Butterfly Conservation

# the state of britain's larger moths

**the Early Thorn** *Selenia dentaria*
**declined by 60% over the period 1968 - 2002**

ROTHAMSTED RESEARCH

**Broad-bordered Bee Hawkmoth** *Hemaris fuciformis* R.Thompson

# Foreword

We hear a lot about the threats to conspicuous and charismatic animals such as birds and mammals, but far less about the insects that make up over half of all the species known to science and which play a vital role in the functioning of the world's ecosystems. This new report helps to fill this gap by compiling, for the first time, important new information on a large and diverse group of insects in Britain; the larger moths.

The results are significant and worrying. A large number of species are in rapid decline, including many once-common species such as the Garden Tiger moth with their characteristic Woolly Bear caterpillars. I, like many others, have observed that common animals and plants, the fabric of our natural heritage, are less abundant now than in our youth; this report provides clear evidence this is true for hundreds of different moths. Although the precise causes of these losses still need to be uncovered, the findings set more alarm bells ringing about the extent of human impact on our environment. Moths are important in food chains and their declines may have significant knock-on effects on many animals, such as birds, bats and invertebrates. However, moths are more than just food for other animals, they are also valuable indicators of the changes affecting thousands of other common insects and the health of our countryside. Moreover, they are fascinating organisms to study and worthy of conservation in their own right.

I commend this report to you and hope that it spurs a concerted action to save moths, not just for themselves, but also for the many species that depend on them or share their habitats, including ourselves.

**Sir David Attenborough**
President of Butterfly Conservation

## Executive summary

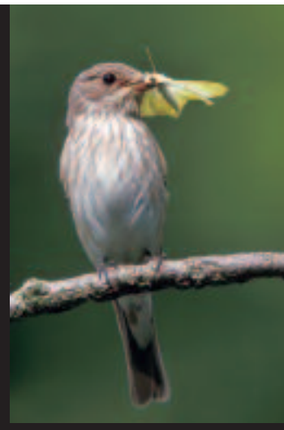
- **Moths are important.**
  They make up a significant part of our biodiversity (c. 2500 species in Britain), occur in large numbers, and many other organisms, such as birds, bats and many invertebrates depend upon them for food.
- **Moths are part of our natural heritage.**
  They have been studied for over 300 years in Britain and the group is well known. There are many thousands of amateur recorders and interest in moths is growing rapidly.
- **Moths are threatened.**
  62 moth species became extinct in Britain during the twentieth century and many more species are considered now to be nationally threatened or scarce.
- The UK Biodiversity Action Plan (BAP) lists 53 moths as national priority species for conservation. Survey work, ecological research and habitat management over the past few years has benefited at least 27 of these priority moths. However, eight species are considered to be in a worse position now than at the beginning of the BAP process a decade ago.
- Further work and far more resources are required to fully implement the existing action plans for priority moths. Additionally, many threatened and scarce species are now known to meet the criteria for inclusion in the UK BAP and, therefore, the number of priority moths may increase after the 2006 review. This needs to be accompanied by a parallel increase in resources if the success of the UK BAP process is to be maintained.

- **Moths are monitored.**
  Since 1968, the Rothamsted network of light traps has been recording numbers of larger moths caught every night from hundreds of locations across Britain. This provides one of the longest-running and geographically extensive data sets on insect populations anywhere in the world. Analysis of this data set, carried out by Rothamsted Research and Butterfly Conservation, has generated national population trends for hundreds of common moths for the first time.
- **Common moths are declining.**
  The total number of moths recorded in Rothamsted trap samples has declined by a third since 1968. Population trends were generated for 337 moth species. Two thirds (226 species) show a decreasing population trend over the 35 year study. Such widespread declines are likely to be having detrimental knock-on effects on other organisms.
- The decline of so many common moths, along with known declines of butterflies and other wildlife, demonstrate a widespread and severe crisis for Britain's natural heritage.
- Moreover, application of international (IUCN) criteria shows that 71 species (21%) of these 'common' moths are threatened: 15 are classified as Endangered and 56 as Vulnerable. None of these moths have been listed as Red Data Book species before in Britain and none were thought previously to warrant any conservation priority in the UK BAP.

