

# The state of the Dutch larger moth fauna

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**Abstract** Moths make up a significant part of the biodiversity both in northwestern Europe and globally. In the Netherlands for instance, 766 species of larger moths are considered native. The interest of amateur recorders in this group in the Netherlands is rapidly growing. This has led to a strong increase in the number of records in the central database, allowing better and more precise calculations on the local trends of moths. About one-third of the species in our analysis are decreasing and could be listed as threatened. On the other hand, some species are strongly increasing. All species together show a significant, declining, trend in abundance. At the same time there exist strong year to year fluctuations in this trend which are due to weather conditions. We conclude, therefore, that the changing climate is having a strong impact on our moth fauna. The absolute number of individuals of the common species has dropped by one-third. We argue that this had a negative impact on plant biodiversity. The need for better protection of moths in northwestern Europe is also implicated by the fact that many species of birds, bats and other groups depend on moths (or their larvae) as main food sources.

**Keywords** Lepidoptera · The Netherlands · Numerical decline · Climate effect · Performance · Abundance · Insectivorous birds · Phytophagous insects

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## Introduction

Moths make up a significant part of the biodiversity both in northwestern Europe and globally (Young 1997). They represent one of the largest insect groups and, therefore, are important elements in many ecosystems at different trophic levels. First of all, moths can act as pollinators for flowering plants (Boggs 1987). In some cases, adult moths are important components of the diets of birds. In addition, many species of bats feed on moths and in some species moths make up a substantial part of their diet (Vaughan 1997). The most important component in ecosystems, however, is the role of larvae in the food chain (Török et al. 2004; Visser et al. 2006). Many bird species eat larvae or feed their young with larvae of moths. In fact, most bird species are, at some time of the year, largely dependent on the presence of moth larvae for survival or successful reproduction (Hogstad 2005). Furthermore, their herbivorous habits often make them effective regulators of vegetation (Bernays et al. 2004; Schowalter 1981).

At the same time, moths have a strong aesthetic appeal, and form one of the insect groups that have attracted most interest among free-time entomologists. Interest among amateur entomologists in the Netherlands in this group is growing rapidly. This is partly due to the publication of field guides (e.g. a Dutch version of Waring and Townsend (2003) was the first available field guide on moths in the Netherlands and was published in 2006) and information on internet sites (e.g. [www.vlindernet.nl](http://www.vlindernet.nl)). These activities are strongly facilitated by activities of Dutch Butterfly Conservation and the Working Group Lepidoptera Faunistics (Groenendijk and van der Meulen 2004). This in turn has resulted in a strong increase in the number of records in our database, allowing better and more precise calculations on trends of moths in the Netherlands. The name of the

database is Noctua and this name is used throughout the paper. Noctua is managed by both the Working Group Lepidoptera Faunistics and Dutch Butterfly Conservation. Although Noctua covers faunistic information of all Lepidoptera, this paper focuses on the larger (macro) moths (defined as the species belonging to the families covered in Waring and Townsend (2003)), of which 766 species are considered as native in the Netherlands. Analysis of the data set available through Noctua has generated national population trends for hundreds of larger moths in the Netherlands, which have never been published before.

The aim of this paper is to present the current state of moth biodiversity trends in the Netherlands. We present (1) figures on trends of larger moths in the Netherlands and (2) a comparison with the state of Britain's larger moths as described in Conrad et al. (2006) and Fox et al. (2006).

## Methods

The database Noctua, at the time of writing, contains about 2.3 million records, covering faunistic information of all Lepidoptera groups that have occurred in the Netherlands, from about 1800 till the present day. Table 1 summarizes the composition of Noctua. Sources include publications, unpublished records and notebooks, and information provided either directly, or through data collecting websites, in particular [www.waarneming.nl](http://www.waarneming.nl). Data are validated in two steps. A first step automatically compares a record with the known flight period and with the national, regional, and local abundance of the species under consideration. Records that do not pass this test are further checked by specialists before inclusion in the database. Note that for

