Butterfly Conservation

Saving butterflies, moths and our environment

The State of Britain's Larger Moths 2013

The Swallow-tailed Moth *Ourapteryx sambucaria* **declined by 60% over the period 1968-2007**

Photograph R. Thompson

ROTHAMSTED RESEARCH

Eyed Hawk-moths *Smerinthus ocellata* R.Thompson

Executive summary

- Moths are an extremely diverse and species-rich group of insects that occur in a wide range of habitats and play vital roles in the functioning of ecosystems both as important components of the food chain and as plant pollinators. They are also fascinating and beautiful insects that are increasingly popular with the public.

- Over 2,500 moth species have been recorded in Great Britain, of which around 900 are so called larger moths (macro-moths), and 1,600 micro-moths. This report summarises the current state of knowledge about larger moths in Britain, based on the world-leading Rothamsted Insect Survey and the recording and conservation work undertaken by Butterfly Conservation and others.

- Across Britain, the total abundance of larger moths declined significantly, by 28%, during the 40-year period from 1968 to 2007.

- In the southern half of Britain, total counts of larger moths decreased significantly, by 40%. In contrast, moth numbers showed no significant change in northern Britain, where declining species are balanced by species spreading north.

- Two-thirds of 337 species of common and widespread larger moths declined over the 40-year study. 37% of the 337 species decreased by at least 50%. One-third of species became more abundant with 53 species (16% of the total) more than doubling their population levels over the 40 years.

- This overall decline is indicative of the rapid loss of insect biodiversity in Britain, and other countries, which may have substantial impacts on other wildlife and affect the delivery of some ecosystem services.

- Generally, the rates of decline of moths have tended to moderate a little since the previous report in 2006. However, regardless of this, the broad patterns of change in moth biodiversity revealed in this report are similar to those in the previous assessment.

- In addition to 62 moth species (macro and micro-moths) that became extinct in Britain during the twentieth century, a further four species may now be extinct here (Orange Upperwing, Bordered Gothic, Brighton Wainscot and, possibly, Stout Dart).

- In contrast, this century, more than 100 moth species (macros and micros) have been recorded for the first time in Britain and 27 moth species are considered to have colonised Britain from the year 2000 onwards. Immigration also appears to be increasing.

- The causes of change among Britain's moths are not yet fully understood. Habitat changes, especially those related to agricultural intensification, changing woodland management and urbanisation, appear to have had substantial, largely negative impacts on moths. Climate change, on the other hand, seems to have had both positive and negative effects. It is still unclear whether other factors such as nutrient enrichment and light pollution have had significant impacts on moth populations.

- Conservation action for some of the rarer moths in Britain has expanded considerably over the past decade under the impetus of the UK Biodiversity Action Plan, with many notable successes. It is vital that targeted species conservation programmes continue, both at a local and landscape scale, in order to prevent future extinctions – an ecosystem approach alone will not be sufficient to conserve many threatened moths and prevent the ongoing loss of biodiversity in Britain.

- However, a focus on threatened moth species, while essential to prevent further loss of biodiversity, is not enough. Pervasive environmental degradation and the decline of common species demand the recreation of a rural and urban landscape that is much more hospitable to biodiversity. Carefully targeted and properly resourced agri-environment and woodland management schemes would be a significant step towards repairing Britain's natural heritage and safeguarding the ecosystem services that underpin human welfare.

Recording and monitoring Britain's moths

Moths provide a rare opportunity to measure and understand change in a large and diverse group of insects.

Although insects account for a high proportion of the earth's biodiversity and play crucial roles in ecosystems that underpin the welfare of the human race, we still know little about how they are faring. Knowledge tends to be limited to a few high-profile groups, such as butterflies, in the most developed countries. While this may provide an important indication of wider trends[1], there is an urgent need to quantify patterns of biodiversity change in other insect groups. Larger (macro-) moths provide such an opportunity in Britain, thanks to long-term population monitoring and distribution recording schemes supported by thousands of amateur naturalists. With some 900 species recorded in Britain, larger moths greatly exceed the species richness of other intensively-monitored wildlife groups, as well as being vital components of food webs (providing essential food for many birds and bats) and important plant pollinators.

Moth population monitoring

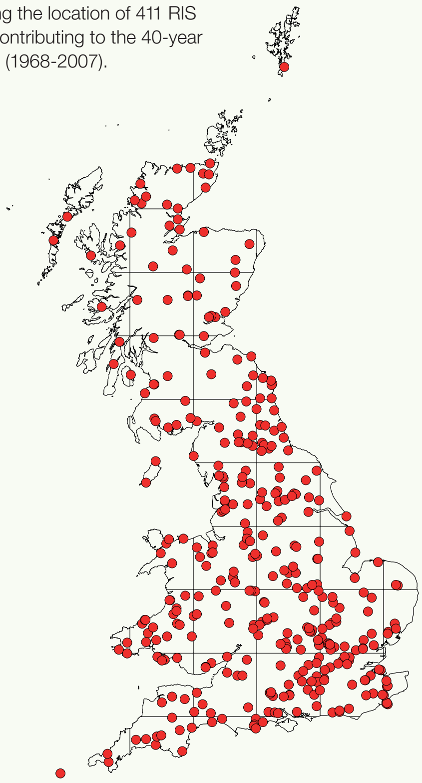
The Rothamsted Insect Survey (RIS) monitors nocturnal larger moth populations through a national network of standardised and automated light-traps that are run every night of the year. From 1968 to the present day, these traps have been run at over 525 sites, covering a variety of habitats, from gardens to upland moor using, on average, 97 traps per year. Moths are identified and counted on site by amateur experts or centrally by professional scientists, before the records are computerised. Through this network, Rothamsted Research has amassed a unique database, with around nine million moths recorded in Britain, over a period spanning more than four decades[2].

Previous detailed analysis of 35 years of RIS data (1968-2002) uncovered, for the first time, significant decreases among Britain's larger moths, mirroring declines already discovered for butterflies. The total abundance of larger moths in Britain had decreased significantly (by 31%) and the decline in southern Britain was even worse (44% decrease)[3].

Two-thirds of 337 common and widespread larger moths, for which national population trends could be determined, had decreased, many severely. Similar patterns of decline among larger moths have since been reported from the Netherlands and Finland[4]. Here we extend the analysis of larger moth population trends in Britain by including a further five years of RIS data (2003-2007). More recent data were still incomplete at the time of analysis due to inevitable time lags in dealing with so many records (from each trap each night). These new 40-year trends provide an updated snap-shot of the state of Britain's larger moths. We used the same methods of data selection and analysis, and focussed on the same 337 species as the previous study, to ensure that this report is directly comparable with its predecessor[5].

Rothamsted light-trap Rothamsted Research

Map showing the location of 411 RIS light-traps contributing to the 40-year assessment (1968-2007).



[1] Thomas *et al.* 2004a
[2] Conrad *et al.* 2007
[3] Conrad *et al.* 2006
[4] Mattila *et al.* 2006, 2008, Groenendijk & Ellis, 2011
[5] Fox *et al.* 2006

Moth distribution recording

Determining the geographical distributions of individual moth species and how these have changed over time is another valuable source of evidence to assess the state of Britain's larger moths. Distribution recording and population monitoring are complementary activities. Long-term, intensive monitoring provides information on rapid responses by moth populations to environmental changes, such as habitat conditions or the weather, but requires considerable resources and is, therefore, limited to a relatively small number of sites and a subset of species.

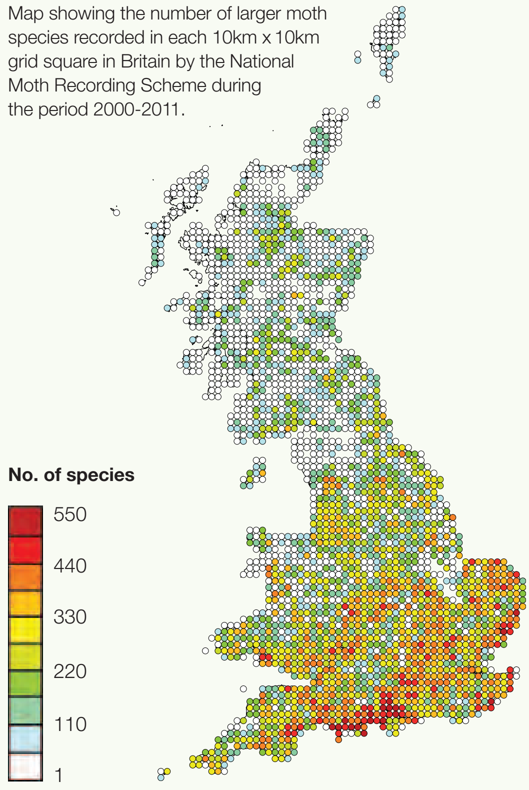
Distribution recording, on the other hand, makes up for what it lacks in spatial and temporal sensitivity, by covering the whole landscape, reporting on all larger moth species (c.900 species) and providing the location information for habitat specialist species that is vital to underpin decision making in nature conservation and land-use planning. Distribution recording of larger moths has a long history in Britain, but it took until 2007 to instigate the current national recording scheme[6].

The National Moth Recording Scheme (NMRS), run by Butterfly Conservation, is still in its infancy, although over 15 million historical and contemporary records have already been collated. Sightings of any larger moth species (including day-flying species), anywhere in the UK and on any date, contribute to the NMRS. There is no standardisation of recording methods or effort and therefore sampling varies from place to place, as well as over time, which complicates the assessment of species trends. On the other hand, it is a very inclusive approach that enables a large number of citizen scientists to contribute to improvements in conservation and scientific knowledge. All records are scrutinised by a network of expert volunteers (County Moth Recorders) before inclusion in the NMRS database.

The NMRS is not yet able to produce robust trends for every species, but distribution data can be used as corroborative evidence to support RIS population trends. Statistical methods are being developed to enable the calculation of trends over time from distribution datasets such as the NMRS.

Moth recorders around a light-trap D. Greves

Map showing the number of larger moth species recorded in each 10km x 10km grid square in Britain by the National Moth Recording Scheme during the period 2000-2011.



[6] Fox *et al.* 2011a

The changing moth fauna of Britain

Moth populations and distributions are in constant flux. During the twentieth century, 62 moth species became extinct in Britain and several more have followed since 2000. In contrast, over 100 moth species have been newly recorded in Britain this century and 27 have become resident.

In recent years, there has been a net increase in the moth fauna, with the number of new species colonising Britain greatly exceeding the number becoming extinct.

Extinctions

Sixty-two species of moths (including micro-moths) became extinct in Britain during the twentieth century[7] and several more are now thought to have been lost. Proving the extinction of a species is often difficult, but evidence suggests that the Orange Upperwing *Jodia croceago*, Bordered Gothic *Heliophobus reticulata*, Brighton Wainscot *Oria musculosa* and, possibly, Stout Dart *Spaelotis ravida* are no longer resident in Britain (although they may occur as rare immigrants).

