Global warming and the change of butterfly distributions: a new opportunity for species diversity or a severe threat (Lepidoptera)?

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Abstract
In order to assess the influence of climatic changes on the distribution of insects, the ranges of non-migratory European butterfly species have been studied. This study revealed that the northern limits of 32 (64%) of 52 species have expanded northwards during the 20th century. The southern limits of ten (25%) of 40 species have retracted northwards. The example of the Peacock butterfly (*Inachis io*) is given to illustrate the response to climatic changes of a species of which the range is not restricted by habitat choice. The northern limit of its range shows a considerable shift to the north during warm periods, and a southward retraction during cooler periods. Several other species showed the same pattern. These results are followed by a discussion of the impact of climate change on species diversity.

Key words: Lepidoptera, Europe, changes in ranges, climate change, *Inachis io*.

Introduction
During recent decades the climate on Earth has clearly become warmer, especially in the northern hemisphere. Whether or not this is due to human induced changes in climate or part of normal global climate fluctuations is still not fully understood. However, an increasing number of scientists believe that the rapid changes observed are caused by human activities.

Whatever the cause, the mean temperature in Europe during the past century has risen 0.8ºC, displacing isotherms 120 km northwards on average. In comparison, the mean temperature during the last ice age was approximately 4ºC lower in Scandinavia than it is today. The recent changes are also more pronounced in northern than in southern Europe.

Insects have short life cycles and often a high reproduction and dispersal capacity. Therefore they have the ability to react relatively quickly to changes in climate. As shown in our study, a number of butterfly species have responded to the recent climatic change by shifting their entire European range northwards. New habitats have become available further north due to the warmer climate and thus allowing northward expansion. In southern Europe many habitats have become too hot and dry, thus causing local extinctions of the species at their southern range limit.

Changes in ranges of European butterflies
The results of a study done in co-operation with a number of European and American butterfly ecologists have shown that a large number of European butterfly species have recently responded to the ongoing changes in climate (often called global warming; Parmesan et al. 1999). In this work we studied non-migratory butterfly species with distributions not restricted by habitat or host plant demands. These species belong to all families of butterflies and use different hibernation strategies. Data were compiled for the period 1900-1997. For the northern border analysis 52 species were used. The use of a very conservative classification method revealed that 33 (64%) of these had expanded their habitats significantly northwards, 17 species (34%) remained stable and one (2%) retracted southwards. However, observations from the years after 1997 indicate that several species in the last two groups have actually started to expand as well. For the southern border analysis 40 species were used. Using the same method 10 species (25%) were found to retract northwards, 28 (70%) remained stable and two (5%) expanded southwards. As could be expected, if these shifts are due to climatic change, the reactions are stronger in the north than in the south (see below). Of these species 35 could be used in an

overall range analysis: 22 species (63%) shifted northwards, ten (29%) remained stable and two (6%) expanded southwards. Taken together these results clearly show that butterfly populations can respond quickly to changes in climate both at their southern and their northern range limit.

Examples

Here distribution data on the peacock butterfly (*Inachis io* Linnaeus, 1758*)* are used to show in more detail how a species' northern range limit in Sweden has varied as a response to different variations in summer temperatures (fig. 1) during the past hundred years. Since the larvae of this species feed on the common nettle (*Urtica dioica*) in various types of habitats, changes in land use etc. cannot explain the observed fluctuation.

In the beginning of the last century, the species had its northern range limit in south-central Sweden at 60º N (fig. 2). As the climate, particularly the summers, became warmer during the 1930-1940s, the species' range expanded dramatically. At the same time a number of other butterfly species expanded their ranges in Sweden and *Ladoga camilla* (Linnaeus, 1764) established itself in southern Sweden. The northernmost populations of *Inachis io* during this period occurred more than 620 km north of its northern limit at the previous turn of the century (fig. 3). A climate deterioration which peaked during the 1960s with a number of wet and cool summers (fig. 1) resulted in a retraction of the range of *Inachis io* nearly back to the northern range limit of the species some 60 years earlier (fig. 4). During this period many other species showed a similar pattern, *Parnassius apollo* (Linnaeus, 1758) declined dramatically and *Ladoga camilla* became extinct in Sweden.