**Table 1** Summary of the composition of the database Noctua

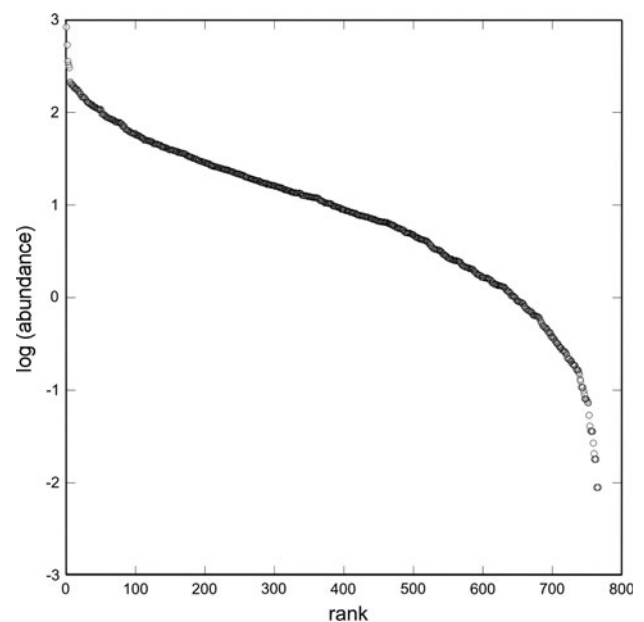
	Numbers of records (*1.000)
Total number of records	2.270
Not yet validated, rejected, or 'migrants_only'	230
Available	2.040
Microlepidoptera	401
Rhopalocera	127
Macrolepidoptera	1.512
1850–1949 (100 years)	83
1950–1979 (30 years)	308
1980–1989 (10 years)	146
1990–1999 (10 years)	304
2000–2009 (10 years)	671

Note that for this publication only data on larger (macro) moths (macrolepidoptera) are used

the present publication over 1.5 million records on 766 species of larger moths (macrolepidoptera) are used (Table 1).

It is important to stress that the moth data in Noctua are not the result of any monitoring scheme (cf Woiwod and Harrington 1994). Some volunteers that provide us with data do collect on an almost daily basis, but most data are the results of random excursions, holidays and so on. The calculated trends, therefore, may suffer from differences in the geographical coverage (cf Telfer et al. 2002). However, we believe that the Noctua database is sufficiently large to draw sensible conclusions for particular species, provided that the temporal or spatial scale is not too restricted. This conviction is reinforced by examination of the rank distribution of log-abundance values which does not show a disproportionately high number of very common or very rare species (Fig. 1).

Abundance, nationwide or in a particular region, and always for a specified time period, is calculated by obtaining the sum of the log-transformed number of individuals divided by the number of collection events. In this way the intensity of recording effort is factored out (cf Telfer et al. 2002). A collection event is defined as the event that a person observed one or more moth species at one date at one kilometer square. The calculations are described in detail at [www.vlindernet.nl](http://www.vlindernet.nl). In the present paper all calculations were limited to the period from 1980 onwards because around 1980 personal computers became available, and field entomologists started in earnest to store their observations in a structured way. Migrants, species



**Fig. 1** Distribution of the log-abundance values of all native larger moth species in the Netherlands ( $n = 766$ )

that periodically moves from one geographical region to another, were left out of the calculations. In these non-resident species their population fluctuations are mostly determined elsewhere.

For those species that were not excessively rare (abundance > 1,  $n = 626$ ), we then calculated their yearly ‘performance’ defined as the difference of their yearly abundance minus their average abundance, divided by the standard deviation. The phrase performance thus informs how well a species is doing in a given year. Moreover, its value is comparable between species. The slope of the linear regression of a species’ performance on year (1980–2009) gives an indication of its rise or decline in that period, its ‘population trend’.

A species’ population trend and its abundance are the two key components of the degree in which it is under threat. We numerically estimated this threat by applying the rule:

if slope < 0 then threat = slope/abundance else threat = slope × abundance.

