSA & COGEM (2013). *Event Report. International scientific Workshop "Non-Target Organisms and Genetically Modified Crops: Assessing the effects of Bt proteins"* (29-30 November 2012, Amsterdam, the Netherlands). Supporting Publications 2013:EN-484.

Ellis, W.N., Groenendijk, D., Groenendijk, M.M., Huigens, M.E., Jansen, M.G.M., van der Meulen, J., van Nieukerken, E.J. & de Vos, R. (2013). *Nachtvlinders belicht: dynamisch, belangrijk, bedreigd.* De Vlinderstichting, Wageningen & Werkgroep Vlinderfaunistiek, Leiden.

Feber, R.E., Smith, H. & Macdonald, D.W. (1996). The effects on butterfly abundance of the management of uncropped edges of arable fields. *Journal of Applied Ecology* 33, 1191-1205.

Fox, R. (2013). The decline of moths in Great Britain: a review of possible causes. *Insect Conservation and Diversity* 6, 5–19.

Fox, R., Oliver, T.H., Harrower, C., Parsons, M.S., Thomas, C.D. & Roy, D.B. (2014). Long-term changes to the frequency of occurrence of British moths are consistent with opposing and synergistic effects of climate and land-use changes. *Journal of Applied Ecology* 51, 949-957

Fuentes-Montemayor, E., Goulson, D. & Park, K.J. (2011). The effectiveness of agri-environment schemes for the conservation of farmland moths: assessing the importance of a landscape-scale management approach. *Journal of Applied Ecology* 48, 532-542.

Gámez-Virués, S., Perovic, D.J., Gossner, M.M., Börschig, C., Blüthgen, N., de Jong, H., Simons, N.K., Klein, A.-M., Krauss, J., Maier, G., Scherber, C., Steckel, J., Rothenwöhrer, C., Steffan-Dewenter, I., Weiner, C.N., Weisser, W., Werner, M., Tscharntke, T. & Westphal, C. (2015). Landscape simplification filters species traits and drives biotic homogenization. *Nature Communications* 6 (8568), 1-8.

Gathmann, A., Wirooks, L., Hothorn, L.A., Bartsch, D. & Schuphan, I. (2006). Impact of Bt maize pollen (MON810) on lepidopteran larvae living on accompanying weeds. *Molecular Ecology* 15, 2677–2685.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W.W., Emmerson, M., Morales, M.B., Ceryngier, P., Liira, J., Tscharntke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., Plantegenest, M., Clement, L.W., Dennis, C., Palmer, C., Oñate, J.J., Guerrero, I., Hawro, V., Aavik, T., Thies, C., Flohre, A., Hänke, S., Fischer, C., Goedhart, P.W. & Inchausti, P. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology* 11, 97-105.

Gilburn, A.S., Bunnefeld, N., McVeanWilson, J., Botham, M.S., Brereton, T.M., Fox, R. & Goulson, D. (2015). Are neonicotinoid insecticides driving declines of widespread butterflies? *PeerJ* 3:e1402.

Groenendijk D. & Ellis, W.N. (2011). The state of the Dutch larger moth fauna. *Journal of Insect Conservation* 15, 95-101

Hahn, M., Schotthöfer, A., Schmitz, J., Franke, L.A. & Brühl, C.A. (2015). The effects of agrochemicals on Lepidoptera, with a focus on moths, and their pollination service in field margin habitats. *Agriculture, Ecosystems and Environment* 207, 153–162.

Hofmann, F., Kruse-Plass, M., Kuhn, U., Otto, M., Schlechtriemen, U., Schröder, B., Vögel, R. & Wosniok, W. (2016). Accumulation and variability of maize pollen deposition on leaves of European Lepidoptera host plants and relation to release rates and deposition determined by standardised technical sampling. *Environmental Sciences Europe*, 28(1), art. no. 14, 1-19.

Klop, E., Omon, B. & WallisDeVries, M.F. (2015). Impact of nitrogen deposition on butterfly communities: the case of the Wall Brown Lasiommata megera. *Journal of Insect Conservation* 19, 393–402.

Kovács-Hostyánszki, A., Espíndola, A., Vanbergen, A.J., Settele, J., Kremen, C. & Dicks, L.V. (2017). Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. *Ecology Letters* 20, 673–689.

Lang, A. (2004). Monitoring the impact of Bt maize on butterflies in the field : estimation of required sample sizes. *Environmental Biosafety Research* 3, 55-66.

Lang, A. & Otto, M. (2010). A synthesis of laboratory and field studies on the effects of transgenic Bacillus thuringiensis (Bt) maize on non-target Lepidoptera. *Entomologia Experimentalis et Applicata* 135, 121-134.

Lang, A., Oehen, B., Ross, J.-H., Bieri, K. & Steinbrich, A. (2015). Potential exposure of butterflies in protected habitats by Bt maize cultivation: A case study in Switzerland. *Biological Conservation* 192, 369-377.

Luijten, S.H. & de Jong, T.J. (2010). A baseline study of the distribution and morphology of *Brassica napus* L. and *Brassica rapa* L. in the Netherlands. Research report COGEM 2010-03, Institute of Biology, University Leiden.

Meek, B., Loxton, D., Sparks, T., Pywell, R., Pickett, H. & Nowakowski, M. (2002). The effect of arable field margin composition on invertebrate biodiversity. *Biological Conservation* 106, 259-271.

Merckx, T., Marini, L., Feber, R.E. & Macdonald, D.W. (2012). Hedgerow trees and extended-width field margins enhance macro-moth diversity: implications for management. *Journal of Applied Ecology* 49, 1396–1404.

Nguyen, H.T. & Jehle, J.A. (2007). Quantitative analysis of the seasonal and tissue-specific expression of Cry1Ab in transgenic maize MON810. *Journal of Plant Diseases and Protection* 114(2), 82-87.

Olesen, J.E., Trnka, M., Kersebaum, K. C., Skjelvåg, A.O., Seguin, B., Peltonen-Sainio, P., Rossi, F., Kozyrah, J. & Micale, F. (2011). Impacts and adaptation of European crop production systems to climate change. *European Journal of Agronomy* 34, 96-112.

Perry, J.N., Devos, Y., Arpaia, S., Bartsch, D., Ehlert, C., Gathmann, A., Hails, R.S., Hendriksen, N.B., Kiss, J., Messéan, A., Mestdagh, S., Neemann, G., Nuti, M., Sweet, J.B. & Tebbe, C.C. (2012). Estimating the effects of Cry1F Bt-maize pollen on non-target Lepidoptera using a mathematical model of exposure. *Journal of Applied Ecology* 49, 29–37.

Pisa, L.W., Amaral-Rogers, V., Belzunces, L.P., Bonmatin, J.M., Downs, C.A., Goulson, D., Kreutzweiser, D.P., Krupke, C., Liess, M., McField, M., Morrissey, C.A., Noome, D.A., Settele, J., Simon-Delso, N., Stark, J.D., Sluijs, J.P. van der, Van Dyck, H. & Wiemers, M. (2015). Effects of neonicotinoids and fipronil on non-target invertebrates. *Environmental Sciences and Pollution Research* 22, Issue 1, pp 68–102.

Riedel, J., Romeis, J., Meissle, M. (2015). Update and expansion of the database of bio-ecological information on non-target arthropod species established to support the environmental risk assessment of genetically modified crops in the EU. *EFSA supporting publication* 2016:EN-956.

Roy, D.B., Bohan, D.A., Haughton, A.J., Hill, M.O., Osborne, J.L., Clark, S.J., Perry, J.N., Rothery, P., Scott, R.J., Brooks, D.R., Champion, G.T., Hawes, C., Heard, M.S. & Firbank, L.G. (2003). Invertebrates and vegetation of field margins adjacent to crops subject to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified herbicide–tolerant crops. *Philosophical Transactions Royal Society London. B* 358 (1439), 1879- 1898.

Rundlöf, M., Bengtsson, J. & Smith, H.G. (2008). Local and landscape effects of organic farming on butterfly species richness and abundance. *Journal of Applied Ecology* 45, 813–820.

Saarinen, K. (2002). *Butterfly communities in relation to changes in the management of agricultural environments.* PhD thesis, University of Joensuu.

Sanchis, V. (2011). From microbial sprays to insect-resistant transgenic plants: history of the biospesticide Bacillus thuringiensis. A review. *Agronomy for Sustainable Development* 31, 217–231.

Sanchis, V. & Bourguet, D. (2008). *Bacillus thuringiensis*: applications in agriculture and insect resistance management. A review. *Agronomy for Sustainable Development* 28, 11–20.

Schmitz, G., Bartsch, D. & Pretscher, P. (2003). Selection of relevant non-target herbivores for monitoring the environmental effects of Bt maize pollen. *Environmental Biosafety Research* 2, 117–132.

Scholte, E.-J. & Dicke, M. (2005). *Effects of insect-resistant transgenic crops on non-target arthropods: first step in premarket risk assessment studies*. Laboratory of Entomology, Wageningen University and Research Centre, Wageningen.

Schuppener, M., Muhlhause, J., Muller, A.K. & Rauschen, S. (2012). Environmental risk assessment for the small tortoiseshell Aglais urticae and a stacked Btmaize with combined resistances against Lepidoptera and Chrysomelidae in central European agrarian landscapes. *Molecular Ecology* 21, 4646–4662.

Tax, M.H. (1989). *Atlas van de Nederlandse dagvlinders.* De Vlinderstichting, Wageningen & Vereniging tot Behoud van Natuurmonumenten in Nederland, 's Graveland.

van Alebeek, F. (2012). *De keuze van inheemse zaadmengsels voor streekeigen landschapselementen in de Natuur- en landschapsnorm (NLN).* Advies aan deelnemers van de Pilot Natuur- en Landschapsnorm (NLN). Wageningen UR – PPO-AGV, Wageningen – Lelystad.