Additions and colonisations

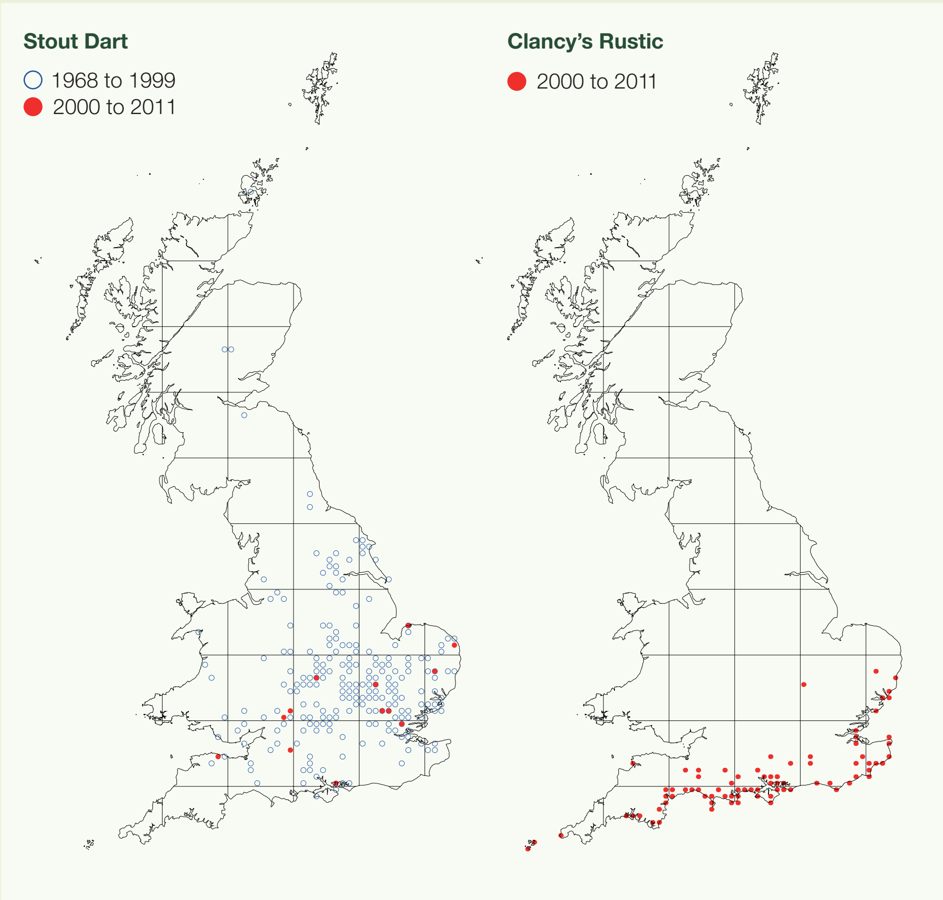
Already this century over 100 species of moths (including micro-moths) have been recorded for the first time in Britain. A few are previously-overlooked resident species; *Ectoedemia heckfordi*, for example, was described as new to science in 2010 and its entire, known global distribution is a small area of Devon! Some of the new arrivals have appeared only as occasional immigrants, while others have established breeding colonies and become resident species (e.g. Horse Chestnut Leaf-miner *Cameraria ohridella*, *Cosmopterix pulchrimella*, Clancy's Rustic *Platyperigea kadenii* and Sombre Brocade *Dryobotodes tenebrosa*). Incredibly, a total of 27 moth species are considered to have colonised Britain from the year 2000 onwards.

Meanwhile many of the 89 species that colonised Britain during the twentieth century[7] have continued to spread (e.g. *Pammene aurita*, Cypress Carpet *Thera cupressata*, Varied Coronet *Hadena compta* (see box opposite) and Toadflax Brocade *Calophasia lunula*).

Many, but not all, of these colonisers utilise non-native plants as hosts for their caterpillars. As a result of human activity, Britain's gardens, parks and, increasingly, countryside contain plants from all corners of the world and, not surprisingly, either by accidental importation or natural colonisation, specialist moth herbivores have followed.

Bordered Gothic *Heliophobus reticulata* D. Green

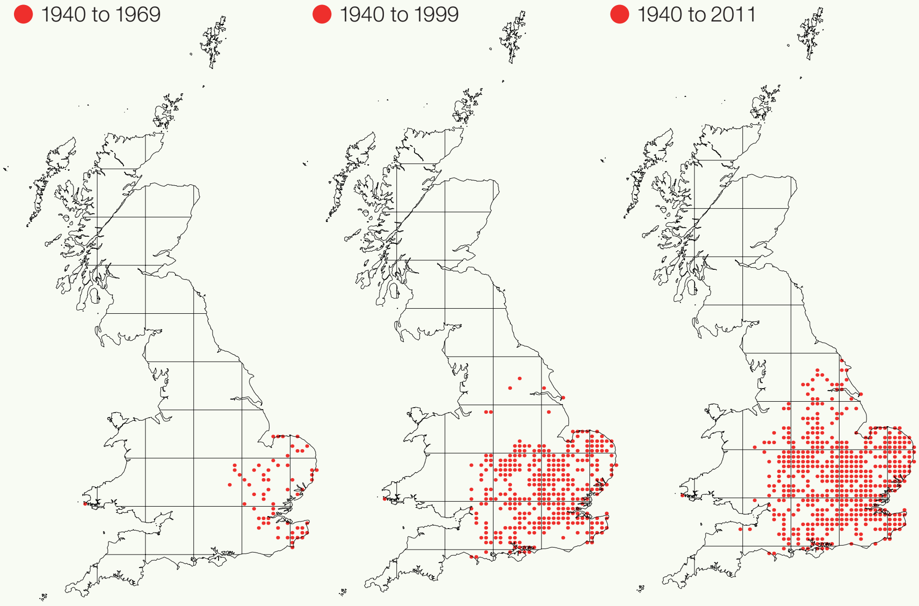
Orange Upperwing *Jodia croceago* P. Sansum



[7] Parsons 2003

The Varied Coronet colonised Britain in 1948 in Kent, and has since spread rapidly across southern and eastern England. The moth's caterpillars feed mainly on Sweet-William, a non-native plant widely grown in gardens.

Varied Coronet *Hadena compta* P. Maton



Immigration

Evidence suggests that both the abundance and diversity of immigrant moths arriving in Britain are increasing over time, probably due to climate change[8]. Recent years have witnessed substantial influxes of scarce immigrants such as *Spoladea recurvalis*, *Antigastra catalaunalis*, Crimson Speckled *Utetheisa pulchella* and Small Marbled *Eublemma parva*. Many, but not all, of our regular immigrants have increased in abundance (e.g. Vestal *Rhodometra sacraria* 925% increase in population levels over the period 1968-2007). Those bucking the trend include the Dark Sword-grass *Agrotis ipsilon* and Silver Y *Autographa gamma* (62% and 46% decreases respectively in population levels over the period 1968-2007).

Recent advances, particularly the use of vertical-looking radar, have revolutionised our knowledge of moth migration[9]. Moths are not simply blown along passively by the wind, but have sophisticated ways of getting to their desired destination. Silver Y and other moths make use of high altitude winds to achieve fast speeds (up to 55mph) and appropriate directions for their migratory movements[10]. Surprisingly, by selecting the most favourable airstreams, several hundred metres above the ground, and by orientating their bodies to compensate for crosswind drift, moths are able to migrate with similar speed and efficiency as songbirds[11].

Silver Y *Autographa gamma* R. Thompson

[8] Sparks *et al.* 2005, Morecroft *et al.* 2009
[9] Chapman *et al.* 2011
[10] Chapman *et al.* 2010
[11] Alerstam *et al.* 2011

Trends of common and widespread moths

The total abundance of moths decreased by 28% over the period 1968-2007. Losses in southern Britain were greater, at 40%, whereas in northern Britain losses were offset by gains.

Utilising annual counts from the Rothamsted Insect Survey light-trap network, 40-year national population trends were calculated using the software TRIM for 337 common and widespread species of larger moths in Britain.

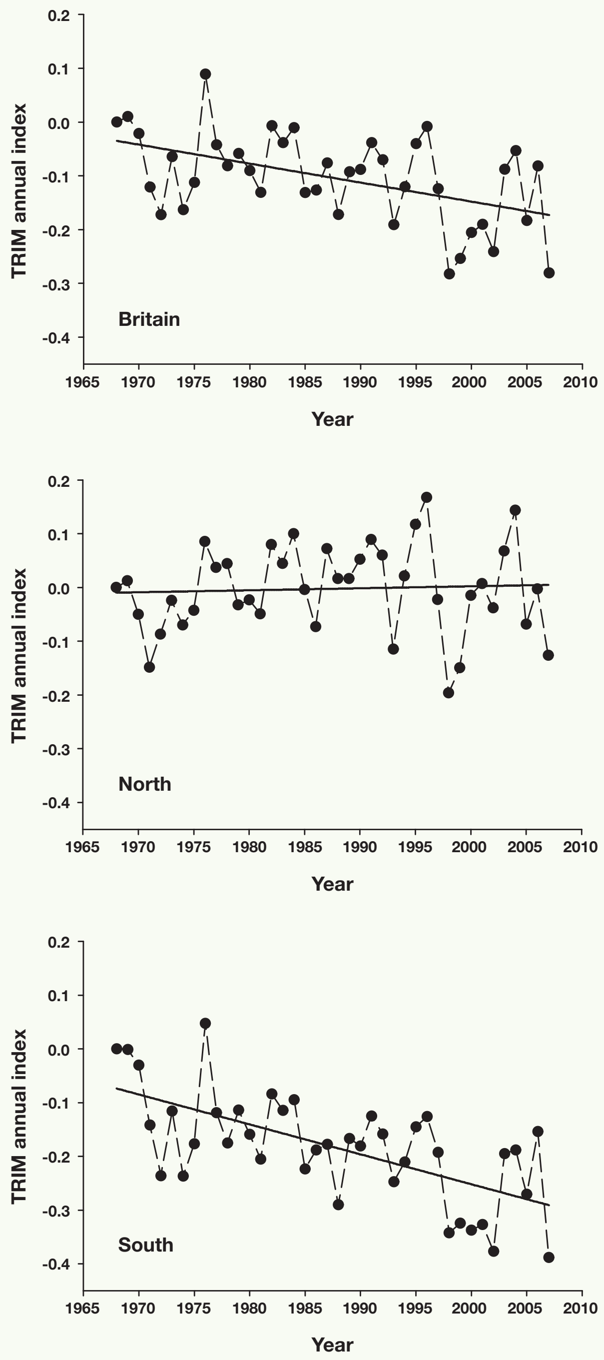
These trends cover the period 1968-2007 and are the longest-running national population trends of insect species known anywhere in the world. The 337 moth species are the same as were used in a previous study[12] (so that comparisons could be made, see p16) and were selected because these species have been caught sufficiently frequently to enable the calculation of robust population trends. While many of the species are common moths frequently caught in gardens, not all of the species occur throughout Britain.

Two of the 337 species in the study are in fact aggregates, where data for two species were combined before analysis into a single aggregate taxon: Deep-brown Dart *Aporophyla lutulenta* / Northern Deep-brown Dart *A. lueneburgensis*, because there is scientific uncertainty as to which of these species occur in Britain, and Lead Belle *Scotopteryx mucronata* /July Belle *S. luridata*, which are difficult to distinguish.

Moth abundance

The total abundance of larger moths caught in the Rothamsted light-trap network decreased by 28% over the 40-year period (Fig. 1). This trend towards lower moth abundance over time was statistically significant[13]. However, there was a clear difference between total abundance trends in northern and southern Britain. In the north (traps situated to the north of the 4500 N grid line, which equates approximately with the locations of the cities of Lancaster and York), there was no significant change, whereas in southern Britain, moth abundance decreased significantly, by 40% (Fig. 1).

Figure 1 Change in the total abundance of all larger moths caught in the Rothamsted light-trap network 1968-2007.



[12] Conrad *et al.* 2006, Fox *et al.* 2006

[13] Trends in total larger moth abundance were significant across Britain ($t = 8.30_{(38)}$, $P < 0.001$) and in southern Britain ($t = 11.98_{(38)}$, $P < 0.001$), but not in the north ($t = 0.54_{(38)}$, $P = 0.50$).

Trends for individual species

Common and widespread larger moths declined over the period 1968-2007 (Fig. 2). Forty-year national population trends showed that 227 species decreased in abundance, two-thirds (67%) of the larger moths assessed. The remaining 110 species (33%) became more abundant over the 40 years. The median change for the 40-year period was -36%.

61 species (18% of the total) decreased by at least 75% between 1968 and 2007 (see Table 1 on p8).

A further 63 larger moth species decreased by over 50% and an additional 64 species by at least 25%. Overall, 188 species (56% of the total) declined by at least 25%.

In contrast, 91 common and widespread moths (27% of the total) increased in abundance by over 25%. Of these, 53 species (16% of the total) more than doubled their population levels over the 40 years.

Twice as many larger moths declined as increased in Britain over 40 years.