We also calculated the yearly average of the number of adult individuals collected or seen per collection event, for all common (abundance ≥ 100) macro-moths. Collection events in which less than five common species were recorded were disregarded, to exclude reports of only casual, potentially incomplete, observations.

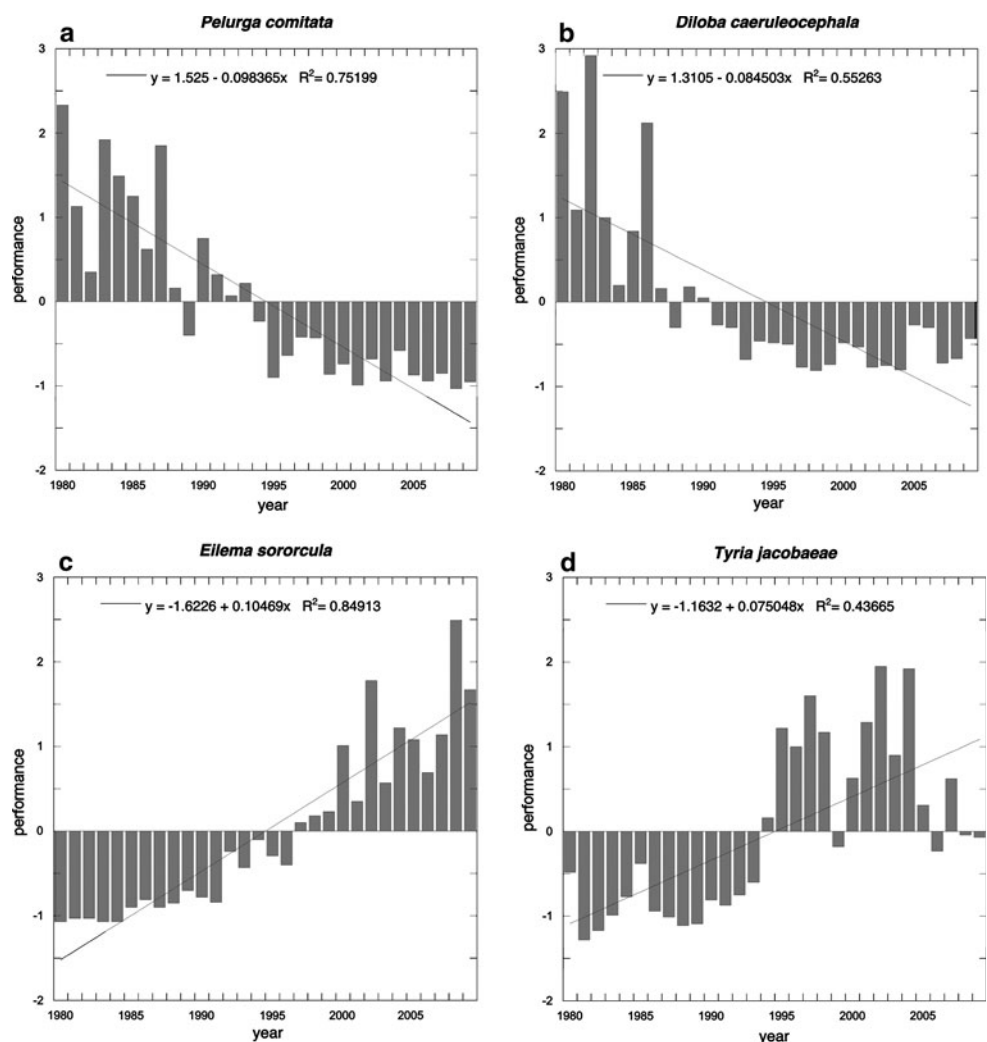
## Results

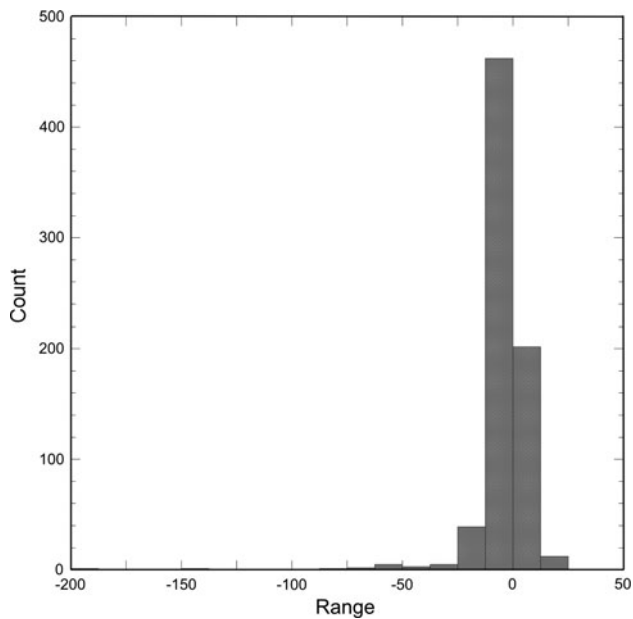
### Trends and numbers

Figure 2 shows four examples of individual moth species with decreasing and increasing trends. Both Dark Spinach (*Pelurga comitata*) and Figure of Eight (*Diloba caeruleocephala*) show strong decreasing trends, whereas Orange Footman (*Eilema sororcula*) and Cinnabar (*Tyria jacobaeae*) are increasing.

Figure 3 shows the frequency distribution of all the species specific threat values. The number of threatened

**Fig. 2** Yearly performance (1980–2009), defined as the difference of the yearly abundance minus average abundance, divided by the standard deviation of *Pelurga comitata*, *Diloba caeruleocephala*, *Eilema sororcula* and *Tyria jacobaeae* in the Netherlands. The linear regression and its equation is also given





**Fig. 3** Frequency distribution