Van Dyck, H., van Strien, A.J., Maes, D. & van Swaay, C.A.M. (2009). Declines in common, widespread butterflies in a landscape under intense human use. *Conservation Biology* 23, 957-965.

Van Halder, I., Thierry, M., Villemey, A., Ouin, A., Archaux, F., Barbaro, L., Balent, G. & Benot, M.-L. (2017). Trait-driven responses of grassland butterflies to habitat quality and matrix composition in mosaic agricultural landscapes. *Insect Conservation and Diversity* 10, 64–77.

Van Swaay, C.A.M. (2006). *Basisrapport Rode Lijst Dagvlinders*. Rapport VS2006.02, De Vlinderstichting, Wageningen.

Van Swaay, C.A.M., Warren, M. & Loïs, G. (2006). Biotope use and trends of European butterflies. *Journal of Insect Conservation* 10, 189-209.

Van Swaay, C.A.M., Nowicki, P., Settele, J. & van Strien, A.J. (2008). Butterfly monitoring in Europe : methods, applications and perspectives. *Biodiversity and Conservation* 17, 3455-3469.

Van Swaay, C., Cuttelod, A., Collins, S., Maes, D., López Munguira, M., Šašić, M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M. and Wynhoff, I. (2010). *European Red List of Butterflies*. Publications Office of the European Union, Luxembourg.

Van Swaay, C.A.M., Van Strien, A.J., Aghababyan, K., Åström, S., Botham, M., Brereton, T. Carlisle, B., Chambers, P., Collins, S., Dopagne, C., Escobés, R., Feldmann, R., Fernández-García, J.M., Fontaine, B., Goloshchapova, S., Gracianteparaluceta, A., Harpke, A., Heliölä, J., Khanamirian, G., Komac, B., Kühn, E., Lang, A., Leopold, P., Maes, D., Mestdagh, X., Monasterio, Y., Munguira, M.L., Murray, T., Musche, M., Õunap, E., Pettersson, L.B., Piqueray, J., Popoff, S., Prokofev, I., Roth, T., Roy, D.B., Schmucki, R., Settele, J., Stefanescu, C., Švitra, G., Teixeira, S.M., Tiitsaar, A., Verovnik, R. & Warren, M.S. (2016). *The European Butterfly Indicator for Grassland species 1990-2015*. Report VS2016.019, De Vlinderstichting, Wageningen.

Van Swaay, C.A.M., Termaat, T., Kok, J., Huskens, K. & Poot, M. (2016). *Vlinders en libellen geteld: jaarverslag 2015*. Rapport VS2016.01, De Vlinderstichting, Wageningen.

Vanreusel, W. & Van Dyck, H. (2007). When functional habitat does not match vegetation types: A resource-based approach to map butterfly habitat. *Biological Conservation* 135 (2), 202-211.

WallisDeVries, M.F. & Van Swaay, C.A.M. (2017). A nitrogen index to track changes in butterfly species assemblages under nitrogen deposition. *Biological Conservation* doi.org/10.1016/j.biocon.2016.11.029.

WallisDeVries, M.F., Van Swaay, C.A.M. & Plate, C.L. (2012). Changes in nectar supply: a possible cause of widespread butterfly decline. Current Zoology 58, 384−391.

Annex 1: Butterfly species occurring in field margins in < 4 countries

For explanation, see Paragraph 3.1

Where available, the occurrence has been expressed as a percentage occupancy; otherwise presence has been denoted as 'x' or between parentheses when only 1 individual was recorded (or unlikely to breed in field margins in the case of GB). HD = protected under the European Habitats Directive; European Red List categories: NT = Near Threatened, VU = Vulnerable

Species name	N countries	CH	D	F	GB	I	NL	S	SF
Apatura ilia	3	x	10			11			
Apatura iris	3	x	(5)		(x)				
Aporia crataegi	1								x
Aricia artaxerxes	1								x
Aricia eumedon	1								x
Bolloria dia	2	x		2					
Boloria euphrosyne	3	(x)			(x)				x
Brenthis hecate	1					2			
Brenthis ino	3	x	x						x
Brintesia circe	1			4					
Callophrys rubi	3			1	(x)				x
Carcharodus alceae	2	x		4					
Carterocephalus palaemon	2	x	(5)						
Carterocephalus silvicola	1								x
Coenonympha arcania	1			(1)					
Coenonympha glycerion	1								x
Colias hyale	3	x	(5)						(x)
Colias palaeno	1								x
Cupido alcetas	1			(1)					
Erebia ligea	1								x
Euchloe simplonia	1			(1)					
Euphydryas aurinia [HD]	2	x		1					
Euphydryas maturna [HD, VU]	1								x
Glaucopsycje alexis	1			(1)					
Gonepteryx cleopatra	1			(1)					
Hesperia comma	1							(6)	
Hipparchia semele	2				(x)	2			
Iphiclides podalirius	2			4		9			
Lasiommata maera	2							(6)	x
Lasiommata petropolitana	1								x
Leptotes pirithous	1					2			
Libythea celtis	1					1			
Limeenitis camilla	2	x	(5)						
Limeenitis populi	1								x
Lycaena dispar [HD]	2			(1)		2			
Lycaena hippothoe	3		x	1					x
Lyceana virgaureae	1								x
Melitaea cinxia	1			10					
Melitaea diamina	1					8			
Melitaea didyma	2			3		3			
Melitaea parthenoides	1			(1)					
Melitaea phoebe	2			9		10			
Minois dryas	1					(1)			
Nymphalis antiopa	2	x							x

Species name	N countries	CH	D	F	GB	I	NL	S	SF
Nymphalis polychloros	3	x				4			(x)
Phengaris alcon	1	x							
Pieris mannii	2	x				2			
Plebejus argus	3	x			(x)				x
Plebejus argyrognomon	1			2					
Plebejus idas	1								x
Plebejus optilete	1								x
Polyommatus amandus	2							25	x
Polyommatus bellargus	2	(x)		1					
Polyommatus coridon	1			1					
Polyommatus escheri	1			(1)					
Pontia daplidice	1								(x)
Pontia edusa	1					10			
Pyrgus alveus	2	x							x
Pyrgus armoricanus	1					3			
Pyrgus cirsii	1			(1)					
Pyronia tithonus	3			37	x	7			
Satyrium pruni	2				x				x
Satyrium w-album	1				x				
Spialia sertorius	1			1					
Thecla betulae	2	x			x				
Thymelicus acteon ^{NT}	1			13					

Annex 2: Moth species occurring in British field margins in 1 or 2 studies

*Presence has been denoted as 'x' when species were caught incidentally (Merckx) or as single individuals in field centres (Alison) Species shown in **bold** are included as endangered or critically endangered in the provisional Red List for the Netherlands.*

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Abraxas grossulariata	10	100	
Abrostola tripartita	2	100	
Acasis viretata	x		
Acronicta aceris	x		
Acronicta leporina		20	
Acronicta psi		100	
Acronicta rumicis	2	50	
Agrochola circellaris	2		
Agrochola litura	16		9
Agrochola lota	8		
Agrochola lunosa	29		
Agrochola lychnidis	45		
Agrochola macilenta	x		
Agrotis clavis	x	37	
Agrotis exclamationis	24	41	
Agrotis ipsilon	x		
Agrotis puta	2	23	
Agrotis segetum	10	100	
Alcis repandata	10	64	
Allophyes oxyacanthae	59		
Amphipyra berbera	x		
Amphipyra pyramidea agg.	6	20	
Anarta trifolii	x		
Apamea anceps	12	100	
Apamea epomidion	x	43	
Apamea remissa	2	18	
Apamea sordens	24	51	
Apamea sublustris	x	6	
Apamea unanimis	x	100	
Apeira syringaria	x	100	
Aplocera efformata	x		
Aplocera plagiata		100	
Apoda limacodes		100	
Aporophyla lutulenta	14		
Aporophyla nigra	69		
Apterogenum ypsillon	x		
Asteroscopus sphinx	4		
Atethmia centrago	2		
Autographa jota	x	43	
Autographa pulchrina	x	100	
Axylia putris	x	37	
Biston betularia	2	69	
Brachylomia viminalis	x		
Bryophila domestica	x		

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Cabera exanthemata	x		
Cabera pusaria	x	100	
Callimorpha dominula	x		
Calliteara pudibunda	2	69	
Camptogramma bilineata	8		8
Caradrina clavipalpis	x	60	
Catarhoe cuculata		0	
Catarhoe rubidata	x	0	
Catocala nupta	2		
Ceramica pisi		100	
Cerapteryx graminis		0	57
Cerura vinula	x		
Charanyca ferruginea	31	28	
Charanyca trigrammica	2	32	
Chloroclysta siterata	x		
Chloroclysta truncata			5
Chloroclystis v-ata	4	16	
Cidaria fulvata	10		
Cilix glaucata	24	20	
Cleorodes lichenaria		33	
Clostera curtula	x		
Colocasia coryli	4	27	
Colostygia pectinataria	22		16
Colotois pennaria	4		
Comibaena bajularia	x		
Conistra ligula	x		
Cosmia pyralina	x		
Cosmia trapezina	8	11	
Cosmorhoe ocellata	x	0	
Craniophora ligustri	x	28	
Crocallis elinguaria	4	100	
Cucullia umbratica	x	0	
Cybosia mesomella	x	67	
Cyclophora linearia	x		
Cyclophora punctaria	x		
Deilephila elpenor	x	35	
Deilephila porcellus	x	12	
Deileptenia ribeata	x		
Deltote pygarga	x	100	
Denticucullus pygmina	x		
Diaphora mendica	2		
Diloba caeruleocephala	6		
Drepana falcataria		100	
Dryobotodes eremita	14		
Dysstroma truncata	43	18	
Ecliptopera silaceata	x	0	
Ectropis crepuscularia	x	48	
Eilema complana	2	6	
Eilema griseola	43	53	
Eilema lurideola	76	53	
Eilema sororcula	x	11	
Electrophaes corylata	x	0	
Ennomos alniaria	8		
Ennomos erosaria	x		