In the warm summers of the 1980s *Inachis io* again started to expand strongly, only to revert to the 'baseline' in the extremely wet and cold summer of 1987. During the mainly warm summers in the 1990s the species has once again established itself in the lowland areas of northern Sweden (fig. 5), thus showing an expansion capacity of at least 600 km in less than ten years! Many other butterflies and other insect species with different host plants and differing life cycles, for instance *Aporia crataegi* (Linnaeus, 1758), *Argynnis paphia* (Linnaeus, 1758) and *Plebicula amanda* (Schneider, 1792), have shifted their distribution range northwards during the same period. Despite the increasing habitat fragmentation, periods of warmer summers clearly allow a number of species to expand towards the north.

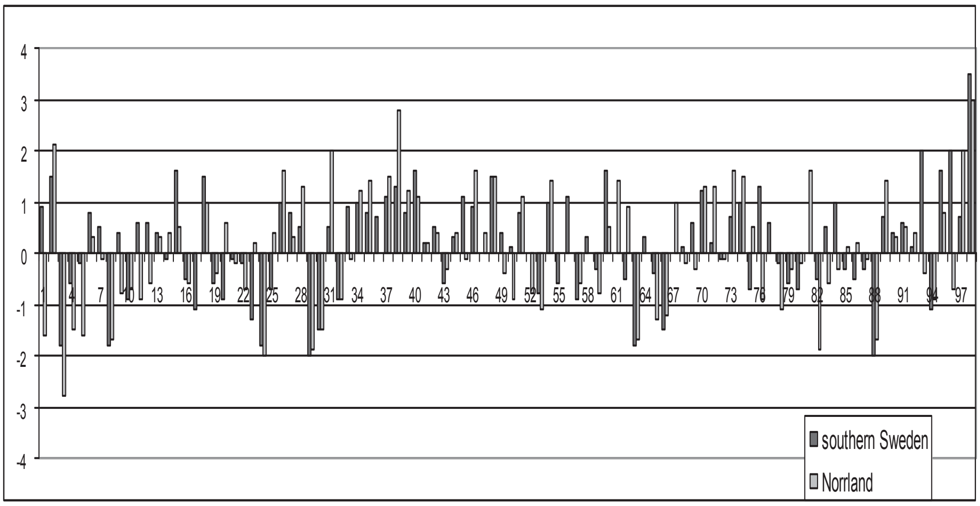

Figure 1
Mean summer (June-August) temperatures in southern (dark) and northern (light) Sweden 1900-1999.