**Mocha** *Cyclophora annularia* P.Pugh

Moths always create interest for all ages at public events J.Stoneman

**Scarce Merveille du Jour** *Moma alpium* R.Thompson



**Spotted Flycatcher** with prey R.Revels

- Although the majority of population trends for larger moths from the Rothamsted network are negative, some species have done spectacularly well over recent decades. 46 species have more than doubled their population levels (i.e. increased by at least 100%) and a further 23 species have increased by more than 50% over the 35 year period.
- More species have declined in southern Britain (75%) than in northern Britain (55%). South-east Britain has been particularly badly affected.
- Some significant correlations exist between population trends and ecological characteristics. Moths whose caterpillars feed on lichens/algae and conifers have done well, as have species that fly during the winter months.

- **Implications.**
  Changes in the extent and quality of suitable habitat are amongst the prime suspects driving the declines of many once common moths, with pesticide use, eutrophication and light pollution perhaps contributing in some or many cases. Climate change also seems to be affecting moth distribution, abundance and phenology and has been implicated in the only case of moth population decline that has been investigated in detail thus far (the Garden Tiger *Arctia caja*).
- The perilous position of so many moths shows that action is needed urgently to conserve them at a landscape scale and within new farming and forestry schemes.
- Our results show that it is important for government agencies to continue to invest in long-term recording and monitoring schemes, such as the Rothamsted light-trap network. The development of a comprehensive national recording scheme covering all larger moths is vital to assess trends and implement effective conservation across this important group of insects.

# Introduction

This report presents an overview of the status of moths in Britain, drawing on important new research carried out by Rothamsted Research and Butterfly Conservation, as well as many other sources, including the ongoing work on conservation priorities under the UK Biodiversity Action Plan (BAP). With this information, and widespread recording at the county level, Britain probably has the best-studied moth fauna in the world.

**The significance of moths**

Moths are important. They represent one of the largest insect groups both in Britain and globally, and thus make up a significant part of our biodiversity. About 2500 species have been recorded in Britain so far, making moths over 30 times more diverse than butterflies and five times more diverse than birds. Moths are traditionally divided into larger (or macro) moths and smaller (or micro) moths, although this separation was born of convenience rather than scientific rationale. There are approximately 900 species of larger moth in Britain, and these are the main focus of this review.

Moths are found in almost all habitats, from the shoreline to the mountain top, and occupy a wide variety of niches. In addition to feeding on the leaves, stems, flowers and seeds of terrestrial plants, there are British moths whose caterpillars feed on roots and wood, as well as on aquatic plants, lichens and algae, honeycomb, fungi, dung, fur and feathers, and even other caterpillars. Moths' reputation for eating clothes and other textiles is greatly overstated. There are very few species amongst all this diversity that can cause such damage, and most of these are now very scarce.

Moths are an important element of many ecosystems. Many other organisms depend upon moths either for pollination[1] or for food. Moths and their caterpillars are an important component of the diets of many birds. A few birds catch moths on the wing, such as the Hobby, Little Owl, Nightjar and Spotted Flycatcher, but many collect moth caterpillars to eat or feed to their young. Examples include almost all the familiar garden species such as Blue Tit and Great Tit, House Sparrow, Wren, Robin, Blackbird and Starling, as well as many birds that have undergone severe declines, such as Grey Partridge, Stone Curlew, Bullfinch and Corn Bunting[2].

All 16 British species of bat (including three UK BAP Priority Species) feed on moths to some extent, and moths make up a substantial part of the diet for Greater and Lesser Horseshoe Bats, Brandt's, Bechstein's and Leisler's Bats, Noctule, Serotine and Barbastelle Bats, and Grey and Brown Long-eared Bats[3]. Many other small mammals, including hedgehogs, wood mice and shrews, eat moth caterpillars and pupae.

Moths and their immature stages are preyed upon by many other invertebrates and are unwilling hosts to numerous species of wasp and fly parasitoids, fungi, bacteria and viruses.

**Blue Tit chicks alone are estimated to eat 150,000,000,000,000 caterpillars in Britain each year.**

[1] Proctor *et al.* 1996
[2] Wilson *et al.* 1996
[3] Vaughan 1997

**The study of moths**

We are fortunate in Britain to have a long and popular tradition of recording and study of natural history by amateur naturalists, dating back over 300 years. Collecting moths and butterflies was a social, even a fashionable, pursuit in the early 1700s and many of the vernacular names still in use today were coined at this time. By comparison, the current vernacular names of dragonflies date only from the 1980s.