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Ennomos fuscantaria	x		
Epione repandaria	2		
Epirrhoe rivata	4		
Erannis defoliaria	x		
Eremobia ochroleuca	18	17	
Eugnorisma glareosa	4		
Eulithis prunata	x		
Eulithis pyraliata			29
Eupithecia absinthiata	2	100	
Eupithecia assimilata	x		
Eupithecia centaureata	6	14	
Eupithecia dodoneata	x		
Eupithecia exiguata	8		
Eupithecia haworthiata	2	23	
Eupithecia icterata	x		
Eupithecia inturbata	x		
Eupithecia millefoliata	x		
Eupithecia simpliciata	2		
Eupithecia subfuscata	x		
Eupithecia succenturiata	x		
Eupithecia tantillaria	x		
Eupithecia tenuiata	x		
Eupithecia tripunctaria	x	100	
Eupithecia valerianata	x		
Eupithecia vulgata	47		
Euplexia lucipara	x	100	
Euproctis similis	14	45	
Eupsilia transversa	8		
Eurois occulta	2		
Euthrix potatoria	4	58	
Euxoa nigricans	x		
Falcaria lacertinaria	x		
Furcula bifida	x		
Furcula furcula	2	100	
Gandaritis pyraliata	71	100	
Gastropacha quercifolia	x	100	
Geometra papilionaria	x	20	
Gortyna flavago	6		
Graphiphora augur	2		
Griposia aprilina	x		
Gymnoscelis rufifasciata	6		
Habrosyne pyritoides	2	53	
Hada plebeja	x	7	
Hadena bicruris	x	100	
Hadena confusa		0	
Hadena perplexa	x		
Hecatera bicolorata	x	8	
Helicoverpa armigera	2		
Heliothis peltigera	x		
Helotropha leucostigma	x		
Hemistola chrysoprasaria	x	100	
Hemithea aestivaria	x	100	
Hepialus humuli	x	0	
Herminia grisealis	x	50	

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Herminia tarsipennalis	x	100	
Hoplodrina alsines/blanda			17
Hoplodrina ambigua	4		
Hoplodrina octogeneria/blanda		29	
Horisme tersata	x	29	
Horisme vitalbata	2	18	
Hydraecia micacea	4		54
Hydrelia flammeolaria	x		
Hydria cervinalis	x		
Hydriomena impluviata		100	
Hylaea fasciaria	x		
Hypomecis punctinalis	x		
Idaea aversata	2	33	
Idaea biselata	x	43	
Idaea dimidiata	4	33	
Idaea emarginata	2		
Idaea fuscovenosa	x	0	
Idaea rusticata	x		
Idaea seriata	x		
Ipimorpha subtusa	2		
Lacanobia oleracea	63	54	
Lacanobia w-latinum		33	
Laothoe populi	18	43	
Larentia clavaria	x		
Lasiocampa quercus	x	20	
Laspeyria flexula	6	33	
Lenisa geminipuncta	x		
Leucania comma	x	38	
Leucoma salicis	x	100	
Ligdia adustata	2	50	
Lithophane leautieri	x		
Lithophane ornitopus	2		
Lithophane socia	6		
Litoligia literosa		9	
Lomaspilis marginata	x	100	
Lomographa temerata	x	6	
Lygephila pastinum	x	0	
Lymantria monacha	x		
Macaria liturata		0	
Macrothylacia rubi		20	
Malacosoma neustria	6		
Mamestra brassicae	x	100	
Melanchra persicariae	x	31	
Melanthia procellata	x	100	
Menophra abruptaria	x		
Mesapamea secalis/didyma		50	357
Mesoligia furuncula	16	100	
Mesotype didymata	x		
Miltochrista miniata		41	
Mimas tiliae		100	
Mormo maura	x		
Mythimna albipuncta		27	
Mythimna straminea	x		
Naenia typica	x		5

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Noctua fimbriata	16	50	
Noctua interjecta	x	100	
Noctua janthe		43	39
Noctua janthina	4		
Noctua orbona		0	
Nola cucullatella	2	0	
Nonagria typhae	x		
Notodonta dromedarius	x	100	
Notodonta ziczac	2	0	
Nudaria mundana	2	64	
Nycterosea obstipata	x		
Nyctobrya muralis	x		
Ochropacha duplaris	x	100	
Ochropleura plecta	27	17	
Odontopera bidentata	x		
Oligia strigilis		33	
Opisthograptis luteolata	75	100	
Orgyia antiqua	2		
Orthonama vittata	x		
Orthosia gothica	14		
Orthosia incerta	x		
Ourapteryx sambucaria	2	100	
Paradarisa consonaria	x		
Parascotia fuliginaria	x		
Parectropis similaria	x		
Pasiphila chloerata	x	0	
Pasiphila rectangulata	4	0	
Pelurga comitata	x		
Pennithera firmata	x		
Peribatodes rhomboidaria	27	33	
Peridroma saucia	x		
Perizoma albulata	x		
Perizoma alchemillata	x		
Perizoma bifaciata	x		
Perizoma flavofasciata	x		
Petrophora chlorosata	x		
Phalera bucephala		23	
Pharmacis lupulina	86	16	
Pheosia gnoma	x		
Pheosia tremula	2		
Philereme transversata	6	27	
Philereme vetulata	x		
Photedes captiuncula			8
Photedes fluxa	x	100	
Photedes minima	x		16
Phragmatobia fuliginosa	4	24	
Phymatopus hecta	x		
Plagodis dolabraria	2	100	
Plemyria rubiginata	x		
Plusia festucae	6		
Polia bombycina	x		
Polia nebulosa	x	50	
Polymixis flavicincta	x		
Pseudoips prasinana	x	6	

Species	Merckx *et al.* (2012) (% occupancy)	Alison *et al.* (2009) (%occupancy)	Fuentes-Montemayor *et al.* (2011) (N total)
Pterapherapteryx sexalata	x		
Pterostoma palpina	2		
Ptilodon cucullina		100	x
Rhizedra lutosa	x		
Rivula sericealis	16	43	
Schrankia costaestrigalis	x		
Scoliopteryx libatrix	x		
Scopula imitaria	2	100	
Selenia dentaria	6	100	
Selenia tetralunaria	x		
Sideridis rivularis	x	100	
Smerinthus ocellata	x	100	
Sphinx ligustri	x	24	
Sphinx pinastri	x	100	
Spilosoma lutea		70	
Spodoptera exigua	2		
Stauropus fagi	x	0	
Subacronicta megacephala	2	20	
Thalpophila matura	x		
Thera britannica	x		
Thera obeliscata	2		
Tholera cespitis	x		
Tholera decimalis	x		
Thumatha senex	x		
Thyatira batis	x	100	
Tiliacea aurago	2		
Trichiura crataegi	2		
Triodia sylvina	12	0	
Triphosa dubitata		100	x
Tyria jacobaeae		43	
Watsolla cultraria	x		
Watsonalla binaria	x		
Xanthia icteritia	12		
Xanthia togata	x		
Xanthorhoe designata	x		
Xanthorhoe ferrugata		50	
Xanthorhoe fluctuata	2	20	
Xanthorhoe montanata	8		
Xanthorhoe quadrifasiata	2	100	
Xanthorhoe spadicearia	8	20	
Xestia baja			64
Xestia c-nigrum	39	32	
Xestia sexstrigata	x		26
Xestia xanthographa	37		16
Zeuzera pyrina	x		