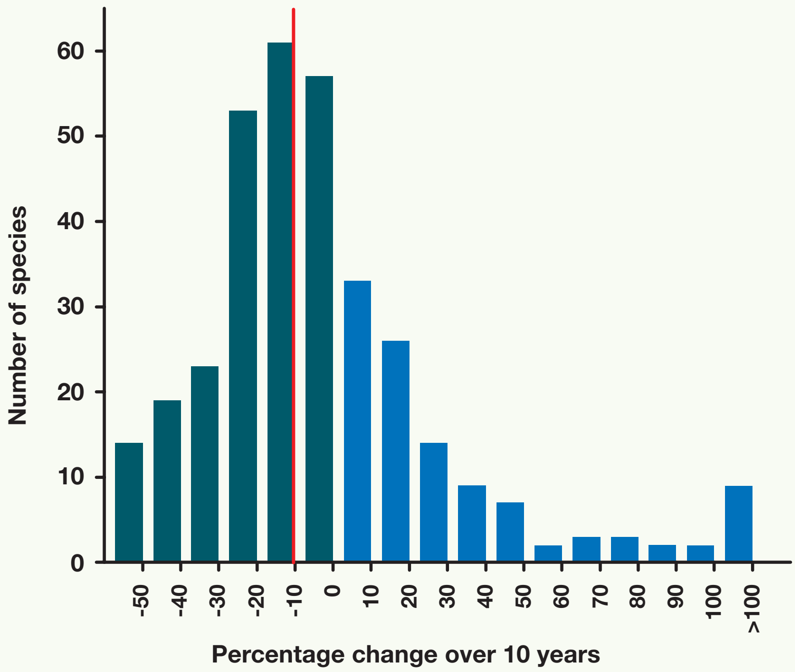
Species' 40-year population trends were also calculated separately in northern Britain (north of the 4500 N grid line) and southern Britain (Fig. 3). In northern Britain, trends were calculated for 259 species: 138 species (53%) decreased and 120 species (46%) increased, with one species showing no change. The median percentage change for larger moths in northern Britain was -11% over the period 1968-2007.

The picture was very different in southern Britain. Here trends were calculated for 308 species; 211 species (69%) decreased in abundance while 97 species (31%) increased. The median 40-year population change in southern Britain was -43%.

On average, moths analysed in both regions had significantly greater declines or lower increases in the south than in the north[14].

[14] Analysis of variance (ANOVA) of the difference between estimated annual change rates of species in southern and northern Britain (mean = -0.017, $F = 100.43_{(1,233)}$, $P < 0.001$).

Figure 2 Frequency distribution of the population changes of 337 British larger moths. The size of population change is given as the average 10-year rate of change, calculated from the annual rate of change estimated to occur over the period 1968-2007. The red line shows the 10-year median change. X-axis labels are the upper limits of each group.



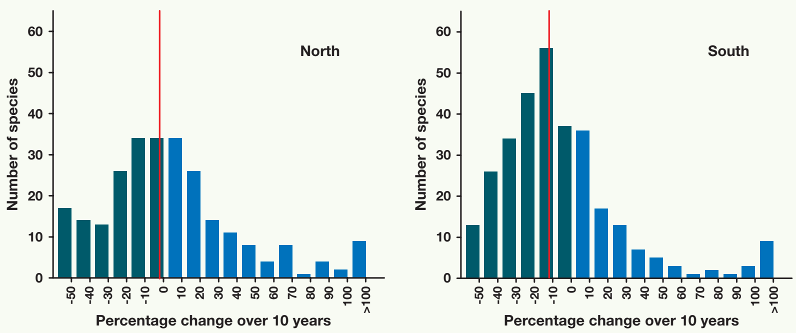


Figure 3 Frequency distributions of the population changes of larger moth species in northern and southern Britain. The size of population change is given as the average 10-year rate of change, calculated from the annual rate of change estimated to occur over the period 1968-2007. The red lines show the 10-year median change. X-axis labels are the upper limits of each group.

Table 1
Sixty-one species of larger moth declined by 75% or more over 40 years (1968-2007)

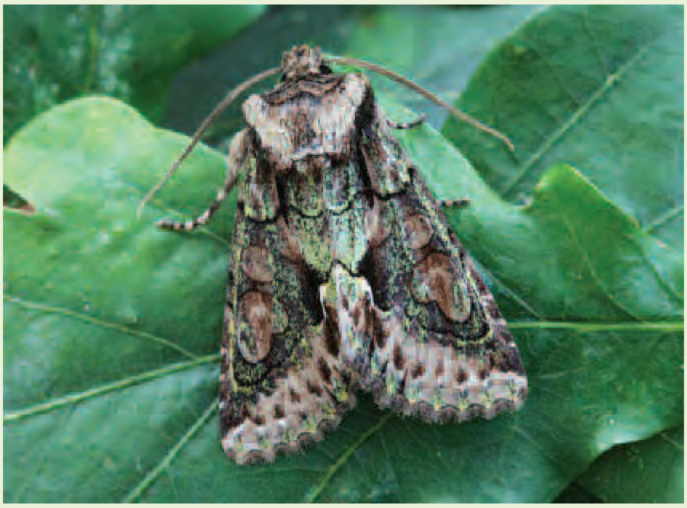
Species		% Change over 40 years
V-moth	*Macaria wauaria*	**-99**
Garden Dart	*Euxoa nigricans*	**-98**
Double Dart	*Graphiphora augur*	**-98**
Dusky Thorn	*Ennomos fuscantaria*	**-98**
Hedge Rustic	*Tholera cespitis*	**-97**
Figure of Eight	*Diloba caeruleocephala*	**-96**
Spinach	*Eulithis mellinata*	**-96**
Dark Spinach	*Pelurga comitata*	**-96**
Heath Rustic	*Xestia agathina*	**-95**
Anomalous	*Stilbia anomala*	**-94**
Dusky-lemon Sallow	*Xanthia gilvago*	**-94**
White-line Dart	*Euxoa tritici*	**-94**
Flounced Chestnut	*Agrochola helvola*	**-94**
Brindled Ochre	*Dasypolia templi*	**-94**
Autumnal Rustic	*Eugnorisma glareosa*	**-94**
Rosy Minor	*Mesoligia literosa*	**-93**
Lackey	*Malacosoma neustria*	**-93**
Grass Rivulet	*Perizoma albulata*	**-93**
Large Nutmeg	*Apamea anceps*	**-93**
Beaded Chestnut	*Agrochola lychnidis*	**-93**
Garden Tiger	*Arctia caja*	**-92**
Haworth's Minor	*Celaena haworthii*	**-92**
Dark-barred Twin-spot Carpet	*Xanthorhoe ferrugata*	**-91**
Dot Moth	*Melanchra persicariae*	**-91**
Grey Mountain Carpet	*Entephria caesiata*	**-91**
Broom-tip	*Chesias rufata*	**-90**
Pale Eggar	*Trichiura crataegi*	**-90**
Feathered Gothic	*Tholera decimalis*	**-89**
Oak Lutestring	*Cymatophorima diluta*	**-88**
Red Carpet	*Xanthorhoe decoloraria*	**-88**
Pretty Chalk Carpet	*Melanthia procellata*	**-88**

Spinach *Eulithis mellinata* **96% decrease** R. Leverton

Pale Eggar *Trichiura crataegi* **90% decrease** P. Clement

Species		% Change over 40 years
Brindled Beauty	*Lycia hirtaria*	**-87**
Small Square-spot	*Diarsia rubi*	**-87**
September Thorn	*Ennomos erosaria*	**-87**
Sprawler	*Asteroscopus sphinx*	**-87**
Rosy Rustic	*Hydraecia micacea*	**-86**
Sallow	*Xanthia icteritia*	**-85**
Latticed Heath	*Chiasmia clathrata*	**-85**
August Thorn	*Ennomos quercinaria*	**-85**
Oblique Carpet	*Orthonama vittata*	**-85**
Mouse Moth	*Amphipyra tragopogonis*	**-85**
Broom Moth	*Melanchra pisi*	**-84**
Mottled Rustic	*Caradrina morpheus*	**-84**
Large Wainscot	*Rhizedra lutosa*	**-83**
Brown-spot Pinion	*Agrochola litura*	**-82**
Minor Shoulder-knot	*Brachylomia viminalis*	**-82**
Green-brindled Crescent	*Allophyes oxyacanthae*	**-81**
Deep-brown/Northern Deep-brown Dart agg.	*Aporophyla lutulenta/luneburgensis*	**-81**
Lead/July Belle agg.	*Scotopteryx mucronata/luridata*	**-81**
Small Autumnal Moth	*Epirrita filigrammaria*	**-81**
Grey Chi	*Antitype chi*	**-80**
Buff Arches	*Habrosyne pyritoides*	**-80**
Galium Carpet	*Epirrhoe galiata*	**-79**
Rustic	*Hoplodrina blanda*	**-78**
Oak Hook-tip	*Watsonalla binaria*	**-78**
Gothic	*Naenia typica*	**-76**
Heart and Dart	*Agrotis exclamationis*	**-76**
Neglected Rustic	*Xestia castanea*	**-76**
Knot Grass	*Acronicta rumicis*	**-75**
Black Rustic	*Aporophyla nigra*	**-75**
Garden Carpet	*Xanthorhoe fluctuata*	**-75**

Latticed Heath *Chiasmia clathrata* **85% decrease** C. Brett



Green-brindled Crescent *Allophyes oxyacanthae* **81% decrease** G. Barlow

Moths in decline

Common and widespread moths have declined considerably in Britain over the past four decades. Two-thirds (227 species) of the larger moths for which 40-year national populations trends were calculated decreased in abundance. Table 1 (p8-9) lists species with the most severe population declines.

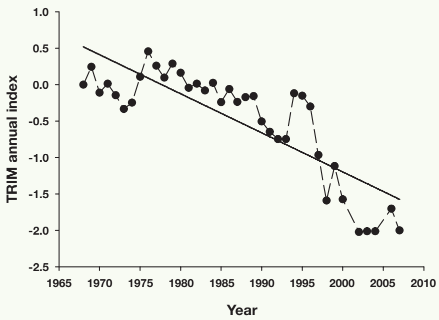
Many of the severely declining moths are still, correctly, regarded as common species and they include some of the most frequent larger moths caught in light-traps, including Small Square-spot *Diarsia rubi* (87% decrease over 40 years), Heart and Dart *Agrotis exclamationis* (76% decrease), Knot Grass *Acronicta rumicis* (75% decrease), Garden Carpet *Xanthorhoe fluctuata* (75% decrease), Lychnis *Hadena bicruris* (72% decrease) and Centre-barred Sallow *Atethmia centrago* (70% decrease).

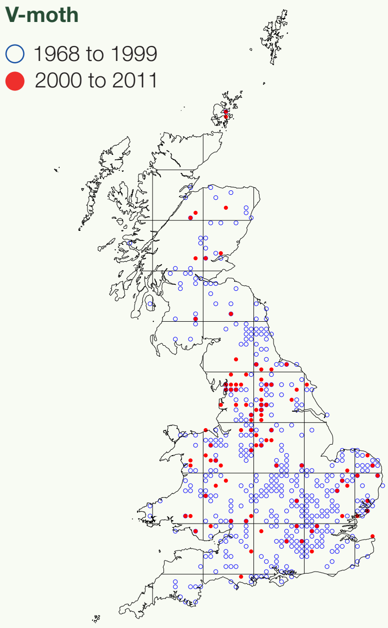
Others have rapidly become much scarcer species – moths that were once commonly encountered which today are special finds for many moth recorders, such as Garden Dart *Euxoa nigricans* (98% decrease), Spinach *Eulithis mellinata* (96% decrease) and Garden Tiger *Arctia caja* (92% decrease). Some examples of declining moths are given in further detail below.

V-moth *Macaria wauaria* shows the greatest 40-year population decline of all the 337 larger moth species that were analysed. It decreased by 99% in the Rothamsted light-trap network over the period 1968-2007. Much of this decline has taken place since 1996.