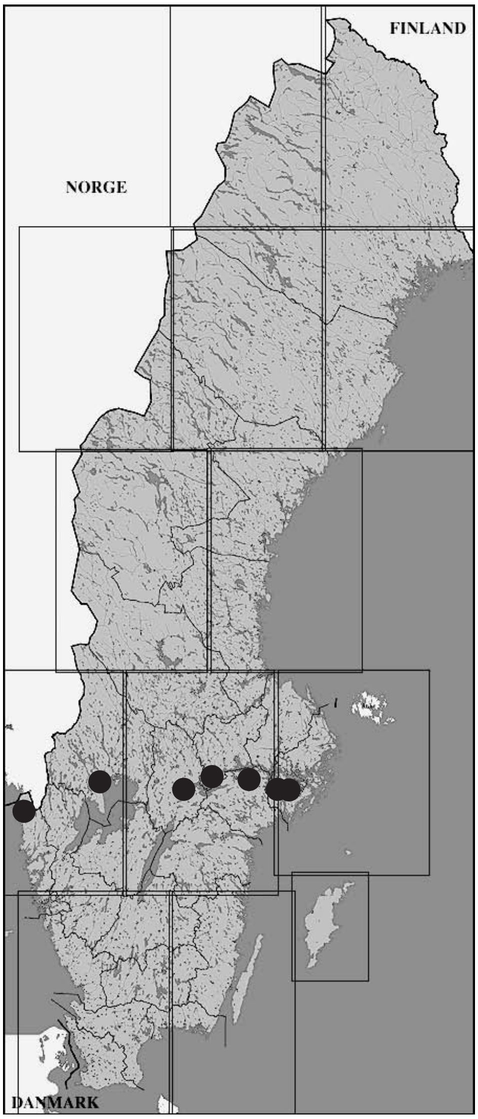

Figure 2
Northernmost finds of *Inachis io* in Sweden during the period 1900-1910.

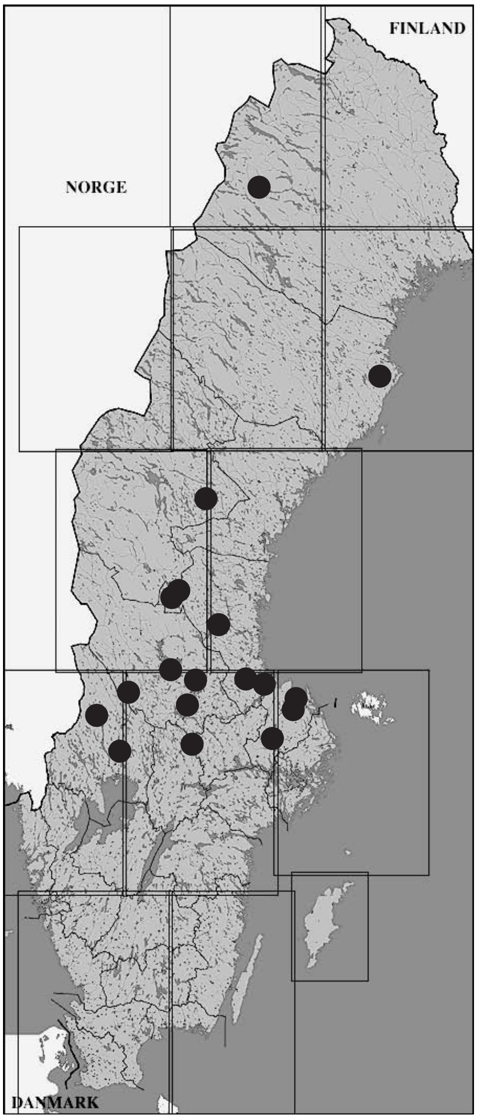

Figure 3
Northernmost finds of *Inachis io* in Sweden during the period 1931-1940.

Discussion

Throughout Europe the increasing demands of the human population and more 'rational' land use is continuously causing habitat destruction and fragmentation, leaving less and less suitable habitats for any kind of flora or fauna. This is most pronounced in western Europe with its high human population density where extremely few suitable habitats are left. If the climate continues to get warmer in southern Europe this will lead to new difficulties for European wildlife. The combination of changing climate and continuously declining habitats may lead to an increasing number of extinctions of species, especially on their