Annex 3: Moth species in maize field margins

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Abraxas grossulariata	0.7	1.3	100	10
Abraxas sylvata	3.6	4.2		
Abrostola tripartita	1.9	8.4	100	2
Abrostola triplasia	1.8	4.1		
Acasis viretata	1.2	2.5		0
Acherontia atropos	1.9	3.8		
Achlya flavicornis	3.6	5.1		
Acontia trabealis	0.0	0.0		
Acronicta aceris	3.4	7.3		0
Acronicta alni	0.0	0.0		
Acronicta auricoma	0.6	1.0		
Acronicta cuspis	0.0	0.0		
Acronicta leporina	1.6	2.4	20	
Acronicta menyanthidis	0.0	0.0		
Acronicta psi	3.3	5.0		
Acronicta psi/tridens	1.0	2.2	100	
Acronicta rumicis	3.0	4.7	50	2
Acronicta strigosa	0.0	0.0		
Acronicta tridens	0.7	2.2		
Actebia praecox	0.0			
Actias selene	0.0			
Actinotia polyodon	1.7	3.0		
Adscita statices	3.5	3.8		
Aethalura punctulata	0.7	1.0		
Aglia tau	0.9	1.0		
Agriopis aurantiaria	1.1	1.3		
Agriopis leucophaearia	3.5	4.3		
Agriopis marginaria	2.5	2.5		
Agrius convolvuli	3.9	7.3		
Agrochola circellaris	2.3	5.1		2
Agrochola helvola	0.4	0.8		
Agrochola litura				16
Agrochola lota	2.1	4.8		8
Agrochola lunosa	2.6	10.1		27
Agrochola lychnidis	2.0	4.0		45
Agrochola macilenta	2.8	4.4		0
Agrotis cinerea	0.0	0.0		
Agrotis clavis	1.1	2.0	37	0
Agrotis exclamationis	2.0	5.5	41	24
Agrotis ipsilon	2.0	4.2		0
Agrotis puta	1.8	4.4	23	2
Agrotis ripae	0.0			
Agrotis segetum	3.3	7.3	100	10
Agrotis vestigialis	1.0	5.4		
Alcis repandata	1.8	2.4	64	10
Aleucis distinctata	3.5	0.0		
Allophyes oxyacanthae	2.7	5.2		59
Alsophila aceraria	0.0	0.0		
Alsophila aescularia	2.8	4.7		
Amata phegea	4.2	4.3		
Ammoconia caecimacula	0.0	0.0		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Amphipoea fucosa	1.4	8.0		
Amphipoea fucosa/lucens/oculea	0.4	0.7		
Amphipoea lucens	0.0	0.0		
Amphipoea oculea	0.5	1.6		
Amphipyra berbera	1.2	2.8		0
Amphipyra berbera/pyramidea	1.3	1.5	20	
Amphipyra pyramidea	1.8	3.9		6
Amphipyra tragopoginis	0.9	2.0	30	4
Anaplectoides prasina	0.0	0.0		
Anarta myrtilli	0.9	1.0		
Anarta trifolii	2.7	6.0		0
Angerona prunaria	2.8	4.0		
Anorthoa munda	2.5	4.2		
Anticlea derivata	0.0			
Anticollix sparsata	0.9	1.4		
Apamea anceps	10.4	57.1	100	12
Apamea aquila	3.3	3.3		
Apamea crenata	2.0	4.3	100	4
Apamea epomidion	0.0		43	0
Apamea furva	20.0	20.0		
Apamea lateritia	0.0	0.0		
Apamea lithoxylaea	1.6	4.2	30	0
Apamea monoglypha	1.3	3.0	40	47
Apamea oblonga	0.0			
Apamea remissa	2.6	5.6	18	2
Apamea scolopacina	3.2	5.6		
Apamea sordens	0.7	3.2	51	24
Apamea sublustris	0.0	0.0	6	0
Apamea unanimis	2.2	5.3	100	0
Apeira syringaria	2.6	3.9	100	0
Aplocera efformata	1.5	2.1		0
Aplocera efformata/plagiata	2.4	3.2		
Aplocera plagiata	4.3	14.9	100	
Apocheima hispidaria	4.0	5.4		
Apoda limacodes	4.5	5.8	100	
Aporophyla australis	0.0			
Aporophyla lueneburgensis	0.0	0.0		
Aporophyla lutulenta	0.0			14
Aporophyla nigra	0.0	0.0		69
Apterogenum ypsillon	0.6	2.4		0
Archanara dissoluta	0.0	0.0		
Archanara neurica	0.0	0.0		
Archiearis parthenias	1.8	1.7		
Arctia caja	1.3	2.5	77	0
Arctia villica	0.0	0.0		
Arctornis l-nigrum	0.0	0.0		
Arenostola phragmitidis	1.2	4.7		
Aspitates ochrearia	0.4	0.0		
Asteroscopus sphinx	2.2	2.8		4
Asthena albulata	0.0	0.0		
Atethmia centrago	1.6	11.1		2
Athetis gluteosa	0.0			
Atolmis rubricollis	1.4	2.1		
Autographa bractea	0.0	0.0		
Autographa gamma	2.4	4.5	33	12
Autographa jota	2.9	6.5	43	0

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Autographa pulchrina	2.0	0.0	100	0
Axylia putris	2.1	4.8	37	0
Bembecia ichneumoniformis	2.9	0.0		
Bena bicolorana	5.1	7.3		
Biston betularia	2.3	3.8	69	2
Biston strataria	3.8	5.8		
Boudinotiana notha	0.0			
Brachylomia viminalis	0.0			0
Bryophila domestica	0.0	0.0		0
Bryophila raptricula	0.0	0.0		
Bupalus piniaria	2.1	2.6		
Cabera exanthemata	2.1	4.2		0
Cabera exanthemata/pusaria	2.6	4.2		
Cabera pusaria	2.2	3.5	100	0
Calamia tridens	3.0	4.1		
Callimorpha dominula	2.4	4.8		0
Calliteara pudibunda	2.6	3.6	69	2
Callopistria juventina	0.0			
Calophasia lunula	1.2	0.0		
Campaea margaritaria	2.3	4.4	33	0
Camptogramma bilineata	1.9	3.9		8
Caradrina clavipalpis	1.1	4.2	60	0
Caradrina gilva	0.0			
Caradrina kadenii	2.5	5.1		
Caradrina morpheus	2.4	8.7	48	6
Catarhoe cuculata	0.0	0.0	0	
Catarhoe rubidata	0.0	0.0	0	0
Catocala fraxini	0.0			
Catocala nupta	2.2	5.9		2
Catocala promissa	0.0			
Catocala sponsa	0.7	1.2		
Celaena haworthii	0.0	0.0		
Cepphis advenaria	2.4	2.9		
Ceramica pisi	1.9	2.2	100	
Cerapteryx graminis	1.9	2.9	0	
Cerastis leucographa	0.0	0.0		
Cerastis rubricosa	0.7	1.2		
Cerura erminea	1.5	4.2		
Cerura vinula	0.2	0.0		0
Chamaesphecia empiformis	0.0			
Chamaesphecia empiformis/tenthrediniformis	0.0	0.0		
Chamaesphecia tenthrediniformis	2.7	5.1		
Charanyca ferruginea	1.8	2.8	28	31
Charanyca trigrammica	2.3	4.4	32	2
Charissa obscurata	0.0	0.0		
Chesias legatella	1.7	2.0		
Chiasmia clathrata	2.6	8.3		
Chilodes maritima	1.3	11.1		
Chloantha hyperici	0.0	0.0		
Chlorissa viridata	4.9	5.1		
Chloroclysta miata	0.0			
Chloroclysta siterata	1.3	2.6		0
Chloroclystis v-ata	1.5	2.7	16	4
Chrysodeixis chalcites	1.2	2.7		
Cidaria fulvata	0.3	0.0		10

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Cilix glaucata	0.5	4.1	20	24
Cleora cinctaria	0.0	0.0		
Cleorodes lichenaria	0.0		33	
Clostera anachoreta	1.1	3.0		
Clostera curtula	1.3	4.2		0
Clostera pigra	1.4	3.1		
Coenobia rufa	1.6	1.9		
Coenophila subrosea	0.0	0.0		
Colocasia coryli	2.7	3.5	27	4
Colostygia multistrigaria	7.4	17.8		
Colostygia pectinataria	1.9	3.5		22
Colotois pennaria	2.0	3.3		4
Comibaena bajularia	3.0	3.9		0
Conistra erythrocephala	2.6	3.6		
Conistra ligula	3.5	14.3		0
Conistra rubiginea	2.1	4.0		
Conistra rubiginosa	1.4	3.8		
Conistra vaccinii	2.8	4.6		
Coscinia cribraria	0.2	2.4		
Coscinia striata	0.0	0.0		
Cosmia affinis	0.0	0.0		
Cosmia pyralina	2.6	6.6		0
Cosmia trapezina	2.5	4.3	11	8
Cosmorhoe ocellata	2.0	4.8	0	0
Cossus cossus	3.2	6.9		
Costaconvexa polygrammata	1.9	2.0		
Craniophora ligustri	1.7	5.5	28	0
Crocallis elinguaria	2.1	5.6	100	4
Cryphia algae	1.0	3.2		
Crypsedra gemmea	4.4	4.4		
Cucullia absinthii	9.5	17.6		
Cucullia asteris	0.0	0.0		
Cucullia chamomillae	9.5	11.3		
Cucullia scrophulariae	5.2	5.5		
Cucullia scrophulariae/verbasci	15.4	22.2		
Cucullia umbratica	1.7	3.2	0	0
Cucullia verbasci	0.6	3.2		
Cybosia mesomella	1.4	2.0	67	0
Cyclophora albipunctata	2.3	2.7		
Cyclophora annularia	0.0	0.0		
Cyclophora linearia	0.8	1.0		0
Cyclophora pendularia	0.0	0.0		
Cyclophora porata	0.5	9.1		
Cyclophora punctaria	3.2	4.3		0
Cyclophora puppillaria	0.0	0.0		
Cymatophorina diluta	4.4	7.5		
Daphnis nerii	0.0			
Deilephila elpenor	2.3	4.6	35	0
Deilephila porcellus	0.9	2.8	12	0
Deileptenia ribeata	0.0	0.0		0
Deltote bankiana	1.9	2.6		
Deltote deceptoria	0.3	0.4		
Deltote pygarga	2.4	3.5	100	0
Deltote uncula	0.4	0.6		
Dendrolimus pini	0.4	0.5		
Denticucullus pygmina	0.6	1.0		0