The V-moth's distribution has also declined substantially at the national scale as can be seen from the National Moth Recording Scheme map. The moth may now be extinct in several southern counties, including Bedfordshire, Devon, Hampshire and Warwickshire. The V-moth utilises currants and gooseberry as larval foodplants and its decline, therefore, might be associated with decreased cultivation of these plants and increased use of insecticides.

V-moth *Macaria wauaria* C. Manley

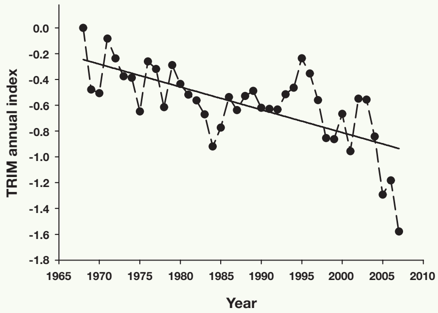


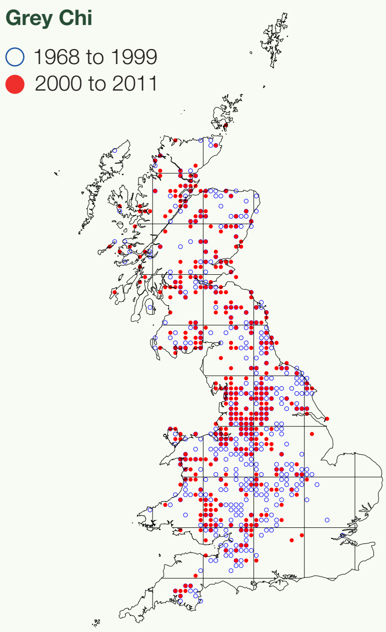


Grey Chi *Antitype chi* is a widespread northern species found commonly in a range of habitats including moorland, grassland and gardens. It has suffered an 80% decrease in population over 40 years, with particularly steep declines since 2003.

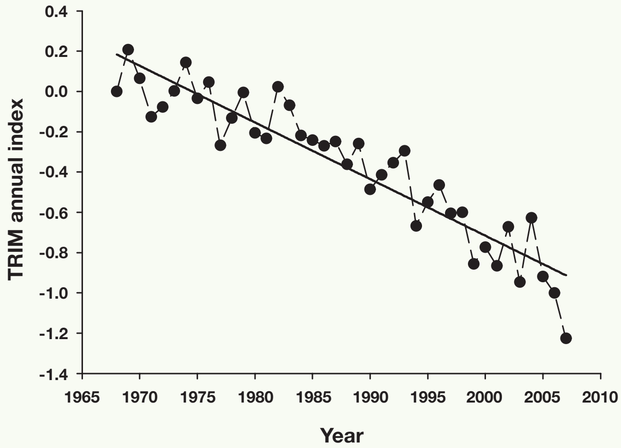
There is also an indication of distribution decline, especially at the southern edge of its range e.g. Herefordshire, Northamptonshire, Warwickshire and Worcestershire, but population declines have taken place in northern Britain as well as in the south.

Grey Chi *Antitype chi* M. Skevington

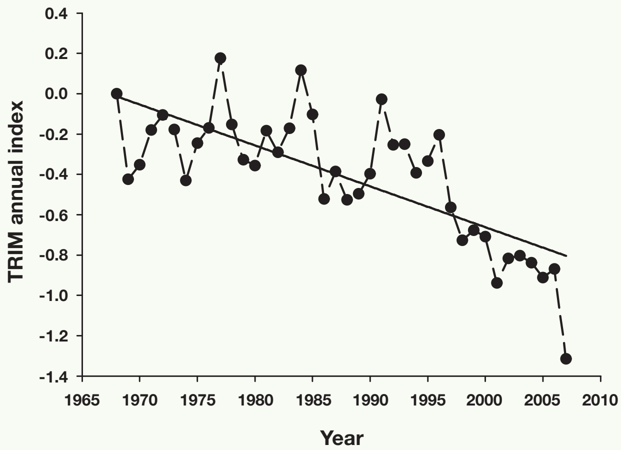




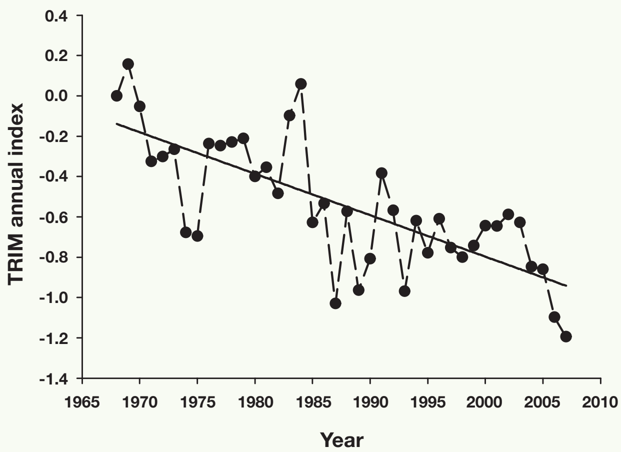
Garden Tiger *Arctia caja* **92% decrease** M. Parsons



Mouse Moth *Amphipyra tragopogonis* **85% decrease** P. Maton



August Thorn *Ennomos quercinaria* **85% decrease** R. Thompson

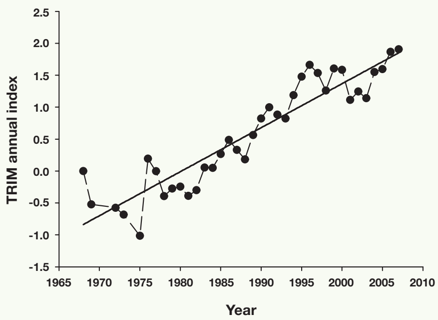


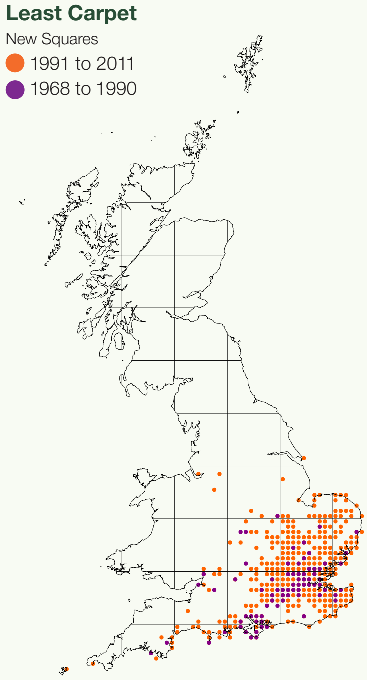
Moths on the increase

Although most of the widespread and common larger moths decreased in abundance during the 40-year study, a substantial minority (one-third of the 337 species studied) increased. Fifty-three species (16% of the total) more than doubled their population levels over the 40 years (Table 2 on p14). Many of the species that have become more abundant have also become more widespread by expanding their distributions, dramatically in some cases (see examples below).

Least Carpet *Idaea rusticata* population levels increased enormously during the 1968-2007 period, with a 40-year increase of 74,684%! The main increase in population levels appeared to occur during the 1980s and 1990s. Since the 1970s, the moth has also dramatically increased its British distribution, spreading out from the London area into East Anglia, the Midlands and south-west England.

Least Carpet *Idaea rusticata* M. Parsons

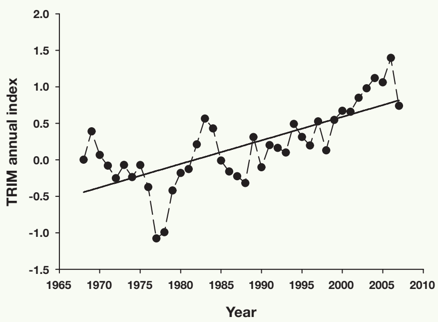


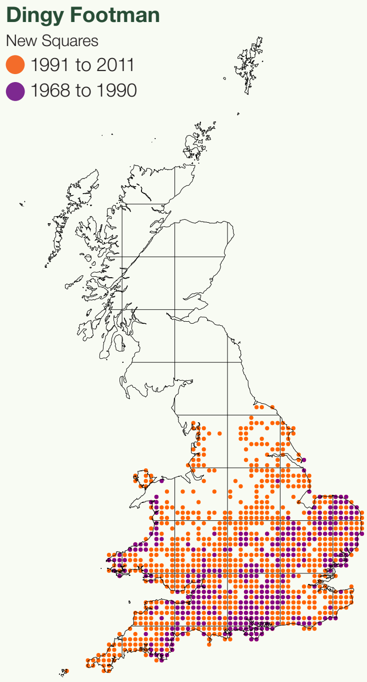


Dingy Footman *Eilema griseola* is one of a number of moths with caterpillars that feed on lichens and algae that have increased spectacularly over the 40-year period. Population levels of Dingy Footman have increased by 1,851% and its distribution has expanded markedly in southern Britain since the 1970s.

Once a restricted species typically found in fens and marshy areas, the moth is now common across a wide variety of habitats including gardens. In addition to much in-filling of its previous range, the Dingy Footman has also spread rapidly northwards, colonising much of Yorkshire and Lancashire since the year 2000.

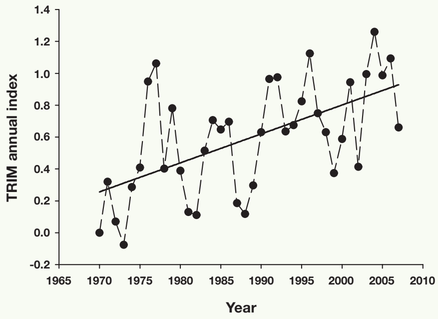
Dingy Footman *Eilema griseola* S. Taylor





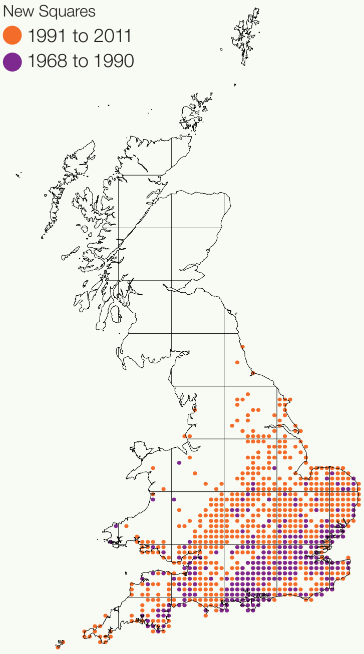
Vine's Rustic *Hoplodrina ambigua* is a resident and immigrant species found in a wide range of habitats. Its population levels have fluctuated from year to year, as expected of a migratory species, but show an increase of 433% over the 40-year period. In keeping with this increase, the resident distribution of the Vine's Rustic has expanded dramatically away from the south coast and Home Counties to occupy much of southern and eastern England. Recently the moth has started to spread into Lancashire, Yorkshire and Northumberland.


Vine's Rustic *Hoplodrina ambigua* P. Clement

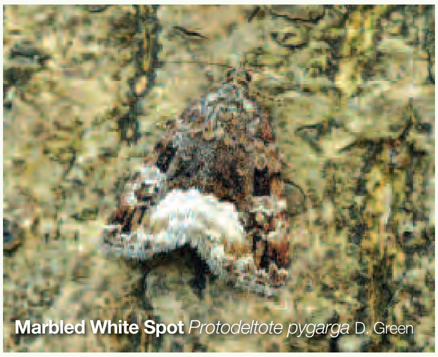


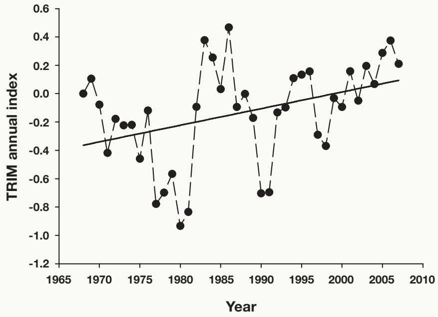
Vine's Rustic

New Squares
1991 to 2011
1968 to 1990



Marbled White Spot *Protodeltote pygarga* is a grass-feeding species found in a range of grassy habitats from woodland to moor. Its population levels have fluctuated considerably over the 40-year period, showing a decreasing trend until 1981 followed by a major recovery. Overall the population trend is a 195% increase for the period 1968-2007. The moth has also shown a substantial increase in distribution since the 1970s, colonising much of England and Wales.