of threat values of all species of larger moths in the Netherlands for which these could be calculated ( $n = 733$ )

species is about two-third compared with the not threatened ones. Out of a total of 733 species extant in the period 1980–present, 519 show a negative slope. Against 43 species strongly decreasing with a slope less than  $-0.08$  there are only 13 with a strongly increasing slope  $> 0.08$ , or in terms of threat, against 91 species with a threat value below  $-10$  there are 19 with a score higher than  $+10$  (Fig. 3).

The negative trend in species also holds true for the number of observed individuals. Although subject to yearly fluctuations, the results strongly indicate that the total number of individual larger moths per collection event has dropped from 59 to 37 individuals, a decline of 37% in the period from 1980 onwards (Fig. 4).

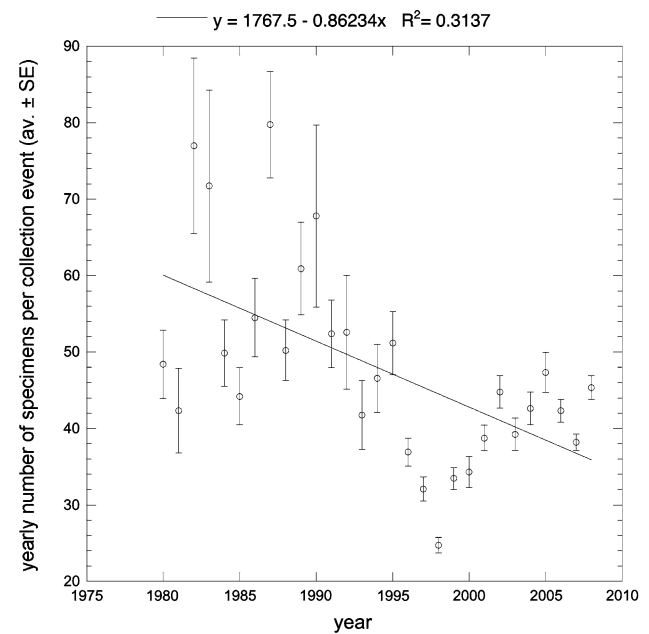
#### Effect of life cycle and abundance

The rate of decline differs among species groups differing in hibernation strategies (Fig. 5). The average slope of all species hibernating as eggs is the lowest, and the average slope of the species overwintering as adults is slightly positive.