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Diachrysia chrysitis	2.2	5.0	44	51
Diacrisia sannio	0.4	0.8		
Diaphora mendica	3.9	5.7		2
Diarsia brunnea	1.9	2.8		
Diarsia dahlii	0.0	0.0		
Diarsia mendica	2.5	6.9	40	0
Diarsia rubi	2.5	6.7	41	16
Dicallomera fascelina	0.5	0.7		
Diloba caeruleocephala	0.9	1.5		6
Drepana curvatula	1.4	2.9		
Drepana falcataria	2.3	3.5	100	
Drymonia dodonaea	6.1	6.6		
Drymonia obliterata	0.0			
Drymonia querna	3.3	3.6		
Drymonia ruficornis	1.7	2.3		
Drymonia velitaris	4.3	5.0		
Dryobotodes eremita	5.8	7.1		14
Dypterygia scabriuscula	3.2	4.5		
Dyscia fagaria	0.0	0.0		
Dysstroma citrata	0.0	0.0		
Dysstroma citrata/truncata	0.5	0.9		
Dysstroma truncata	1.7	3.7	18	43
Earias clorana	1.6	5.0		
Earias vernana	0.0	0.0		
Earophila badiata	0.0	0.0		
Ecliptopera capitata	0.0	0.0		
Ecliptopera silaceata	1.5	2.7	0	0
Ectropis crepuscularia	1.8	3.0	48	0
Eilema caniola	0.0	0.0		
Eilema complana	3.1	4.7	6	2
Eilema depressa	1.3	1.8		
Eilema griseola	2.1	3.7	53	43
Eilema lurideola	2.6	4.5	53	76
Eilema pygmaeola	0.0	0.0		
Eilema sororcula	2.0	3.0	11	0
Elaphria venustula	2.7	3.6		
Electrophaes corylata	1.8	2.4	0	0
Ematurga atomaria	0.3	0.3		
Enargia paleacea	6.1	10.4		
Endromis versicolora	4.4	4.4		
Ennomos alniaria	2.2	4.6		8
Ennomos autumnaria	6.7	13.6		
Ennomos erosaria	4.6	4.9		0
Ennomos fuscantaria	0.0	0.0		0
Ennomos quercinaria	1.1	1.3		
Epione repandaria	1.3	2.4		2
Epione vespertaria	0.0	0.0		
Epirrhoe alternata	2.7	5.5	50	71
Epirrhoe galiata	0.0	0.0		
Epirrhoe rivata	2.5	2.8		4
Epirrhoe tristata	1.0	1.1		
Epirrita autumnata	1.6	2.6		
Epirrita christyi	4.8	14.3		
Epirrita christyi/dilutata/autumnata	1.1	1.6		
Epirrita dilutata	1.8	3.4		
Erannis defoliaria	2.1	2.8		0

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Eremobia ochroleuca	0.0		17	18
Ericeia inangulata	0.0			
Eriogaster catax	0.0			
Eublemma parva	0.0			
Eublemma purpurina	0.0			
Eucarta virgo	0.0	0.0		
Euchoeca nebulata	2.7	4.2		
Euclidia glyphica	5.1	9.3		
Euclidia mi	1.1	1.7		
Eugnorisma glareosa	0.7	0.9		4
Eulithis mellinata	2.5	4.6		
Eulithis populata	1.6	2.0		
Eulithis prunata	1.5	3.7		0
Eulithis testata	0.2	0.3		
Euphyia biangulata	0.0	0.0		
Euphyia unangulata	0.9	0.9		
Eupithecia abbreviata	1.6	2.9		
Eupithecia abietaria	0.0	0.0		
Eupithecia absinthiata	1.8	4.2	100	2
Eupithecia assimilata	1.6	2.8		0
Eupithecia centaureata	1.9	5.7	14	6
Eupithecia dodoneata	3.4	7.8		0
Eupithecia egenaria	0.0	0.0		
Eupithecia exiguata	0.0	0.0		8
Eupithecia expallidata	0.0			
Eupithecia haworthiata	0.4	0.0	23	2
Eupithecia icterata	2.9	5.0		0
Eupithecia indigata	0.0	0.0		
Eupithecia innotata	1.0	5.2		
Eupithecia insigniata	0.0	0.0		
Eupithecia intricata	1.4	3.4		
Eupithecia inturbata	0.6	2.9		0
Eupithecia lanceata	0.0	0.0		
Eupithecia lariciata	6.2	13.2		
Eupithecia linariata	2.3	3.5		
Eupithecia millefoliata	0.0			0
Eupithecia nanata	2.6	3.4		
Eupithecia phoeniceata	0.0			
Eupithecia plumbeolata	0.0			
Eupithecia pulchellata	0.9	1.4		
Eupithecia pusillata	0.0	0.0		
Eupithecia pygmaeata	0.0	0.0		
Eupithecia satyrata	0.0	0.0		
Eupithecia selinata	0.0	0.0		
Eupithecia simpliciata	0.0	0.0		2
Eupithecia spec.	8.3	14.7		
Eupithecia subfuscata	1.4	3.7		0
Eupithecia subumbrata	0.0	0.0		
Eupithecia succenturiata	2.5	5.0		0
Eupithecia tantillaria	1.1	1.9		0
Eupithecia tenuiata	1.1	3.9		0
Eupithecia tripunctaria	0.8	2.6	100	0
Eupithecia trisignaria	4.3	0.0		
Eupithecia valerianata	0.0	0.0		0
Eupithecia venosata	0.0			
Eupithecia virgaureata	1.1	1.6		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Eupithecia vulgata	0.9	2.7		47
Euplagia quadripunctaria	1.5	4.5		
Euplexia lucipara	1.9	3.6	100	0
Euproctis chrysorrhoea	0.5	0.0		
Euproctis similis	2.7	3.5	45	14
Eupsilia transversa	2.4	4.0		8
Eurois occulta	0.0	0.0		2
Euthrix potatoria	1.2	1.9	58	4
Euxoa cursoria	0.8	6.3		
Euxoa nigricans	1.8	5.3		0
Euxoa obelisca	0.0	0.0		
Euxoa obelisca/tritici	0.0	0.0		
Euxoa tritici	0.3	2.6		
Falcaria lacertinaria	1.5	2.0		0
Furcula bicuspis	2.4	2.6		
Furcula bifida	3.9	8.2		0
Furcula furcula	1.7	4.4	100	2
Gagitodes sagittata	0.0	0.0		
Gandaritis pyraliata	2.9	7.5	100	71
Gastropacha populifolia	0.0	0.0		
Gastropacha quercifolia	0.0	0.0	100	0
Geometra papilionaria	1.7	2.4	20	0
Globia algae	0.0	0.0		
Globia sparganii	1.0	2.5		
Gluphisia crenata	1.2	2.7		
Gortyna flavago	0.7	1.7		6
Graphiphora augur	0.0	0.0		2
Griposia aprilina	5.6	9.2		0
Gymnoscelis rufifasciata	1.1	2.3		6
Habrosyne pyritoides	1.6	3.2	53	2
Hada plebeja	0.8	1.6	7	0
Hadena albimacula	0.0			
Hadena bicruris	2.9	6.3	100	0
Hadena compta	1.6	3.7		
Hadena confusa	0.0		0	
Hadena perplexa	10.0	0.0		0
Harpyia milhauseri	2.4	3.9		
Hecatera bicolorata	3.7	7.0	8	0
Hecatera dysodea	1.0	2.8		
Helicoverpa armigera	0.6	0.0		2
Heliothis maritima	0.0	0.0		
Heliothis nubigera	0.0	0.0		
Heliothis peltigera	1.6	5.8		0
Heliothis viriplaca	0.0			
Helotropha leucostigma	1.0	3.0		0
Hemaris fuciformis	0.3	1.3		
Hemaris tityus	0.0	0.0		
Hemistola chrysoprasaria	0.0	0.0	100	0
Hemithea aestivaria	1.6	3.2	100	0
Hepialus humuli	0.5	1.4	0	0
Herminia grisealis	1.0	1.8	50	0
Herminia tarsicrinalis	1.2	2.3		
Herminia tarsipennalis	0.8	1.6	100	0
Heterogenea asella	0.0	0.0		
Hippotion celerio	0.0	0.0		
Hoplodrina ambigua	1.6	5.7		4

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Hoplodrina ambigua/blanda/octogenaria	2.6	7.7		
Hoplodrina blanda	1.7	6.0		
Hoplodrina octogenaria	2.9	7.3		
Hoplodrina octogeneria/blanda			29	
Horisme radicaria	5.3			
Horisme tersata	0.8	0.0	29	0
Horisme vitalbata	0.0		18	2
Hydraecia micacea	2.0	4.7		4
Hydraecia petasitis	0.0	0.0		
Hydrelia flammeolaria	1.3	2.0		0
Hydria cervilis				
Hydria cervinalis	0.0	0.0		0
Hydria undulata	2.1	2.7		
Hydriomena furcata	1.0	0.7	100	2
Hydriomena impluviata	1.8	4.1	100	
Hylaea fasciaria	1.2	1.5		0
Hyles euphorbiae	0.0	0.0		
Hyles gallii	1.7	5.9		
Hyles livornica	0.0	0.0		
Hypena crassalis	1.9	2.3		
Hypena obesalis	0.0	0.0		
Hypena obsitalis	0.0			
Hypena proboscidalis	2.4	4.7	100	27
Hypena rostralis	4.0	6.2		
Hypenodes humidalis	0.4	0.5		
Hypercompe scribonia	0.0			
Hypomecis punctinalis	1.5	2.3		0
Hypomecis roboraria	2.6	3.7		
Hyppa rectilinea	0.0	0.0		
Idaea aversata	1.6	3.4	33	2
Idaea biselata	0.9	2.4	43	0
Idaea dimidiata	2.0	4.9	33	4
Idaea emarginata	0.5	0.9		2
Idaea fuscovenosa	2.7	5.5	0	0
Idaea humiliata	0.0	0.0		
Idaea inquinata	17.6	25.0		
Idaea laevigata	0.0	0.0		
Idaea muricata	0.0	0.0		
Idaea ochrata	0.0			
Idaea rusticata	0.2	0.4		0
Idaea seriata	0.7	1.6		0
Idaea straminata	2.5	3.3		
Idaea subsericeata	1.7	4.8		
Idaea sylvestraria	0.0	0.0		
Idia calvaria	0.0	0.0		
Ipimorpha retusa	1.6	4.9		
Ipimorpha subtusa	3.4	11.7		2
Isturgia limbaria	0.0	0.0		
Jodis lactearia	2.7	3.4		
Jodis putata	0.7	0.7		
Lacanobia contigua	0.0	0.0		
Lacanobia oleracea	1.9	5.1	54	63
Lacanobia splendens	0.0	0.0		
Lacanobia suasa	0.9	2.9		
Lacanobia thalassina	2.4	3.8		
Lacanobia w-latinum	0.0	0.0	33	