Marbled White Spot *Protodeltote pygarga* D. Green



Marbled White Spot

New Squares
1991 to 2011
1968 to 1990

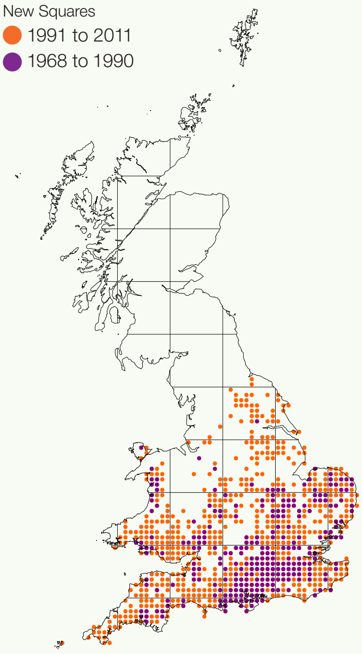


Table 2
Fifty-three species of larger moth increased by 100% or more over 40 years (1968-2007)

Species		% Change over 40 years
Least Carpet	*Idaea rusticata*	**74,684**
Blair's Shoulder-knot	*Lithophane leautieri*	**7,878**
Treble Brown Spot	*Idaea trigeminata*	**4,312**
Buff Footman	*Eilema depressa*	**3,884**
Scarce Footman	*Eilema complana*	**3,590**
Satin Beauty	*Deileptenia ribeata*	**2,928**
Peacock Moth	*Macaria notata*	**2,409**
Dingy Footman	*Eilema griseola*	**1,851**
Spruce Carpet	*Thera britannica*	**1,731**
Devon Carpet	*Lampropteryx otregiata*	**1,279**
Grey Shoulder-knot	*Lithophane ornitopus*	**1,269**
Dotted Carpet	*Alcis jubata*	**1,009**
Broad-bordered Yellow Underwing	*Noctua fimbriata*	**984**
Vestal	*Rhodometra sacraria*	**925**
Juniper Carpet	*Thera juniperata*	**836**
Red-green Carpet	*Chloroclysta siterata*	**739**
Olive	*Ipimorpha subtusa*	**698**
Plain Wave	*Idaea straminata*	**634**
Dwarf Cream Wave	*Idaea fuscovenosa*	**599**
Rosy Footman	*Miltochrista miniata*	**488**
Vine's Rustic	*Hoplodrina ambigua*	**433**
Blue-bordered Carpet	*Plemyria rubiginata*	**388**
Pine Beauty	*Panolis flammea*	**345**
Pine Carpet	*Thera firmata*	**336**
Marbled Beauty	*Cryphia domestica*	**297**
Ruby Tiger	*Phragmatobia fuliginosa*	**296**
Barred Chestnut	*Diarsia dahlii*	**288**
Brindled Green	*Dryobotodes eremita*	**287**
Pale Mottled Willow	*Paradrina clavipalpis*	**275**
Maiden's Blush	*Cyclophora punctaria*	**240**
Green Carpet	*Colostygia pectinataria*	**230**
Early Tooth-striped	*Trichopteryx carpinata*	**220**
Dingy Shell	*Euchoeca nebulata*	**214**
Common Lutestring	*Ochropacha duplaris*	**203**
Least Black Arches	*Nola confusalis*	**198**
Marbled White Spot	*Protodeltote pygarga*	**195**
Large Yellow Underwing	*Noctua pronuba*	**186**
Small Waved Umber	*Horisme vitalbata*	**167**
Black Arches	*Lymantria monacha*	**164**
Small Dusty Wave	*Idaea seriata*	**155**
Green Arches	*Anaplectoides prasina*	**154**
Orange Swift	*Hepialus sylvina*	**150**
Green Silver-lines	*Pseudoips prasinana*	**144**
Slender Brindle	*Apamea solopacina*	**137**
Lunar Underwing	*Omphaloscelis lunosa*	**137**
Yellow-barred Brindle	*Acasis viretata*	**131**
Barred Umber	*Plagodis pulveraria*	**128**
Lunar Marbled Brown	*Drymonia ruficornis*	**117**
Satellite	*Eupsilia transversa*	**116**
Muslin Footman	*Nudaria mundana*	**113**
Spectacle	*Abrostola tripartita*	**108**
V-Pug	*Chloroclystis v-ata*	**103**
Yellow Shell	*Camptogramma bilineata*	**101**

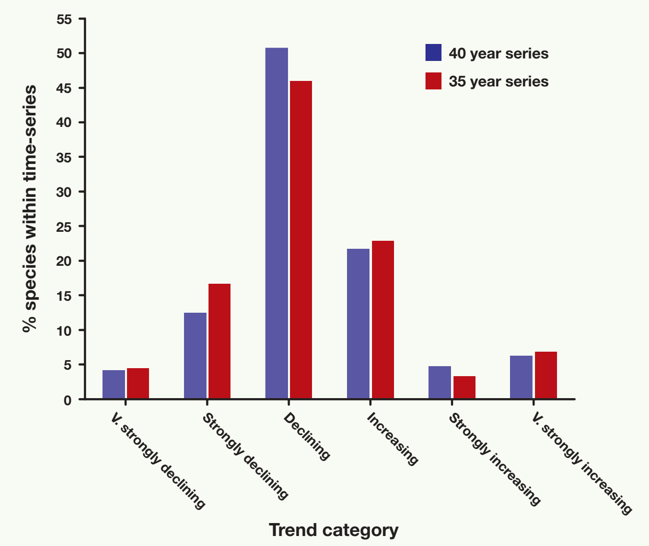
Grey Shoulder-knot *Lithophane ornitopus* **1269% increase** P. Clement
Marbled Beauty *Cryphia domestica* **297% increase** R. Wasley
Ruby Tiger *Phragmatobia fuliginosa* **296% increase** R. Thompson

Green Carpet *Colostygia pectinataria* **230% increase** R. Thompson
Orange Swift *Hepialus sylvina* **150% increase** D. Green
Yellow Shell *Camptogramma bilineata* **101% increase** R. Thompson

Comparison between 35-year and 40-year trends

Moth declines have ameliorated a little but overall patterns of change remain similar.

Figure 4 A comparison of the proportion of species in different broad categories of 10-year rates of population change between the 40-year analysis (1968-2007) (blue bars) and the 35-year analysis (1968-2002) (red bars). Categories are: Very strongly declining = >50% 10-year decrease, Strongly declining = >30% decrease, Declining = <30% decrease, Increasing = <30% increase, Strongly increasing = >30 % increase, Very strongly increasing = >50% increase.



A previous study calculated 35-year (1968-2002) national population trends for the same group of 337 larger moths and these formed the core of the first *State of Britain's Larger Moths* report published in 2006[15]. Comparing these previous trends to the new 40-year (1968-2007) trends provides some insight into the changing state of these widespread larger moths. However, it is important to realise that the percentage change figures cannot be compared directly: percentage change over 35 years for a particular species cannot be compared simply to change over 40 years. Rate of change, however, can be compared, over the same duration. For each moth species an annual rate of change was calculated for both the 35-year and the 40-year time periods, and each of these annual rates of change was then converted into a 10-year rate of change (trend). Such trends do not apply to a specific 10-year period such as 1981-1990, but are an average rate of change for any given 10-year period, which is derived from the overall rate of change estimated from the whole time period being analysed.

Following the calculation of equivalent 10-year trends for each species in the two studies, the general pattern of change can be examined. Generally, the strength of trends moderated in the 40-year analysis compared to the 35-year one, with rates of decline in particular becoming a little less pronounced. Figure 4 shows the proportion of moth species in broad categories of change for each analysis. Smaller proportions of moths were in the very strongly and strongly declining categories, and in the very strongly increasing category in the 40-year assessment compared with the 35-year study. Thus, a greater proportion of species showed lower rates of change over 40 years than over 35 years. For example, in the previous 35-year analysis, 71 species (21% of the total) had decreased strongly or very strongly, whereas in the 40-year analysis 56 species (17% of the total) were in these categories.

By comparing the average change for species in each of these broad categories between the two studies, we were able to test statistically whether these differences were significant. Figure 5 (on p17) shows the results and confirms that declining and severely declining species (those in the very strongly and strongly declining categories) fared less badly over the 40-year period than the 35-year period. This was also true for the separate southern Britain and northern Britain analyses. Indeed in each case, trends for severely declining species ameliorated by more than declining species.

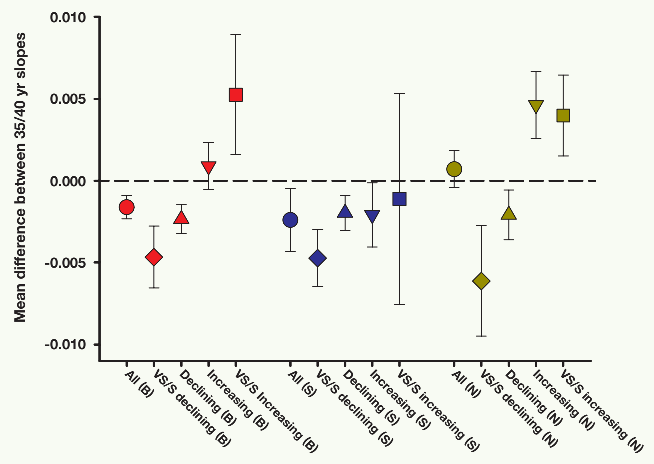
The situation is more complex for increasing species. Species in the strongly and very strongly increasing categories were increasing their numbers at slightly, but significantly, lower rates in the 40-year assessment compared with the 35-year one in Britain overall and in northern Britain, but there was no significant change for these species in the southern analysis[16]. The rest of the increasing species showed no significant difference between the two date periods in Britain overall. However, in southern Britain these species increased their numbers at significantly greater rates than in the 35-year period, while conversely, in northern Britain the same species were increasing at significantly less strong rates in the 40-year assessment.

Overall, moth trends moderated significantly over the 40-year period compared with the 35-year period in Britain. This was also the case in the separate southern analysis, but not in the north (where the change was not significant). The actual changes in these rates are comparatively small, but where they are statistically significant it is due to these differences being rather consistent across species. This suggests a trend towards rates of change (both positive and negative) becoming somewhat ameliorated with the addition of the data for the years 2003-2007 (the additional years included in the 40-year analysis). However, it should be emphasised that the effect on long-term changes, although consistent, is relatively small and most species continued to show long-term declines.

[15] Fox *et al*. 2006

[16] Analysis of variance (ANOVA) for differences in rates of population change between 35 and 40-year analyses, within species categories, for: a) Britain; all ($F = 20.25_{(1,336)}$, $P < 0.001$), very strongly/strongly declining ($F = 24.37_{(1,70)}$, $P < 0.001$), declining ($F = 28.28_{(1,154)}$, $P < 0.001$), increasing ($F = 1.49_{(1,76)}$, $P = 0.23$) and very strongly/strongly increasing ($F = 8.55_{(1,33)}$, $P < 0.01$); b) southern Britain; all ($F = 6.14_{(1,297)}$, $P < 0.05$), very strongly/strongly declining ($F = 29.60_{(1,76)}$, $P < 0.001$), declining ($F = 12.87_{(1,145)}$, $P < 0.001$), increasing ($F = 4.55_{(1,49)}$, $P < 0.05$) and very strongly/strongly increasing ($F = 0.13_{(1,23)}$, $P = 0.72$), and c) northern Britain; all ($F = 1.50_{(1,256)}$, $P = 0.22$), very strongly/strongly declining ($F = 13.28_{(1,50)}$, $P < 0.001$), declining ($F = 7.44_{(1,88)}$, $P < 0.01$), increasing ($F = 20.42_{(1,67)}$, $P < 0.001$) and very strongly/strongly increasing ($F = 10.50_{(1,48)}$, $P < 0.01$).