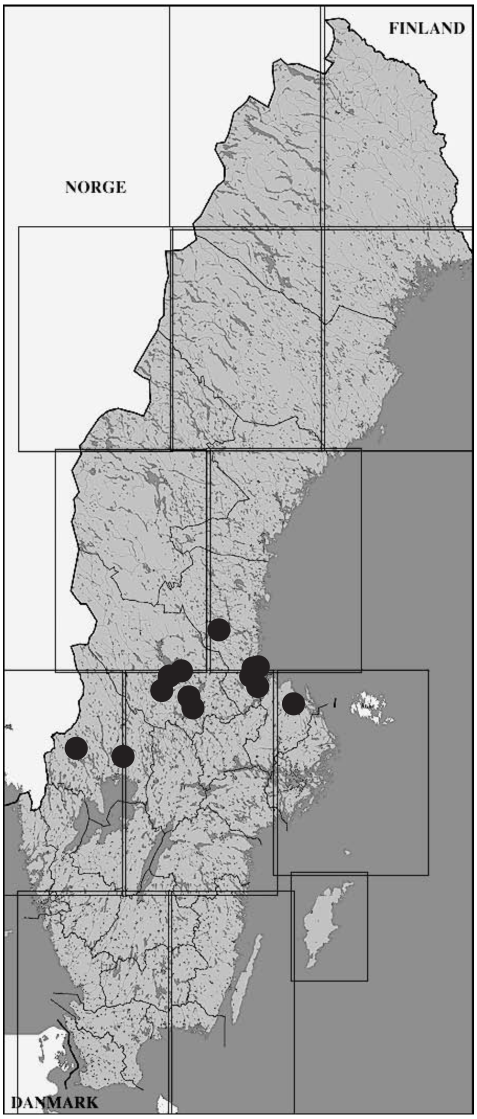

Figure 4
Northernmost finds of *Inachis io* in Sweden during the period 1961-1970.

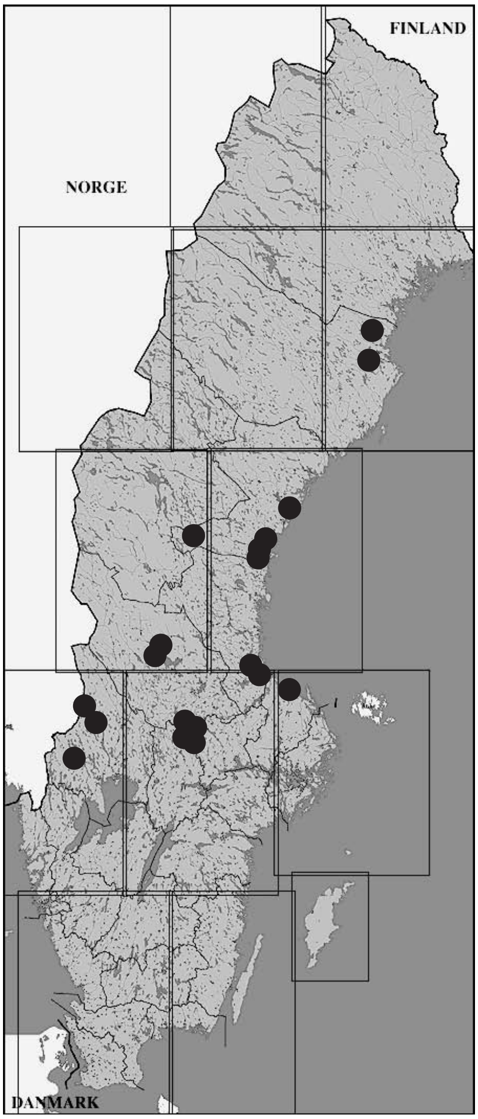

Figure 5
Northernmost finds of *Inachis io* in Sweden during the period 1991-1997.

southern range limit, as they are 'forced' further north and into areas with dense human populations where no suitable habitats are left. The further suitable habitats are from each other, the higher the risk for species to become extinct. Species like *Inachis io* which have a high dispersal capacity and low habitat demands may perhaps find suitable areas to colonise. However, those species with low dispersal capacity or high habitat demands will have severe problems in finding new habitats when their old ones become unsuitable. The degree of fragmentation in a landscape will determine the survival/extinction rate of species in a changing climate. The more fragmentation, the higher the extinction risk even at moderate levels of climate change. Insect populations living in a highly fragmented landscape will have much less chance to survive any climatic change (warmer/dryer – cooler/wetter) than those living in more undisturbed areas. These perspectives must be taken into account in the European conservation work of today in order to compensate for the changes of tomorrow.

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References

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