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Laelia coenosa	0.0	0.0		
Lampropteryx suffumata	0.0	0.0		
Lamprotes c-aureum	0.0			
Laothoe populi	2.5	7.3	43	18
Larentia clavaria	0.0	0.0		0
Lasiocampa quercus	0.7	0.7	20	0
Lasiocampa trifolii	0.3	0.8		
Laspeyria flexula	0.9	1.3	33	6
Lateroligia ophiogramma	1.5	4.2		
Lemonia dumi	0.0	0.0		
Lenisa geminipuncta	0.0	0.0		0
Leucania comma	2.1	3.4	38	0
Leucania obsoleta	0.8	3.8		
Leucodonta bicoloria	0.0	0.0		
Leucoma salicis	1.3	4.3	100	0
Ligdia adustata	2.0	3.7	50	2
Lithophane lamda	0.0	0.0		
Lithophane leautieri	0.8	1.5		0
Lithophane ornitopus	1.1	5.9		2
Lithophane semibrunnea	0.0	0.0		
Lithophane socia	0.0	0.0		6
Lithosia quadra	1.0	1.0		
Litoligia literosa	0.0	0.0	9	
Lobophora halterata	1.0	2.4		
Lomaspilis marginata	2.1	4.6	100	0
Lomographa bimaculata	1.9	4.1		
Lomographa temerata	1.5	2.8	6	0
Longalatedes elymi	0.0			
Luperina testacea	1.7	3.6	100	39
Lycia hirtaria	5.2	8.9		
Lycia zonaria	0.0	0.0		
Lycophotia molothina	0.0	0.0		
Lycophotia porphyrea	1.5	1.9		
Lygephila pastinum	3.0	0.0	0	0
Lymantria dispar	3.2	5.1		
Lymantria monacha	1.1	1.5		0
Lythria cruentaria	2.9	3.7		
Macaria alternata	2.1	4.2		
Macaria alternata/notata	50.0	100.0		
Macaria brunneata	0.7	0.8		
Macaria liturata	2.8	3.2	0	
Macaria notata	2.5	3.5		
Macaria signaria	2.5	3.5		
Macaria wauaria	3.5	5.2		
Macdunnoughia confusa	4.5	7.7		
Macrochilo cribrumalis	1.6	3.3		
Macroglossum stellatarum	1.4	3.4		
Macrothylacia rubi	0.7	0.8	20	
Malacosoma castrensis	0.3	0.3		
Malacosoma neustria	2.3	3.1		6
Mamestra brassicae	1.3	2.4	100	0
Meganola albula	0.9	1.4		
Meganola strigula	0.0	0.0		
Melanchra persicariae	1.9	4.0	31	0
Melanthia procellata	0.5	0.0	100	0
Menophra abruptaria	0.0			0