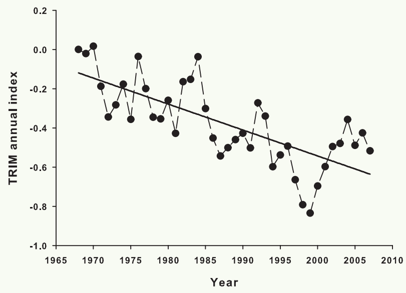
Figure 5 The mean of the differences between individual species' annual rates of change, within broad categories, in the 35-year analysis (1968-2002) and the 40-year analysis (1968-2007). Values above zero indicate a difference in the rate of change leading to lower moth abundance regardless of trend direction (i.e. a higher rate of decline or a lower rate of increase), whereas points below zero indicate a difference leading to higher abundance (i.e. lower rates of decline or higher rates of increase). Error bars show 95% confidence intervals of the mean differences: if they do not cross the dashed line at zero, the trend is significant (see footnote for test results). Red symbols show the all Britain assessment (B in the x-axis labels), blue show southern Britain (S) and green show northern Britain (N). Symbol shapes represent categories of trend as defined in Fig. 4.



The average improvement of moth trends as a result of adding an extra five years of national population data has not been reflected in all species. The graphs for some rapidly declining species, such as V-moth, Grey Chi and August Thorn (see p10-11), show that the most recent years were very poor for these moths. However, the trends for 15 species, previously categorised as strongly or very strongly declining, have ameliorated to the extent that these species are now in the declining category. These include the Cinnabar *Tyria jacobaeae*, Small Emerald *Hemistola chrysoprasaria*, White Ermine *Spilosoma lubricipeda* (see below), Buff Ermine *Spilosoma luteum*, Ghost Moth *Hepialus humuli* and Ear Moth *Amphipoea oculea*, all of which were among the most rapidly declining species in the 35-year analysis[15]. None of these moths remain in the strongly declining category in the 40-year study. However, the 40-year trends of the Cinnabar (67% decrease), Small Emerald (64% decrease), White Ermine (70% decrease), Buff Ermine (68% decrease) and Ghost Moth (62% decrease) are still worrying. In contrast, Ear Moth populations have recovered to such an extent that this species now shows little overall change during the 40-year period. Some other species that were in decline (albeit not strong decline) have improved substantially in the new analysis (see below).

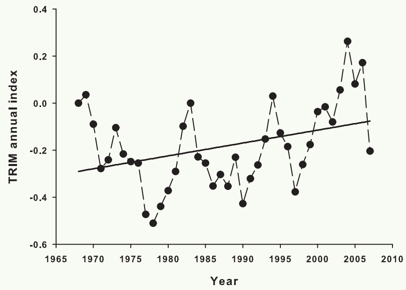
White Ermine *Spilosoma lubricipeda* populations improved considerably in the most recent years of the assessment from a low point in the late 1990s. Although numbers are still well below the peaks in the early decades of the study, this recent recovery has improved the trend for this widespread early-summer species.

White Ermine *Spilosoma lubricipeda* R. Scopes

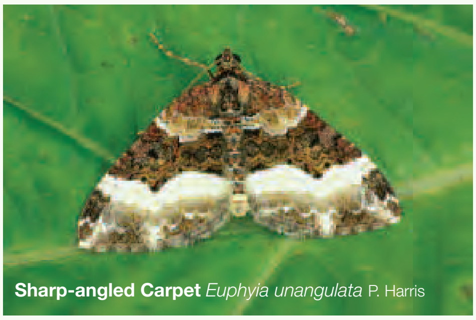


Drinker *Euthrix potatoria* was categorised as a declining species in the 35-year study, but its population increased markedly in recent years, and its overall trend is now an increase. The four best years for Drinker moth since monitoring began in 1968 occurred between 2003 and 2006.

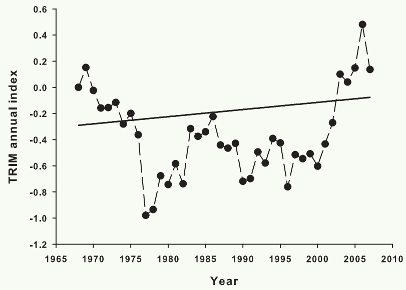
Drinker *Euthrix potatoria* R. Hatcliffe



Sharp-angled Carpet *Euphyia unangulata* has also undergone a major improvement in population levels, with high abundance in all five of the most recent years in the study. This has changed quite a steep decline over the 35-year period into a slight increase over 40 years.



Sharp-angled Carpet *Euphyia unangulata* P. Harris



Wider context

Declines in moth populations add to growing evidence that the world is undergoing substantial declines in its biodiversity.

Biodiversity loss and human wellbeing

The world is facing a biodiversity crisis with profound consequences for human wellbeing. The decline and extinction of species is occurring at a rapid rate[17], described by some scientists as the sixth mass extinction event to occur during the earth's history[18] (the previous one put paid to the dinosaurs some 65 million years ago). There is little indication that the rate of biodiversity loss is slowing, despite high-profile political promises[19].

Humans are not passive bystanders in this process. All of the principal causes of current biodiversity loss are directly related to human activity[20] and this loss threatens natural processes upon which the human race depends[21]. They include 'ecosystem services' such as pollination, nutrient cycling and the provision of clean water[22]. To put it simply, we cannot live without biodiversity.

Wider moth declines

The significant declines of larger moths in Britain, revealed by studies of the Rothamsted light-trap network data, provided the first evidence of national-scale population trends in this species-rich insect group[23]. However, similar patterns of decline among moths have also now been reported from other European countries. In the Netherlands, for example, 71% of 733 larger moth species decreased in abundance and the total abundance of moths decreased by one-third over the period 1980-2009[24]; strikingly similar results to the British findings. In Finland, analysis of long-term distribution records showed significant overall decreases in the distribution of larger moths in the families Geometridae and Noctuidae (590 species in total)[25]. Preliminary analysis of the new National Moth Recording Scheme dataset in the UK also indicated severe contractions in the distributions of some larger moths[26].

Taken together, these studies provide overwhelming evidence of moth declines on a large geographical scale and mirror previous studies of butterflies. Such losses are likely to have substantial impacts on other organisms, because of the importance of moths as herbivores, pollinators and prey items[27] and, therefore, affect the delivery of some ecosystem services.

Wheatear eating an Emperor moth *Saturnia pavonia* S. Batt

Declines of other insects

Although insects make up the majority of global animal biodiversity, little is known about their trends[28]. Thankfully, this is starting to change, at least for a few well-studied insect groups in developed countries. Assessments have been carried out initially for butterflies[29], but now also for some bees[30], beetles[31] and, of course, larger moths.

The results are unequivocal: insect biodiversity is declining rapidly and, in many cases, it is specialist species that are being lost, while a relatively small number of generalist species come to dominate once-diverse wildlife communities.

[17] Thomas *et al*. 2004a, May 2010
[18] Barnosky *et al*. 2011
[19] Butchart *et al*. 2010
[20] UK National Ecosystem Assessment 2011
[21] Chapin *et al*. 2000, Balmford & Bond 2005, Rockström *et al*. 2009, UK National Ecosystem Assessment 2011
[22] Cardinale *et al*. 2006, Isbell *et al*. 2011
[23] Conrad *et al*. 2006
[24] Groenendijk & Ellis 2011
[25] Mattila *et al*. 2006, 2008
[26] Fox *et al*. 2011a
[27] see refs. in Young 2002, Fox *et al*. 2006, Devoto *et al*. 2011
[28] Dunn 2005, Thomas 2005
[29] Warren *et al*. 2001, van Swaay *et al*. 2006, Van Dyck *et al*. 2009, Fox *et al*. 2011b
[30] Biesmeijer *et al*. 2006, Goulson *et al*. 2008, Cameron *et al*. 2011
[31] Kotze & O'Hara 2003, Brooks *et al*. 2012

Causes of change for Britain's larger moths

There are a number of possible causes for the observed changes in moth biodiversity; principally degradation of habitat quality and climate change. However, more research is needed to adequately explain changes in Britain's larger moth fauna.

Understanding of the major factors that are driving the changes revealed in this report remains limited. There is little direct evidence linking moth population (or distribution) trends to particular drivers of change. However, information continues to accumulate, and gradually a clearer understanding of the complex situation is starting to emerge. A comprehensive review of the evidence has recently been published[32], and the main potential causes of change are summarised here.

Habitat change

Habitat loss (including degradation of habitat quality and the effects of fragmentation) is a major cause of biodiversity loss in Britain and worldwide. It would be extraordinary if widespread larger moths had not been affected by the massive habitat changes in the British countryside brought about by agricultural intensification, changing woodland management and urbanisation over the past 40 years.

Several studies have shown higher abundance and species richness of moths associated with lower intensity farming practices implemented as part of organic conversion, agri-environment schemes or experimental treatments[33]. In particular, moths benefit from the presence of field margins and boundary features, including mature trees[34]. Conversely, we might assume that the general intensification of agricultural management that has taken place since the 1950s, which has included widespread loss of hedgerows, boundary trees and botanically-rich field margins, as well as the intensive use of pesticides, will have impacted negatively on moths.

In broad-leaved woodland, changing management over recent decades has led to greatly reduced open space within woods and increased shade. The subsequent changes in plant communities, micro-climates and vegetation structure appear to have been detrimental to a wide range of woodland wildlife including birds, butterflies and plants. Some woodland specialist moths may have benefitted from these changes in management, but many generalist species or moths that require open conditions in woods are likely to have declined[35]. Past and future threats to native tree species, such as Dutch Elm Disease, Ash Dieback Disease and Sudden Oak Death, may have substantial impacts on associated moths.

Pine Beauty *Panolis flammea* **345% increase** P. Withers

In contrast, the widespread planting of coniferous trees for commercial forestry and as ornamentals has provided a greatly increased habitat resource for larger moths with caterpillars that feed on these trees. Blair's Shoulder-knot *Lithophane leautieri* (7878% population increase over 40 years), Satin Beauty *Deileptenia ribeata* (2928% increase), Spruce Carpet *Thera britannica* (1731% increase), Juniper Carpet *T. juniperata* (836% increase), Pine Beauty *Panolis flammea* (345% increase) and Pine Carpet *T. firmata* (336% increase) will all have benefitted from increased planting of native and non-native conifers.

Nutrient enrichment

The fertility of soil and water is increasing (eutrophication) as a result of nutrients released into the environment (e.g. by agriculture, vehicle emissions). The impacts are pervasive and substantial, altering plant communities and vegetation structure, and generally have a detrimental effect on biodiversity[36]. Moths associated with low nutrient habitats and larval foodplants that are unable to compete in high fertility conditions are likely to have declined, but this remains to be proven.

[32] Fox 2012
[33] Wickramasinghe *et al*. 2004, Littlewood 2008, Taylor & Morecroft 2009, Fuentes-Montemayor *et al*. 2011, Merckx *et al*. 2012a
[34] Pocock & Jennings 2008, Merckx *et al*. 2009, Merckx *et al*. 2012a
[35] Broome *et al*. 2011, Clarke *et al*. 2011, Merckx *et al*. 2012b
[36] Bobbink *et al*. 1998, Stevens *et al*. 2004, UK Ecosystem Assessment 2011

Climate change

Climate change is causing numerous changes in the geographical range, abundance, phenology, ecology and interactions of species[37] and is widely perceived as a significant and increasing risk to global biodiversity[38]. Evidence of moth responses to climate change include uphill shifts[39], changes in voltinism and phenology[40], potential disruption of food chains[41] and increasing immigration[42].

In Britain, evidence of the impact of climate change on moth populations and distributions is emerging. There are numerous examples of larger moths that are expanding their distributions northwards, for which climate change is the most likely or only plausible explanation[43] (e.g. Fig. 6). Some of these species also have increasing 40-year population trends, including Least Carpet and Marbled White Spot (see p12-13), Shuttle-shaped Dart *Agrotis puta* (see below), Red-green Carpet *Chloroclysta siterata*, Black Arches *Lymantria monacha* and Yellow-barred Brindle *Acasis viretata*.