Moth recording is more popular today than it has ever been. Although it is difficult to estimate precise numbers, there are at least 2000 active moth recorders in Britain at present, and almost certainly many more[4]. However, there is no national recording scheme covering all of the larger moths. The National Scarce Moth Recording Scheme has operated since 1991, collating records of only the threatened and scarce larger moths and there are schemes for some groups of the smaller (micro) moths[4].

The study of moths was revolutionised during the twentieth century by the invention of light traps. These traps, which are used by the vast majority of moth recorders today, all utilise a light source to attract moths, which are then funnelled into a box in which they settle, enabling them to be identified before release. Whilst, such traps have greatly facilitated the recording of moths, some species are rarely caught in light traps. Light traps also do not provide direct evidence of breeding status (unlike searching for caterpillars), as it is not always possible to tell whether a captured moth has bred locally or originated from much further away.

[4] Fox *et al.* 2005
[5] Woiwod and Harrington 1994
[6] For references see Conrad *et al.* 2004

**Rothamsted light trap** Rothamsted Research

**The Rothamsted Light-trap network**

Rothamsted Research began a national network of specially designed light traps in 1968[5]. Since then, these standard traps have been operated by volunteers at over 430 sites, with an average of 83 traps running per year. The traps are run every night at a wide range of sites and habitats including private gardens, woodland, moorland and on the coast.

Rothamsted traps tend to catch small, representative numbers of moths, which makes the samples effective and manageable without threatening or affecting the moth populations being studied[6]. For example, the average number of Large Yellow Underwing *Noctua pronuba*, one of the most common larger moths in Britain, caught by Rothamsted traps since 1968 is just 12 individuals per trap per year. This is a tiny and insignificant fraction of the overall population. Trends from this unique network of traps are described later in this report.

**The Rothamsted light-trap network has generated one of the longest-running and geographically extensive data sets on insect populations anywhere in the world.**

# The changing moth fauna of Britain

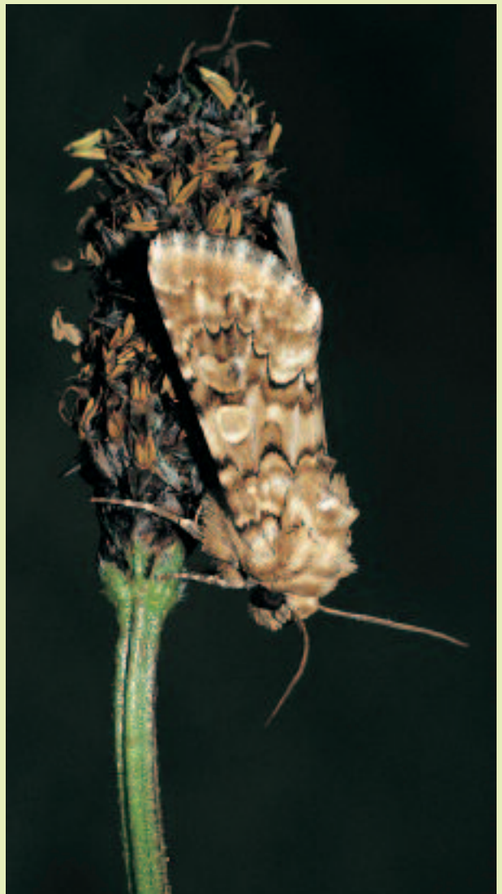
**Lesser Belle** *Colobochyla salicalis* and **Viper's Bugloss** *Hadena irregularis* became extinct in Britain during the twentieth century D.Green

**Light Brown Apple Moth** *Epiphyas postvittana* P.Pugh

The number of moth species living in Britain is changing all the time as resident species become extinct and new ones colonise our islands from continental Europe or further afield. The most recent summary of these changes to the resident moth fauna during the twentieth century, concluded that 62 resident moth species are now considered extinct in Britain and 89 species have colonised successfully[7]. Many of these new colonisers feed on non-native plants in our gardens and parks[7, 8]. Several other species may be extinct, having not been seen for a number of years (e.g. the Orange Upperwing *Jodia croceago*). Since 2000, over 25 moth species have been recorded as new to Britain and several of these are now breeding (e.g. *Ectoedemia heringella* and the Horse Chestnut Leaf-miner *Cameraria ohridella*). South-east England has borne the brunt of more extinctions and received more colonisations than any other region[7].

There is a clear national pattern of moth species richness, with more species recorded in southern counties than in the north. Dorset has the highest total of larger moths (687 species by 2001) and Shetland the lowest (146 species)[9]. Of course, some species only occur in the north and others only in the south.