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Mesapamea secalella	0.3	1.1		
Mesapamea secalella/secalis	1.1	2.9	50	
Mesapamea secalis	2.9	9.9		
Mesoleuca albicillata	2.0	2.7		
Mesoligia furuncula	1.6	3.8	100	16
Mesotype didymata	3.0	3.6		0
Miltochrista miniata	2.3	3.1	41	
Mimas tiliae	2.2	4.4	100	
Minoa murinata	0.0			
Minucia lunaris	0.0	0.0		
Mniotype adusta	0.0	0.0		
Mniotype satura	0.0	0.0		
Moma alpium	2.9	3.9		
Mormo maura	0.7	1.7		0
Mythimna albipuncta	2.0	6.1	27	
Mythimna conigera	0.0	0.0	29	47
Mythimna favicolor	0.0			
Mythimna ferrago	1.5	3.7	29	20
Mythimna impura	0.8	2.0	47	49
Mythimna l-album	4.2	11.0		
Mythimna litoralis	0.0			
Mythimna pallens	4.2	14.8	56	98
Mythimna pudorina	1.2	2.3		
Mythimna sicula	0.0	0.0		
Mythimna straminea	0.5	1.4		0
Mythimna turca	0.7	0.7		
Mythimna unipuncta	0.0	0.0		
Mythimna vitellina	0.0	0.0		
Naenia typica	1.9	6.1		0
Noctua comes	1.4	3.9	57	18
Noctua fimbriata	1.4	2.3	50	16
Noctua interjecta	1.4	3.4	100	0
Noctua janthe	0.5	1.5	43	
Noctua janthe/janthina	2.6	6.5		
Noctua janthina	0.5	1.0		4
Noctua orbona	4.3	9.2	0	
Noctua pronuba	1.4	3.2	25	61
Nola aerugula	2.0	3.0		
Nola confusalis	0.2	0.9		
Nola cucullatella	1.3	2.3	0	2
Nonagria typhae	0.6	2.1		0
Nothocasis sertata	0.0			
Notodonta dromedarius	1.7	2.8	100	0
Notodonta tritophus	0.6	1.5		
Notodonta ziczac	0.8	1.9	0	2
Nudaria mundana	0.0		64	2
Nycteola asiatica	0.0	0.0		
Nycteola revayana	2.0	2.9		
Nycterosea obstipata	3.3	10.0		0
Nyctobrya muralis	1.3	1.2		0
Ochropacha duplaris	0.6	1.2	100	0
Ochropleura plecta	2.6	5.5	17	27
Odezia atrata	0.0			
Odonestis pruni	0.0	0.0		
Odontopera bidentata	1.1	1.5		0
Odontosia carmelita	0.0	0.0		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Oligia fasciuncula	2.5	4.7	30	2
Oligia latruncula	1.3	3.6		
Oligia latruncula/strigilis/versicolor	0.0	0.0		
Oligia strigilis	1.2	4.0	33	
Oligia versicolor	0.8	2.9		
Operophtera brumata	1.7	2.7		
Operophtera fagata	1.5	1.6		
Opisthograptis luteolata	1.8	3.9	100	75
Orgyia antiqua	4.2	4.5		2
Orgyia antiquoides	0.0	0.0		
Orgyia recens	0.0	0.0		
Orthonama vittata	1.2	2.7		0
Orthosia cerasi	2.6	5.2		
Orthosia cruda	3.3	5.5		
Orthosia gothica	2.3	5.3		14
Orthosia gracilis	1.7	3.4		
Orthosia incerta	2.8	6.0		0
Orthosia miniosa	2.1	3.4		
Orthosia opima	0.0	0.0		
Orthosia populeti	3.8	12.0		
Ourapteryx sambucaria	1.1	2.0	100	2
Pachetra sagittigera	2.1	2.2		
Pachycnemia hippocastanaria	2.8	3.6		
Panemeria tenebrata	3.3	4.2		
Panolis flammea	3.5	4.2		
Panthea coenobita	1.1	1.1		
Paracolax tristalis	1.3	1.7		
Paradarisa consonaria	1.2	1.3		0
Paranthrene tabaniformis	3.2	25.0		
Parascotia fuliginaria	0.3	0.6		0
Parasemia plantaginis	0.0			
Parastichtis suspecta	5.1	7.5		
Parectropis similaria	0.3	0.6		0
Pareulype berberata	0.4	1.8		
Pasiphila chloerata	0.0	0.0	0	0
Pasiphila debiliata	0.0	0.0		
Pasiphila rectangulata	0.9	2.5	0	4
Pechipogo plumigeralis	0.5	0.0		
Pechipogo strigilata	0.0	0.0		
Pelosia muscerda	1.7	2.4		
Pelosia obtusa	2.1	3.6		
Pelurga comitata	1.0	1.2		0
Pennisetia hylaeiformis	0.0	0.0		
Pennithera firmata	0.4	0.6		0
Perconia strigillaria	1.6	1.6		
Peribatodes rhomboidaria	0.9	2.4	33	27
Peribatodes secundaria	3.0	4.1		
Peridea anceps	2.4	3.0		
Peridroma saucia	4.0	10.6		0
Perizoma affinitata	7.5	28.6		
Perizoma albulata	0.6	1.1		0
Perizoma alchemillata	2.7	4.1		0
Perizoma bifaciata	0.0	0.0		0
Perizoma flavofasciata	2.5	5.4		0
Petrophora chlorosata	2.1	2.9		0
Petrophora convergata	0.0	0.0		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Phalera bucephala	3.0	5.0	23	
Pharmacis fusconebulosa	0.0	0.0		
Pharmacis lupulina	0.2	0.0	16	86
Pheosia gnoma	2.0	2.8		0
Pheosia tremula	1.5	4.8		2
Phibalapteryx virgata	0.0	0.0		
Phigalia pilosaria	1.9	2.8		
Philereme transversata	0.0	0.0	27	6
Philereme vetulata	0.0	0.0		0
Phlogophora meticulosa	1.7	3.6	11	47
Photedes extrema	0.0	0.0		
Photedes fluxa	0.0	0.0	100	0
Photedes minima	0.0	0.0		0
Phragmataecia castaneae	0.9	5.1		
Phragmatiphila nexa	0.0	0.0		
Phragmatobia fuliginosa	2.6	4.9	24	4
Phyllodesma ilicifolia	0.0	0.0		
Phyllodesma tremulifolia	2.7	2.8		
Phymatopus hecta	1.2	1.3		0
Phytometra viridaria	0.0	0.0		
Plagodis dolabraria	2.3	3.3	100	2
Plagodis pulveraria	0.0	0.0		
Plemyria rubiginata	2.4	3.6		0
Plusia festucae	1.5	3.3		6
Plusia putnami	0.5	0.7		
Poecilocampa populi	3.7	5.3		
Polia bombycina	0.0	0.0		0
Polia hepatica	0.0	0.0		
Polia nebulosa	0.0	0.0	50	0
Polychrysia moneta	0.0	0.0		
Polymixis flavicincta	0.0	0.0		0
Polymixis lichenea	0.0	0.0		
Polyploca ridens	2.5	2.5		
Proserpinus proserpina	6.1	12.1		
Protarchanara brevilinea	0.0			
Protolampra sobrina	0.0	0.0		
Protoschinia scutosa	0.0			
Pseudeustrotia candidula	0.0	0.0		
Pseudoips prasinana	1.7	2.3	6	0
Pseudopanthera macularia	2.3	2.1		
Pseudoterpna pruinata	0.0	0.0		
Pterapherapteryx sexalata	0.7	1.7		0
Pterostoma palpina	0.9	2.6		2
Ptilodon capucina	2.3	3.3	100	0
Ptilodon cucullina	0.0	0.0	100	
Pungeleria capreolaria	0.0	0.0		
Pyrrhia umbra	1.4	3.2		
Rhagades pruni	0.0	0.0		
Rheumaptera hastata	0.0	0.0		
Rhizedra lutosa	0.9	3.5		0
Rhodometra sacraria	1.9	3.2	100	0
Rhodostrophia vibicaria	0.0	0.0		
Rhyacia simulans	1.1	9.5		
Rhyparia purpurata	0.0	0.0		
Rivula sericealis	2.9	5.3	43	16
Saturnia pavonia	0.7	0.5		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Saturnia pyri	0.0	0.0		
Schrankia costaestrigalis	1.2	2.7		0
Schrankia taenialis	0.0	0.0		
Scoliopteryx libatrix	2.3	5.6		0
Scopula emutaria	0.0	0.0		
Scopula floslactata	1.6	2.1		
Scopula imitaria	0.0	0.0	100	2
Scopula immutata	2.9	5.0		
Scopula marginepunctata	5.8	34.6		
Scopula nigropunctata	1.6	1.5		
Scopula ornata	0.7			
Scopula rubiginata	0.0	0.0		
Scopula ternata	0.0	0.0		
Scotopteryx chenopodiata	1.2	0.0	100	20
Scotopteryx luridata	0.0	0.0		
Scotopteryx mucronata	0.0	0.0		
Sedina buettneri	0.0			
Selenia dentaria	1.8	3.1	100	6
Selenia lunularia	0.0	0.0		
Selenia tetralunaria	1.7	2.2		0
Selidosema brunnearia	0.0	0.0		
Senta flammea	0.0	0.0		
Sesia apiformis	4.4	10.1		
Sesia bembeciformis	0.0	0.0		
Setina irrorella	0.0	0.0		
Sideridis reticulata	1.4	8.8		
Sideridis rivularis	1.4	3.3	100	0
Sideridis turbida	0.5	4.3		
Simyra albovenosa	1.4	3.1		
Siona lineata	3.3	12.3		
Smerinthus ocellata	2.0	4.8	100	0
Spargania luctuata	0.0	0.0		
Sphinx ligustri	1.6	3.7	24	0
Sphinx pinastri	2.0	2.6	100	0
Spilosoma lubricipeda	2.5	4.8	44	2
Spilosoma lutea	2.3	4.2	70	
Spilosoma urticae	2.3	10.6		
Spodoptera exigua	1.4	7.1		2
Stauropus fagi	1.8	2.5	0	0
Stegania cararia	0.0			
Stegania trimaculata	2.6	4.5		
Subacronicta megacephala	1.4	4.9	20	2
Synanthedon culiciformis	6.7	7.1		
Synanthedon formicaeformis	2.2	1.8		
Synanthedon myopaeformis	0.0	0.0		
Synanthedon spheciformis	1.5	0.0		
Synanthedon tipuliformis	7.9	0.0		
Synanthedon vespiformis	6.8	6.9		
Syngrapha interrogationis	0.0	0.0		
Tathorhynchus exsiccata	0.0			
Tethea ocularis	1.6	4.0		
Tethea or	1.3	2.3		
Tetheella fluctuosa	0.7	0.8		
Thalera fimbrialis	1.5	1.3		
Thalpophila matura	0.0	0.0		0
Thaumetopoea processionea	4.6	7.0		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Thera britannica	4.8	7.2		0
Thera britannica/obeliscata/variata	0.6	1.0		
Thera cupressata	0.0			
Thera juniperata	0.9	1.5		
Thera obeliscata	1.2	1.7		2
Thera spec.	5.7	8.1		
Thera variata	0.0	0.0		
Theria primaria	1.4	0.0		
Theria rupicapraria	11.8	0.0		
Tholera cespitis	3.1	6.2		0
Tholera decimalis	2.5	5.1		0
Thumatha senex	2.1	3.3		0
Thyatira batis	2.2	3.4	100	0
Thyris fenestrella	0.0			
Tiliacea aurago	1.7	2.8		2
Tiliacea citrago	3.8	8.2		
Timandra comae	4.1	6.3		
Trachea atriplicis	2.9	6.4		
Trichiura crataegi	0.0	0.0		2
Trichoplusia ni	0.0	0.0		
Trichopteryx carpinata	0.8	1.6		
Trichopteryx polycommata	0.0			
Triodia sylvina	1.7	3.8	0	12
Triphosa dubitata	0.0	0.0	100	
Trisateles emortualis	0.6	1.1		
Tyria jacobaeae	2.5	4.1	43	
Tyta luctuosa	0.0			
Utetheisa pulchella	0.0			
Watsonalla binaria	3.3	5.1		0
Watsonalla cultraria	2.1	3.1		0
Xanthia gilvago	2.1	9.8		
Xanthia icteritia	2.7	3.9		12
Xanthia ocellaris	2.8	2.3		
Xanthia ruticilla	0.0	0.0		
Xanthia togata	2.9	5.3		0
Xanthorhoe biriviata	1.5	3.8		
Xanthorhoe designata	1.5	3.1		0
Xanthorhoe ferrugata	2.2	5.5	50	
Xanthorhoe ferrugata/spadicearia	2.1	4.1		
Xanthorhoe fluctuata	1.1	2.9	20	2
Xanthorhoe montanata	2.7	5.0	50	8
Xanthorhoe quadrifasiata	4.2	14.3	100	2
Xanthorhoe spadicearia	1.7	4.2	20	8
Xestia agathina	0.0	0.0		
Xestia baja	0.2	0.3		
Xestia castanea	0.0	0.0		
Xestia c-nigrum	2.4	5.7	32	39
Xestia ditrapezium	0.0	0.0		
Xestia ditrapezium/triangulum	1.3	1.0		
Xestia sexstrigata	1.6	2.3		0
Xestia triangulum	2.0	4.8	40	0
Xestia xanthographa	1.6	5.3		37
Xylena exsoleta	0.0			
Xylena solidaginis	0.0	0.0		
Xylena vetusta	0.0			
Xylocampa areola	2.4	4.2		

Species	NL % Records	Pleistocene sands % Records	%UK (Alison)	%UK (Merckx)
Zanclognatha lunalis	0.0	0.0		
Zeuzera pyrina	0.7	1.4		0
Zygaena filipendulae	2.5	5.2		
Zygaena trifolii	5.6	12.1		
Zygaena viciae	0.0	0.0		

Annex 4: Characteristics of potentially significantly exposed species of Macrolepidoptera in the Netherlands

Species characteristics according to the database from De Vlinderstichting; Red List Status: LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

Family	Species	Dutch name	English name	Status NL	Habitat	Host plant	Voltinism	Flight period	Caterpillar period
				BUTTERFLIES					
Hesperiidae	*Carterocephalus palaemon*	Bont Dikkopje	Chequered Skipper	VU	Grassy woodland clearings and heathland margins	*Molinia caerulea, Calamgrostis canescens, Brachypodium sylvaticum*	Univoltine	May-Jul	Jun-May
	Hesperia comma	Kommavlinder	Silver-spotted Skipper	EN	Heathlands and dry grasslands	*Festuca ovina, Corynephorus canescens*	Univoltine	Jul-Sept	Mar-Jul
	Heteropterus morpheus	Spiegeldikkopje	Large Chequered Skipper	CR	Marshes, damp meadows and woodland margins	*Molinia caerulea, Calamgrostis canescens*	Univoltine	Jun-Jul	Jul-Jun
	Ochlodes sylvanus	Groot dikkopje	Large Skipper	NT	Scrub, woodland margins and clearings, hedges	Broad-leaved grasses	Univoltine	Jun-Aug	Jul-Jun
	Pyrgus malvae	Aardbeivlinder	Grizzled Skipper	EN	Grasslands and heathlands	*Potentilla, Agrimonia, Rubus*	Partially bivoltine	May-Jun	Jul-Apr
Lycaenidae	*Aricia agestis*	Bruin blauwtje	Brown Argus	NT	Dry grasslands, ruderal areas	*Geranium, Erodium, Helianthemum*	Multivoltine	May-Oct	Jun-Jul / Aug-Apr
	Callophrys rubi	Groentje	Green Hairstreak	LC	Woodland clearings and margins, scrub, heathlands, grasslands	*Cytisus, Erica, Calluna, Vaccinium, Rhamnus*	Univoltine	Apr-Jul	May-Aug
	Cupido argiades	Staartblauwtje	Short-tailed Blue	New	Damp, rough and ruderal grasslands	Mainly *Lotus uliginosus*	Multivoltine	May-Sep	Sep-Apr
	Cyaniris semiargus	Klaverblauwtje	Mazarine Blue	X	Dry to moist semi-natural grasslands and road verges	Mainly *Trifolium pratense*	Multivoltine	May-Sep	All year
	Lycaena tityrus	Bruine vuurvlinder	Sooty Copper	VU	Semi-natural grasslands and heathlands,	Mainly *Rumex acetosa, R. acetosella*	Bivoltine	May-Aug	Jun-Jul / Aug-May