Meanwhile other species may be declining in response to changing climatic patterns. The Garden Tiger is the best studied example, with population levels negatively correlated with higher winter rainfall and spring temperature[44], but other studies have found population declines among moths with northerly distributions[45].

Climate change is also affecting the timing and, indeed, number of moth generations during the year for some species especially in northern parts of Britain. In Yorkshire, species such as Green Carpet *Colostygia pectinataria*, Flame Shoulder *Ochropleura plecta*, Setaceous Hebrew Character *Xestia c-nigrum*, Common Wainscot *Mythimna pallens*, Straw Dot *Rivula sericealis* and Snout *Hypena proboscidalis* have all become regularly double brooded in recent decades[46].

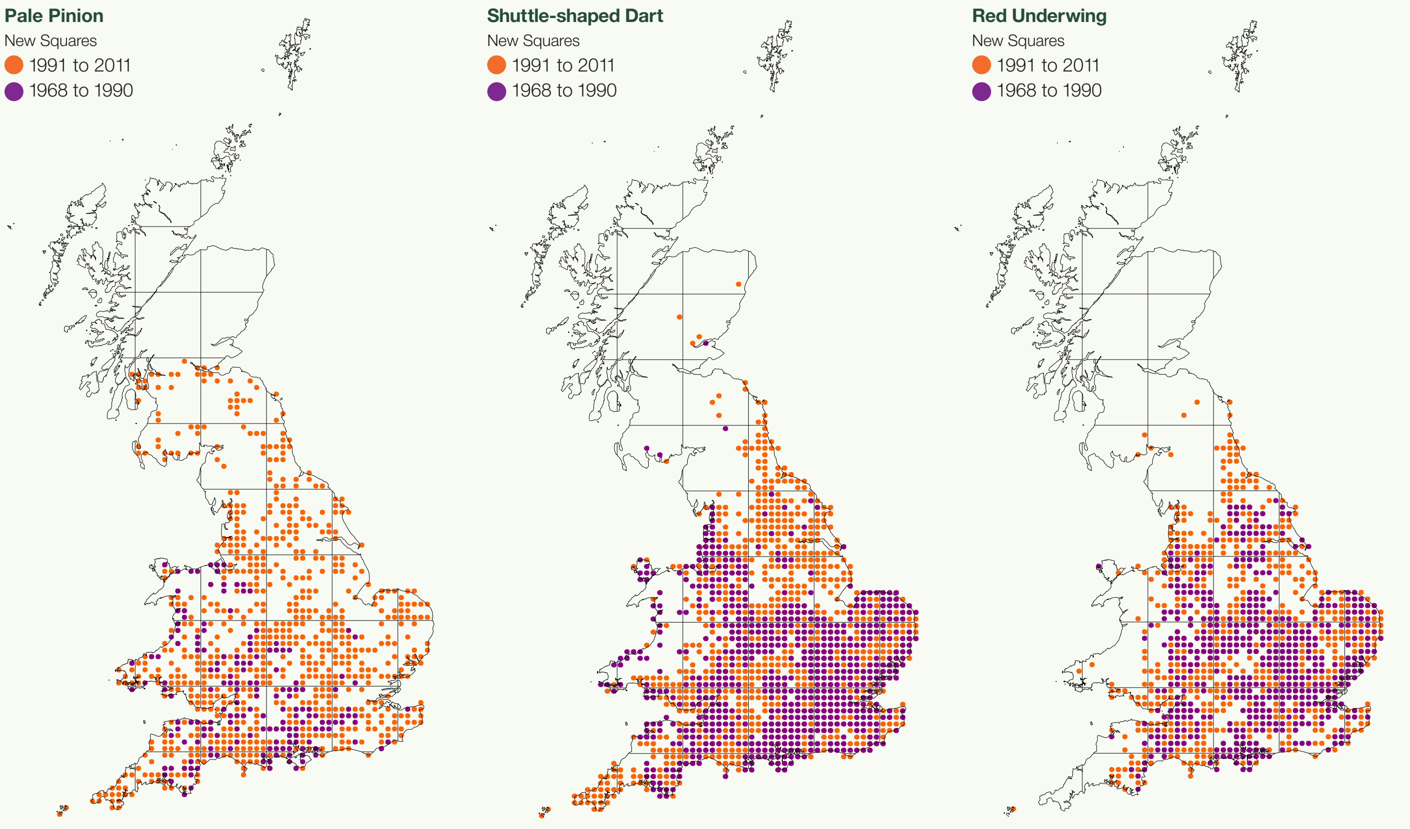
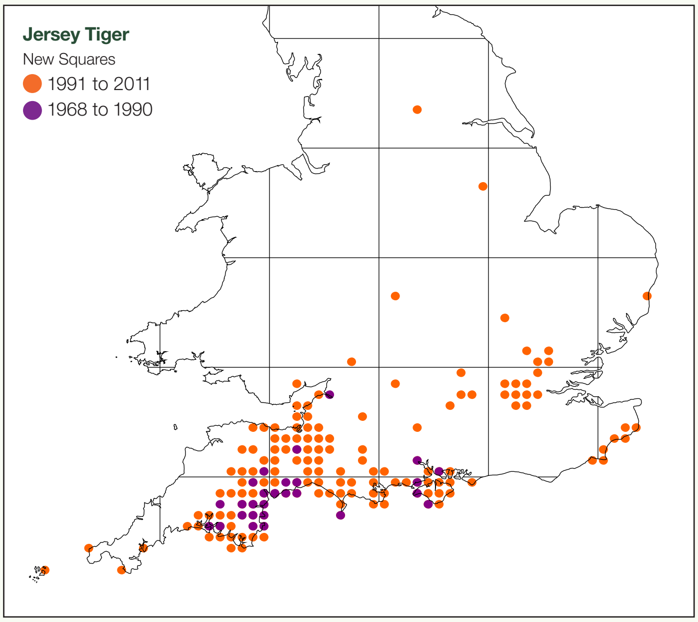


Figure 6 The distributions of Pale Pinion *Lithophane hepatica*, Shuttle-shaped Dart *Agrotis puta* and Red Underwing *Catocala nupta* have increased northwards substantially, probably as a result of climate change.

[37] Walther *et al*. 2002, Root *et al*. 2003, Hickling *et al*. 2006, Parmesan 2006, Chen *et al*. 2011
[38] Thomas *et al*. 2004b, Thuiller *et al*. 2005, Maclean & Wilson 2011
[39] Chen *et al*. 2009, Dieker *et al*. 2011
[40] Altermatt 2010, Pöyry *et al*. 2011
[41] Both *et al*. 2009
[42] Sparks *et al*. 2005
[43] Fox *et al*. 2011a
[44] Conrad *et al*. 2002
[45] Conrad *et al*. 2004, Morecroft *et al*. 2009
[46] Fletcher 2006

Jersey Tiger *Euplagia quadripunctaria* L. Sebastiani



Jersey Tiger *Euplagia quadripunctaria* spread rapidly in Britain over the past two decades. It originally became established in south Devon c.1880 and this situation persisted with little change for a century, although occasional immigrant individuals occurred along the south coast of England. However, in the 1990s the moth started to spread westwards and northwards within Devon and into Dorset. This accelerated during the 2000s, with further spread across Dorset and establishment in Somerset. Elsewhere, Jersey Tiger became firmly established on the Isle of Wight in the 1990s, and formed a small colony in east Sussex.

After the millennium, the moth became established in Kent, first on the coast and later in north Kent and south London. Just in the last few years, Jersey Tiger has spread very rapidly in south London, from the leafy Kent and Surrey suburbs right through the inner city to start appearing in north London and beyond (first Hertfordshire record in 2012).

Although some introductions of this species have taken place, the overall spread of this moth in Britain seems most likely to be driven by climate change.

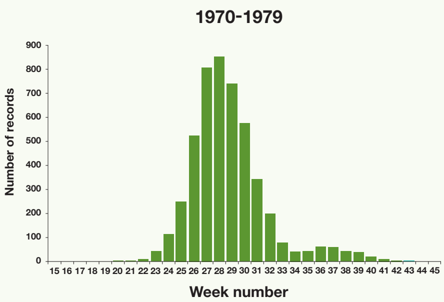
There are many ways in which changing climate could influence the population levels or distributions of larger moths. Some are obvious, for example if mortality is directly related to climatic conditions (e.g. cold temperatures) or if a certain threshold of warmth is needed over a certain duration of time in order to complete larval development. Others may be much more complex, such as mismatches in timing between moths and their larval foodplants as a result of differing rates of phenological change[47] or longer growing seasons for plants leading to changes in vegetation structure and micro-climates[48].

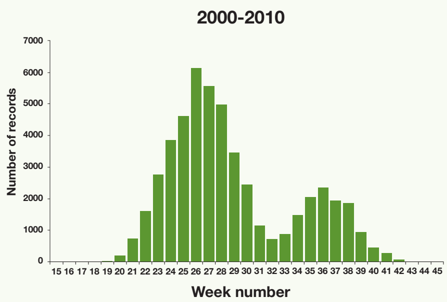
For many widespread larger moths, the warming climate should improve conditions in Britain leading to longer flight periods, additional generations (see box on p22), and an increase in the extent of the landscape that is suitable for habitation, leading to increased distribution and population sizes. However, climate change also brings much uncertainty and concerns for moths that occur at high altitude or latitude and those that occur on low-lying coastal habitats such as salt marshes and fens. In addition, climate change may make Britain more hospitable to moths that are pests in agriculture or forestry.

[47] van Asch & Visser 2007
[48] WallisDeVries & van Swaay 2006


Light Emerald *Campaea margaritata* D. Green

Light Emerald *Campaea margaritata* has become much more strongly double brooded over recent decades, presumably in response to climate change. Data from the National Moth Recording Scheme show that almost all Light Emerald sightings in the 1970s were during a single main flight period from the beginning of June until mid-August, with only a small proportion of later, second generation individuals. This has changed substantially, with a prominent second generation now recorded from mid-August through to early October, as well as a slightly earlier emergence and peak of the first generation.





Light pollution

Light pollution has long been recognised as a potential problem for moths and other wildlife[49]. It can alter moths' behaviour, life cycles and predation rates, as well as, in some cases, killing moths directly through contact with hot bulbs or glass. However, there are no studies that have measured the impact of outdoor lighting on moth populations and communities. Thus we do not know whether the massive increase in background light levels in Britain has made any contribution to the trends reported here. Hopefully, this situation will change in the near future as there is increasing interest in and concern about the impact of light pollution on biodiversity. For example, recent work has shown effects of street lighting on the numbers and types of ground-dwelling invertebrates in Britain[50], the first time that light has been shown to affect wildlife communities.


L. Nilsson

[49] Bruce-White & Shardlow 2011
[50] Davies *et al*. 2012

Moth conservation

Over the past 15 years, action to conserve moths in Britain has increased substantially. Spearheaded by Butterfly Conservation's Action for Threatened Moths project, but involving numerous organisations, local groups and individuals, dozens of projects have been undertaken to improve knowledge, habitat and land management to benefit Britain's most endangered larger moths[51].

At the beginning of this century there were 53 moths listed as Priority Species in the UK Biodiversity Action Plan (BAP), all but one of which were larger moths. When the UK BAP was revised in 2007, this number rose to 81 (of which 25 were micro-moths) and, in addition, 71 widespread but rapidly declining larger moths were added[52]. This latter group were species identified from the 35-year population trends assessed in the first State of Britain's Larger Moths report[53] and were included in the UK BAP as "research only" with the aim of stimulating research into the causes of decline among common moths.