The decline of moths at the local level is highlighted in many county moth books, which include long lists of locally extinct and declining species. For example, in Cornwall 135 moth species are listed as not recorded since 1906[10], 112 species have been judged likely to be extinct in Hertfordshire[11], and in Herefordshire and Worcestershire 104 are deemed to be extinct in both counties with many more declining[12].



[7] Parsons 2003
[8] Agassiz 1996
[9] Leverton 2001
[10] Smith 1997
[11] Plant 2004
[12] Harper and Simpson 2004

## Australian invader

### The Light Brown Apple Moth

*Epiphyas postvittana*, a smaller moth native to Australia, was first recorded breeding in the wild in Britain in Cornwall in 1936. Initially its spread was slow, taking almost 20 years to reach Devon, but since the 1980s it has expanded rapidly and is now recorded widely across England and Wales, mainly in gardens, and has been reported in Ireland. It has not been recorded in continental Europe, yet!

**The spread of the Light Brown Apple Moth**

| | |
|---|---|
| 1936 | Cornwall<br>First confirmed breeding in the wild |
| by 1955 | Devon |
| by 1970 | Essex, Hampshire |
| by 1980 | Kent, Oxfordshire |
| by 1990 | Dorset, Gloucestershire, Middlesex, Leicestershire, Somerset, Sussex, Wiltshire.<br>First record in Wales (Glamorgan) |
| by 1995 | Much of southern England, had reached North Wales, Lancashire and Yorkshire |
| by 2000 | Continued expansion in the Midlands and North Wales, and had reached Suffolk and Cumbria.<br>First record for Ireland (Co. Wexford) |
| 2001 | First record in Scotland (Dundee) |
| 2002 | Isle of Man, Merionethshire, Midlothian |
| 2003 | Co. Wicklow.<br>First record for Northern Ireland (Co. Antrim) |

**References:**
Porter 2001, Bland 2002, Langmaid and Young 2003, 2004.

### Declines from the Rothamsted network

Perhaps the most convincing evidence of widespread moth declines comes from the analysis of 35 years of data from the Rothamsted light-trap network in Britain. This shows that between 1968 and 2002 the total number of larger moths had decreased by almost one third (Figure 1).

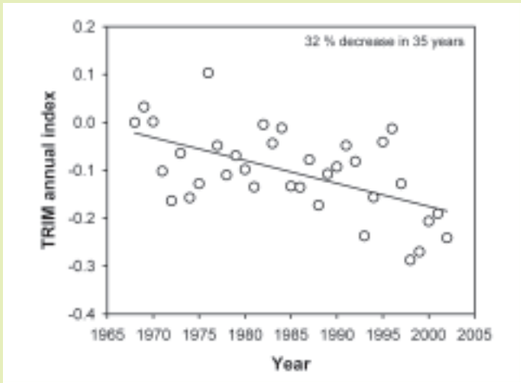



**Figure 1** Total larger moth catches in the Rothamsted light-trap network 1968-2002[13]. The total number of moths recorded has decreased by 32%.

[13] The TRIM index provides a good estimate of relative change in moth abundance (see Conrad *et al*. 2004 for more information on TRIM)

## Trends of rare moths

In addition to the 62 moth species considered to have become extinct in Britain during the twentieth century, the National Scarce Moth Recording Scheme[14], shows that many species are now nationally threatened or scarce.

**Moths and the UK Biodiversity Action Plan**
Following the 1992 Earth Summit in Rio, the UK Biodiversity Action Plan (BAP) was developed to focus Government action to conserve species and habitats. Currently, 53 moths are afforded the top priority status under the UK BAP. These Priority Species comprise 52 larger moths and a single smaller moth (the Basil Thyme Case-bearer *Coleophora tricolor*). Butterfly Conservation takes the lead role in co-ordinating action on all but one (the New Forest Burnet *Zygaena viciae*) of these species, sometimes in collaboration with other organisations. Actions typically involve survey and monitoring work, ecological research, habitat management and safeguarding colonies, as well as promoting moth conservation to landowners, councils, wildlife organisations and the general public.

The progress made towards achieving the targets set out in the 53 action plans for UK BAP moths has been reviewed recently[15]. The discovery of new colonies, ecological research and habitat management have helped the situation of 27 priority moths since the UK BAP was published, but the fortunes of eight species have worsened considerably. 15 are considered to have no overall change (although in three cases this is because the species are thought to be extinct!) and there is insufficient information for the remaining three to make a sound judgement (the Barred Tooth-striped *Trichopteryx polycommata*, Northern Dart *Xestia alpicola* and Sword-grass *Xylena exsoleta*).