Family	Species	Dutch name	English name	Status NL	Habitat	Host plant	Voltinism	Flight period	Caterpillar period
					woodland margins and road verges				
Lycaenidae	*Phengaris nausithous*	Donker Pimpernelblauwtje	Dusky large blue	CR	Damp meadows and road verges	*Sanguisorba major*	Univoltine	Jul-Aug	Aug-Jul
Nymphalidae	*Aphantopus hyperantus*	Koevinkje	Ringlet	LC	Woodland clearings and margins, rough grasslands, hedgerows	Broad-leaved grasses	Univoltine	Jun-Aug	Aug-Jun
	Hipparchia semele	Heivlinder	Grayling	NT	Dry heathland and grassland	*Festuca ovina, Agrostis*	Univoltine	Jun-Sep	Sep-Jun
	Issoria lathonia	Kleine Parelmoervlinder	Queen of Spain Fritillary	VU	Dry grasslands and pioneer vegetation on fallows and field margins	Mainly *Viola arvensis, V. tricolor, V. curtisii*	Multivoltine	Apr-Oct	All year
	Lasiommata megera	Argusvlinder	Wall Brown	LC	Open grasslands, agricultural areas: field margins, embankments, road verges, hedgerows, woodland edges	Mainly Broad-leaved grasses	Multivoltine	Apr-Jun / Jul-Aug	Jun-Jul / Aug-Apr
	Melitaea cinxia	Veldparelmoervlinder	Glanville Fritillary	CR	Dry grasslands and ruderal vegetation	Mainly *Plantago lanceolata*	Partially bivoltine	May-Jun	Jun-Apr
	Pyronia tithonus	Oranje Zandoogje	Gatekeeper	LC	Rough grassland along woodland margins, scrub, hedgerows	Mainly Broad-leaved grasses	Univoltine	Jun-Aug	Aug-Jun
Papilionidae	*Papilio machaon*	Koninginnenpage	Swallowtail	LC	Flowery meadows, ruderal areas, agricultural fields, community gardens	Apiaceae, incl. *Daucus, Pastinaca, Foeniculum*	Bivoltine	Apr-Sep	May-Jun / Aug-Sep
Pieridae	*Colias croceus*	Oranje Luzernevlinder	Clouded Yellow	Migrant	Flowery meadows, ruderal areas, agricultural (lucerne) fields	Mainly *Medicago, Vicia*	Multivoltine	May-Oct (in NL)	All year (depending on climate)

Family	Species	Dutch name	English name	Status NL	Habitat	Host plant	Voltinism	Flight period	Caterpillar period
				MACRO-MOTHS					
Geometridae	*Chiasmia clathrata*	Klaverspanner	Latticed Heath	LC	Miscellaneous open areas incl. grasslands, fields, ruderal urban areas	*Trifolium, Medicago*	Bivoltine	Apr-Sep	May-Jun / Aug-Sep
	Ennomos autumnaria	Iepentakvlinder	Large Thorn	EN	Deciduous woodlands, scrub, gardens	Miscellaneous deciduous trees	Univoltine	Jun-Sep	Apr-Aug
	Ennomos erosaria	Gehakkelde Spanner	September Thorn	EN	Woodlands, gardens	Miscellaneous deciduous trees	Possibly bivoltine	Jun-Oct	Apr-Jul
	Siona lineata	Vals Witje	Black-veined Moth	LC	Semi-natural grasslands	Miscellaneous dicots & woody plants	Univoltine	Apr-Jun	Jul-May
	Thera britannica	Schijn-Sparspanner	Spruce Carpet	VU	Coniferous woodlands & gardens	*Picea*	Bivoltine	Apr-Oct	Jun-Jul / Sep-May
	Timandra comae	Lieveling	Blood-vein Timandra	LC	Damp places with lush vegetation, incl. embankments, woodland rides and wet grasslands	*Rumex, Polygonum*	Multivoltine	May-Sep	All year
Erebidae	*Amata phegea*	Phegeavlinder	Nine-spotted moth	LC	dry open ranges with shrubs and trees as well as open forests and slopes	Miscellaneous dicots	Univoltine	May-Aug	Aug-May
	Diaphora mendica	Mendicabeer	Muslin Moth	LC	Open woodland, grasslands, scrub, gardens	Miscellaneous dicots	Univoltine	Apr-Jun	Jun-Aug
	Euclidia glyphica	Bruine Daguil	Burnet Companion	LC	Grasslands, woodland margins and road verges	Legumes	Bivoltine	Apr-Aug	May-Jun /Aug-Sep
	Hypena rostralis	Hopsnuituil	Buttoned Snout	LC	Woodland, scrub, clearings, embankments	*Humulus lupulus*	Univoltine	Mar-Jun / Aug-Oct	May-Aug
	Orgyia antiqua	Witvlakvlinder	The Vapourer	LC	Open woodland, heathlands, scrub, marshes, gardens	Miscellaneous woody plants (*Betula, Corylus, Salix*)	Bivoltine	May-Oct	May-Sep
Limacodidae	*Apoda limacodes*	Slakrups	The Festoon	LC	Deciduous woodlands, scrub, gardens	Deciduous trees, esp. *Quercus*	Univoltine	May-Aug	Jul-Apr
Noctuidae	*Acronicta aceris*	Bont Schaapje	The Sycamore	VU	Woodlands, woodland margins, scrub, gardens, urban areas	Deciduous trees (*Quercus, Betula, Acer campestre, Aesculus*)	Univoltine	May-Aug	Jun-Oct
	Agrotis segetum	Gewone Velduil	Turnip Moth	LC	Agricultural areas, open woodland, gardens	Miscellaneous plants incl. crops	Bivoltine	May-Nov	Jul-Mar

Family	Species	Dutch name	English name	Status NL	Habitat	Host plant	Voltinism	Flight period	Caterpillar period
Noctuidae	*Cucullia chamomillae*	Kamillevlinder	Chamomile Shark	EN	Field margins, fallows, ruderal areas and road verges	*Matricaria*	Univoltine	Apr-Jun	May-Jul
	Cucullia scrophulariae	Helmkruidvlinder	Water Betony	EN	Woodland margins & clearings, also road verges	*Scrophularia, Verbascum*	Univoltine	May-Jul	Jun-Sep
	Diarsia mendica	Variabele Breedvleugeluil	Ingrailed Clay	VU	Woodland, scrub, heathland, gardens	Miscellaneous dicots, dwarfshrubs, deciduous shrubs and trees	Partially bivoltine	May-Sep	Aug-May
	Diarsia rubi	Gewone Breedvleugeluil	Small Square-spot	NT	Damp woodlands & grasslands, marshy places, also gardens	Miscellaneous divots incl. *Taraxacum, Rumex, Digitalis*	Bivoltine	May-Sep	Jun-Jul / Sep-Apr
	Hecatera bicolorata	Tweekleurige Uil	Broad-barred White	VU	Grasslands, road verges, gardens	*Hieracium, Crepis, Sonchus*	Partially bivoltine	May-Sep	Jun-Oct
	Hoplodrina octogenaria	Gewone Stofuil	The Uncertain	LC	Mainly grasslands, wooded areas, gardens	Miscellaneous dicots, incl. *Stellaria, Rumex, Lamium, Primula*	Univoltine	May-Aug	Jul-Apr
	Macdunnoughia confusa	Getekende Gamma-Uil	Dewick's Plusia	NT	Miscellaneous habitats	Miscellaneous dicots, incl. *Urtica, Lamium, Matricaria, Artemisia*	Multivoltine	Apr-Oct	Jun-Jul / Oct-Apr
	Mythimna l-album	Witte-L-Uil	L-album Wainscot	LC	Mainly (rough) grasslands	Miscellaneous (tough) grasses	Bivoltine	Jun-Nov	Oct-May / Aug
	Mythimna pallens	Bleke Grasuil	Common Wainscot	LC	Grasslands, woodland margins and rides	Miscellaneous grasses	Bivoltine	May-Oct	Jul-Aug / Sep-May
Nolidae	*Bena bicolorana*	Grote Groenuil	Scarce Silver-lines	VU	Deciduous woodlands, parks	*Quercus, Betula trees*	Univoltine	May-Aug	Jul-May
Notodontidae	*Drymonia dodonaea*	Gestreepte Tandvlinder	Marbled Brown	EN	Woodlands with mature oak	Deciduous trees (*Quercus*)	Univoltine	May-Jul	Jun-Sep
Sesiidae	*Synanthedon tipuliformis*	Bessenglasvlinder	Currant Clearwing	LC	Mainly community gardens	*Ribes, Euonymus*	Univoltine	May-Jul	Aug-Apr
Sphingidae	*Agrius convolvuli*	Windepijlstaart	Convolvulus Hawk-moth	Migrant	Miscellaneous habitats	*Convolvulus*	Univoltine	May-Oct	Jun-Oct
Sphingidae	*Laothoe populi*	Populierenpijlstaart	Poplar Hawk-moth	LC	Woodlands, parks, gardens, marshes	*Populus, Salix* trees	Bivoltine	Apr-Aug	Jul-Oct