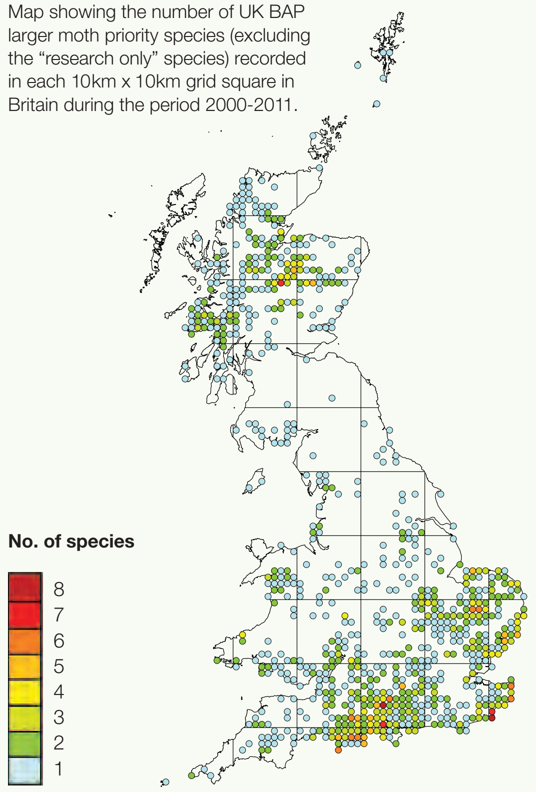
The inclusion of so many moths in the UK BAP had enormous benefits for moth conservation, raising awareness of threatened species, stimulating habitat management and generating funding from government for surveys, monitoring, ecological studies and direct conservation action. Many other non-target wildlife species have also benefitted.

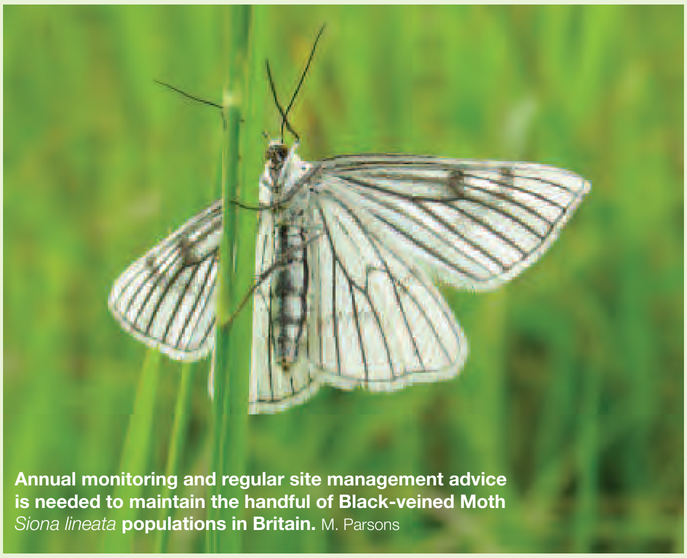
Progress has been made for 69 threatened moth species, ranging from improved distribution information through to active programmes of habitat creation and management, species reintroductions and advice to landowners[51]. Highly targeted grant schemes, such as higher-level agri-environment schemes and woodland grants, and land-fill tax projects have benefitted many UK BAP moths.

Sadly, the UK BAP has now been replaced with a government focus on ecosystem services and funding for targeted species conservation has been reduced. Nevertheless, vital work to conserve individual threatened species continues. In England, 142 moth species (all of those previously included in the UK BAP) are listed as Species of Principal Importance in England under Section 41 of the Natural Environment and Rural Communities Act. In addition, 97 moths are listed on the equivalent list in Wales (Section 42 list) and 29 species are included in the Scottish Biodiversity List.

Some notable examples of conservation action for threatened moths are given on p25.

Map showing the number of UK BAP larger moth priority species (excluding the "research only" species) recorded in each 10km x 10km grid square in Britain during the period 2000-2011.





Annual monitoring and regular site management advice is needed to maintain the handful of Black-veined Moth *Siona lineata* **populations in Britain.** M. Parsons

[51] Parsons *et al*. 2011
[52] Parsons & Davis 2007
[53] Fox *et al*. 2006

Landscape-scale conservation

Over the past decade, conservationists have realised that many threatened species are best conserved by landscape-scale projects (see box right). This approach aims to co-ordinate habitat management and restoration across many sites in the local landscape, rather than treating each in isolation. This improves the chances of species' survival in the long term by increasing the amount of suitable habitat in the landscape, maximising both the size and number of colonies[54] and by allowing the natural processes of colonisation and extinction to occur at individual sites.

Landscape-scale conservation also brings other benefits including improvements in the cost efficiency and logistics of habitat management, employment, partnerships between organisations from statutory, private and non-governmental sectors, and far greater involvement of local communities.

Targeted conservation of rare species

While landscape-scale conservation is a good approach for many species and biodiversity as a whole, rare species still need targeted conservation on specific sites if they are to survive. Many, such as the Reddish Buff *Acosmetia caliginosa*, Marsh Moth *Athetis pallustris*, New Forest Burnet *Zygaena viciae* and Sussex Emerald *Thalera fimbrialis*, are reduced to one or a few isolated sites that need to be protected and managed appropriately.

Moth conservation in the wider countryside

While site-based and landscape-scale conservation projects provide the focus for ongoing efforts to prevent the extinction of threatened moths, the rapid declines of widespread (and in some cases still common) larger moths described in this report necessitate the restoration of habitats and adoption of less environmentally-damaging activities on a massive scale.

Mass-participation 'entry level' agri-environment schemes, for example, could deliver significant improvements, but only if such schemes are evidence-based, properly resourced, targeted and monitored. To date, such schemes appear to have had little measurable benefit for moths or other wildlife, despite large investment of public money[55]. In particular, there is a vital need to ensure that habitats created or managed under such government grants are capable of providing sufficient breeding habitat and other important resources to enable local moth populations to increase. This will require new research to understand the effects of different management options on moth populations.

Heavy machinery creating Breckland plots S. Hearle

Breckland plot with Viper's Bugloss S. Hearle

The first ever landscape-scale conservation project focussing on moths started in the Breckland of East Anglia in 2008. Butterfly Conservation led a partnership of organisations and volunteers to recreate the traditional disturbed ground habitats of Breckland, which are vital to the survival of many scarce wildlife species including threatened moths such as the Grey Carpet *Lithostege griseata*, Basil Thyme Case-bearer *Coleophora tricolor*, Lunar Yellow Underwing *Noctua orbona*, Marbled Clover *Heliothis viriplaca* and Forester *Adscita statices*.

Fifty-nine large strips of bare ground were created, trialling a variety of techniques from rotovation to turf stripping. Follow-up surveys showed a rapid and highly successful colonisation of the bare ground plots by plants and target moths. During three years of surveys, target moths were recorded on over 50% of the plots, with Grey Carpet and Lunar Yellow Underwing larvae found on 13% and 27% of all plots respectively[56].

[54] Hodgson *et al*. 2011
[55] Kleijn *et al*. 2011
[56] Ellis *et al*. 2012

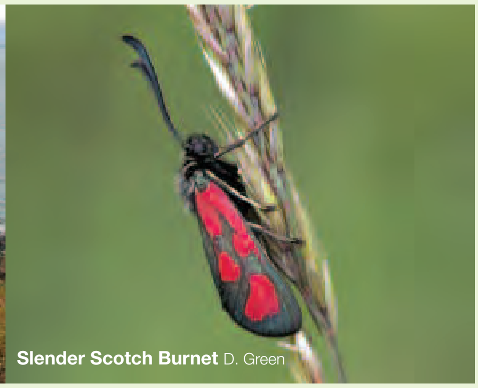
Netted Carpet G. Jones

Cattle grazing for Netted Carpet G. Jones

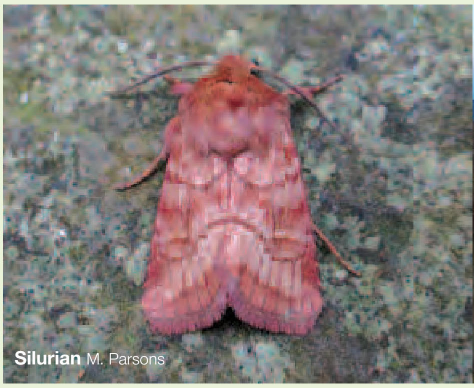
Netted Carpet *Eustroma reticulatum* has benefitted greatly from the reintroduction of winter cattle grazing by the National Trust and other landowners in the Lake District woodlands where it survives. The ground disturbance caused by the livestock promotes germination of Touch-me-not Balsam, the Netted Carpet's only larval foodplant.

One of the colonies of the very rare **Slender Scotch Burnet** *Zygaena loti*, which only occurs in Britain on the island of Mull, is threatened by the invasive alien plant Cotoneaster. Control of the plant by volunteers and specialist climbers has proved beneficial as the moth was rediscovered in 2012, the first sighting for three years.

Cotoneaster control T. Prescott



Slender Scotch Burnet D. Green



Silurian M. Parsons

Silurian survey C. Williams/Brecon Beacons National Park

For decades the **Silurian** *Eriopygodes imbecilla* was known from only one small area of hills in south-east Wales. Recent surveys in extremely challenging terrain have revealed the presence of a separate population in the Black Mountains on both Welsh and English sides of the border.

Fisher's Estuarine Moth *Gortyna borelii* is rare and threatened by tidal inundation at its few sites on the coast of Essex and Kent. A major conservation programme has successfully established new inland colonies by planting the larval foodplant, Hog's Fennel, and then introducing the moth.

Habitat creation A. Roscoe

Fisher's Estuarine Moth M. Andrews

Conclusions

The new 40-year national population trends and other results presented here provide overwhelming evidence of moth declines. This reinforces previous findings for British moths[57] and mirrors declines recorded in other wildlife groups.

With over 2,500 species recorded, moths comprise a substantial part of Britain's biodiversity and play important roles in food chains. Although a species-rich group, there is considerable public and scientific interest in moths and moth recording. The Rothamsted Insect Survey and National Moth Recording Scheme provide long time-series of data collected by thousands of volunteer naturalists. Through these world-class schemes, reliable population and distribution information can be assessed for hundreds of larger moths. This is important as most assessments of insect biodiversity loss rely heavily on a few charismatic but species-poor groups, such as butterflies and bumblebees, which may be less representative of other insects.

The substantial decline of Britain's larger moths is one of the clearest signals yet of potentially catastrophic biodiversity loss caused by human impacts on the environment, which is of great conservation concern and potentially threatens some of the ecosystem services upon which the human race depends.

It is tempting to focus on the minority of moth species that are faring well, spreading northwards, increasing in abundance or arriving more frequently as immigrants. However, this would be to ignore the bigger picture; there are significantly fewer individual moths in Britain now than 40 years ago and, while many rapidly declining moths are still regularly recorded in back gardens and other habitats across the country, their populations are a shadow of their former selves. Like the House Sparrow, Hedgehog and Small Tortoiseshell butterfly, moths that were once taken for granted, such as V-moth and Garden Tiger, are now unusual sightings in many people's gardens.

The future for Britain's moths is uncertain. Conservation efforts targeted at threatened species have yielded positive results, but more is needed. Funding cuts and shifting government policy (away from the species-focussed UK BAP approach) threaten this hard-fought progress. Likewise, for more widespread species, the optimism that 'entry level' agri-environment schemes would see the restoration of wildlife-friendly habitats on a massive scale across the landscape has melted away. The need remains, but tax-payers' money needs to be spent more judiciously on management options with proven benefits for wildlife and the environment.

Archer's Dart *Agrotis vestigialis* **68% decrease** C. Manley

Pink-barred Sallow *Xanthia togata* **58% decrease** R. Thompson

What is certain is that change will continue. Moth populations are naturally dynamic, responding to short-term weather and long-term climate variation, as well as other environmental factors. Over time species have waxed and waned, new ones continue to arrive and some will inevitably be lost. However, we are witnessing a period of increased change, driven largely by human activity, with increasing numbers of new arrivals and significant declines in many of our native species. It is vital that increased conservation effort is undertaken to ensure the net effect of this change is positive rather than negative.

[57] Fox *et al*. 2006

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