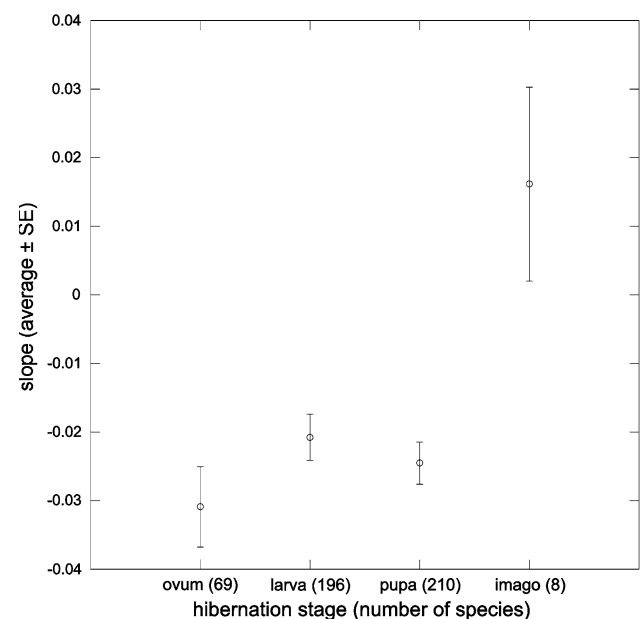
Another tendency in the results is the influence of abundance. When all larger moth species are grouped in six equally sized abundance classes, the rarest species show the greatest losses, whereas the most common species are on average stable or show only a slightly decreasing trend (Fig. 6).

#### Effect of climate change

One could assume, as a nul-hypothesis, that the yearly performance of each species is independant of that of any

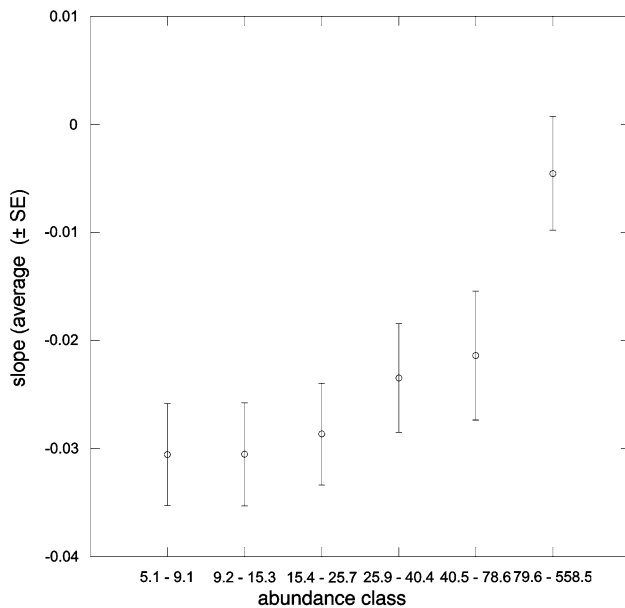


**Fig. 4** Average number of individuals per observation per year. Error bars present standard errors. The linear regression and its equation is also given



**Fig. 5** Relationship between the average of the slopes of the linear regression of the performance on year, and hibernation stage. The number of larger moth species in each category is given in brackets. Error bars present standard errors

other. In that case the average of the yearly performances of all species would be roughly similar. Given the declining trend that has been documented above, one would expect that the course of the averages from 1980 on would show as a smoothly declining line. Contrary to this expectation,



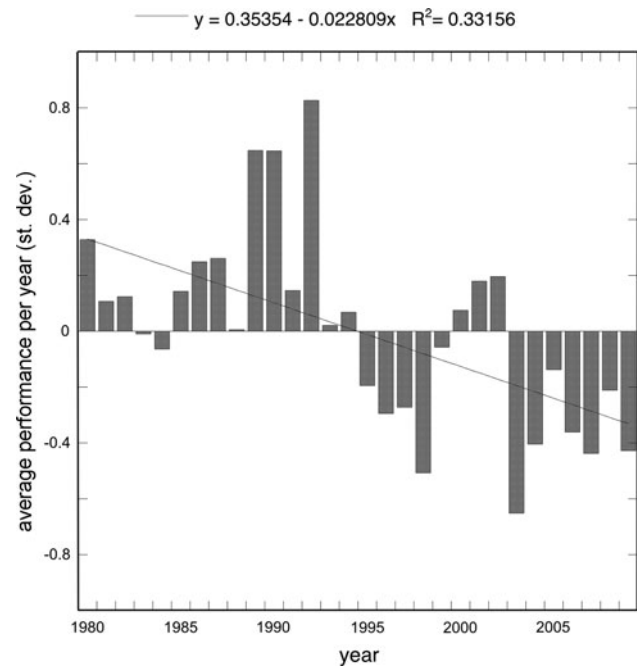
**Fig. 6** Relationship between the average of the slopes of the linear regression of the performance on year, and six equally sized abundance classes. The class limits are given below. Error bars present standard errors

there is a very strong year-to-year fluctuation (Fig. 7), which is assumed to be largely influenced by climatic variables. Obviously, for the larger moths good and bad years are a reality (anova:  $F = 86.78$ ;  $P < 0.001$ ). As the regression equation shows, there is a highly significant declining trend. Moreover, note the strong match in year-to-year fluctuations with Fig. 4.

## Discussion

### Comparison with the British situation

Clearly, the bleak situation depicted by Fox et al. (2006) for Britain does hardly differ from that in the Netherlands. A comparison at the level of individual species, for instance, shows a close congruence. Species like Dark Spinach (*Pelurga comitata*) and Figure of Eight (*Diloba caeruleocephala*) are, like in Britain, among the most severely in decline in the Netherlands (Fig. 2). In addition, the increase of Orange Footman (*Eilema sororcula*) in the Netherlands is also supported by the positive trends of eight other footman species in Britain. Footman moths (subfamily Lithosiinae) are doing very well as a group. In Britain eight species are included in the analysis, all of which have increased (Fox et al. 2006). Larvae of Footman moths are algae and lichen feeders and lichens have been increasing in Northwestern Europe during recent decades (Gilbert 1992).



**Fig. 7** Yearly averages of the performance of the macro-moths in the Netherlands (rarest species and migrants omitted;  $n = 626$ ). The linear regression and its equation is also given

Comparing the species trends from Britain and the Netherlands, there are some interesting exceptions. The White Ermine (*Spilosoma lubricipeda*) for instance, which shows a decline of 77% in Britain over 35 years, is doing quite well in the Netherlands, with an abundance of 175 (average 1980–now) and a positive slope of 0.03, which equates to a 41% increase in 30 years. Most remarkable is the situation of Cinnabar (*Tyria jacobaeae*), that meets the criteria to be classified as vulnerable in Britain, whereas in the Netherlands it is one of the sharpest rising species. There are, however, some indications that the species is faring less well during the last few years (Fig. 2). Figure 2 gives a few examples of trends of moth species while the condition of each species of the Dutch larger moth fauna is shown on our website [www.vlindernet.nl](http://www.vlindernet.nl).

Not only at the species level the situation in Britain and the Netherlands is highly comparable, other patterns also show a striking similarity. The relation between moth species population trends and overwintering stage (Fig. 5) is very similar (Fox et al. 2006) and also the distribution of threat values (Fig. 3), are highly comparable with the figures presented in Fox et al. (2006). We conclude, therefore, that, although there are differences in the way of calculations and underlying data between the present study and the long term study based on the Rothamsted Insect Survey (Woiwod and Harrington 1994; Conrad et al. 2004), the situation in the Netherlands hardly differs from that in

Britain and is most likely an illustration of the situation in much of Northwestern Europe.

#### Climatic effects

As was shown in Fig. 4, the yearly performance, averaged over all species, declined strongly. Many interacting factors will have contributed to this effect, like loss of habitat quality and connectivity, loss of biodiversity in the lower trophic level, lowering of water tables, use of pesticides, light pollution and other factors. However, the figure also shows that this declining trend has strong year to year variations. An inspection of individual species illustrates this dramatically. Even species, that in the long run are doing exceptionally poor, most often show a peak in their performance in, for instance, the year 1992, which was on average a good year (Fig. 7). We do not believe that the peaks and troughs observed can be attributed only to the deleterious factors mentioned above. On average, they are long term effects that change only slowly and unidirectionally over time. Natural population fluctuations are not a likely explanation either, because it would be difficult to understand why these would be so strongly synchronised to give this averaged pattern. One might think of an observational artefact (a nice summer, many observers afoot, high scores), but observation effort is factored out in our calculations. The only environmental factor of a sufficiently large geographical scale that remains is the weather. Indeed, we think that weather fluctuations have played a decisive effect on top of the general trend. We conclude that weather has a strong influence on a species' performance, and that on average all species in our fauna react in a similar way. Future changes in the long term pattern of weather conditions, i.e. climate, therefore, are expected to have a strong impact on our moth fauna.

#### Numerical decline

The drop in the number of individuals across all species is certainly dramatic and almost certainly it is real. The rise in the number of recorders and observations in itself can have no effect, because the figures are based on the number of observations. As a matter of fact, big changes have occurred in the period since 1980 in the population of observers and their methods of observing and reporting. The most influential change, in our view, the rising popularity of online databases where anyone can record a casual observation, has been eliminated from the calculation. What remains is the rise in the proportion of new and little trained observers, and changes in the technical equipment. One would guess, however, that both would result in higher, rather than lower, numbers of individuals of common moths. This means that the changes in our larger moth

fauna not only implies a replacement of rare species by common ones. Rather we see that the entire moth fauna, and by implication the entire basis of our ecosystem is being jeopardized with the trophic levels below, and above, the moth fauna being most severely affected.

#### Implications

As a consequence, we hypothesize that moth declines will have a huge impact on biodiversity in the Netherlands, the United Kingdom (cf Conrad et al. 2004) and, therefore, most likely in the whole of Northwestern Europe. The ecological implications of this decline are, however, still poorly understood.

The larvae of the majority of species of larger moths have a rather generalized spectrum of host plants. The decline in their number will translate, therefore, in a general decline in herbivore pressure. The impact of insect herbivory on vegetation composition is not particularly well known, especially because exclusion experiments have strong side effects. Yet, a general theme is a change in competition patterns, resulting in a decline of plant diversity, following exclusion (Brown et al. 1988; Crawley 1989; Maron and Crone 2006; Olf and Ritchie 1998; Scherber et al. 2006).

The same effect, lush plant growth and a declining botanical diversity, is also caused by an enhanced fertilizer deposition, and by a reduction in herbivory by vertebrates (e.g., rabbits, sheep). This has been an reason of much concern among conservationists in the Netherlands (Tamis et al. 2005; Tilman 1987). Our results indicate that also a reduction in insect herbivory must be taken into consideration.

In addition, it may well be that the severe decline in some bird species in Northwestern Europe, especially of those that inhabit agricultural landscapes (Chamberlain et al. 2000) like Corn Bunting (*Miliaria calandra*) and Eurasian Skylark (*Alauda arvensis*), is related to the decline in moth diversity. It can be hypothesized, that the most important trigger is the period in which these birds feed their young. As larvae of moths are one of the most important prey items in these farmland birds, a decline in moths can be responsible for lower reproduction rates and, consequently, declining trends of these bird species.

Another example is found in research on European Nightjar (*Caprimulgus europaeus*), a migratory bird that is present in northwestern Europe from late April to early September. During its presence in northwestern Europe the birds mainly feed on moths (Schlegel 1994; Sierro et al. 2001). In addition, recent research showed that about 80% of the prey caught by adult birds to feed their young consist of moths. Therefore, we predict that the widespread declines of larger moths in the Netherlands and the United



Kingdom will be having strong effects on the birds, bats and mammals, which depend on them for food. This emphasizes the urgent need for the protection and restoration of moth habitats.

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