All of the UK BAP priority moths have undergone substantial declines in the past and eight species have continued to decline. Examples include the Brighton Wainscot *Oria musculosa* (Figure 2), which is associated with cereal fields, and Pale Shining Brown *Polia bombycina* (Figure 3), both of which occur on and around Salisbury Plain. No Brighton Wainscot have been reported in Britain since 2001, prompting concerns that the species may now be extinct, but habitat management undertaken for it may have benefited other species such as the Pale Shining Brown, Corn Bunting and rare arable weeds. The Marsh Moth *Athetis pallustris* appears to have become extinct at several former sites and is now known from only two sites (in Lincolnshire). In addition, a further UK BAP species, the Orange Upperwing may be extinct now, as there have been no confirmed British records since 1994, despite considerable survey effort.

Under the auspices of the UK BAP, and the regional and local biodiversity action plans that have developed more recently, great improvements have been made in understanding the status of the priority moth species and some notable conservation successes achieved. However, much more work and far more resources are required to fully implement the existing action plans for priority moths. Many additional scarce species meet the criteria for inclusion in the UK BAP, as do many 'common' species found to be in rapid decline in the analysis of Rothamsted network data. Therefore, the number of priority moths may increase after the BAP review in 2006. Additional resources to maintain the success and the credibility of the BAP process must accompany such an increase.

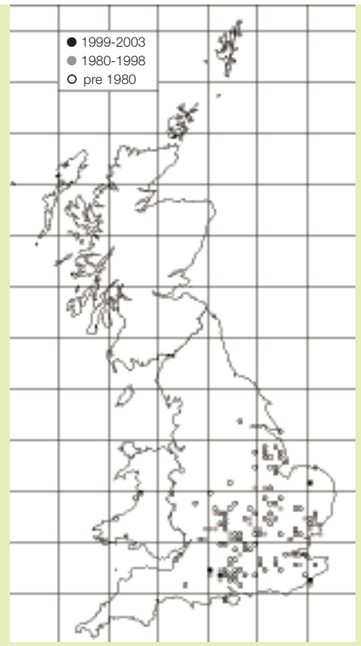
[14] A recording scheme run by Butterfly Conservation in association with the Joint Nature Conservation Committee, collating records of all Red Data Book and Nationally Scarce larger moths

[15] Parsons 2004

**Figure 2**
Declining distribution of the Brighton Wainscot *Oria musculosa*.

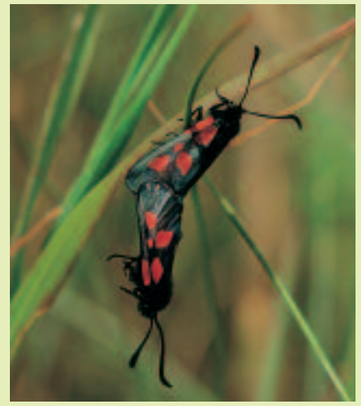
**Figure 3**
Declining distribution of the Pale Shining Brown *Polia bombycina*.

Maps produced from the National Scarce Moth Recording Scheme database


New colonies of the very rare moth **Dark Bordered Beauty** *Epione vespertaria* have been located in Scotland and habitat management is underway. However, the species remains a high conservation priority, as it is only known from four sites in the whole of Britain (in Scotland and northern England). R.Leverton

Research conducted on the **Fiery Clearwing** *Pyropteron chrysidiformis* has led to a much better understanding of its ecological requirements. As a result, management recommendations can now be given to landowners and new habitat has been created in Kent for this very rare moth. R.Thompson



The **New Forest Burnet** *Zygaena viciae* survives at a single British site, in western Scotland. The population has responded positively to conservation action (protection from sheep grazing), with adult moth numbers increasing from only 20 individuals in 1990 to over 8,500 in 2003. R.Leverton
**Reference:** Young and Barbour 2004.

Thanks to new surveys by volunteers and Butterfly Conservation staff, the known distribution of the **Buttoned Snout** *Hypena rostralis* has almost tripled from only c.65 10km squares prior to the UK BAP to around 180 10km squares. P.Pugh

Populations of these species have declined 1968-2002.
**Iron Prominent** *Notodonta dromedarius* (top) by 34%,
**Birch Mocha** *Cyclophora albipunctata* (below right) by 51% and
**Clouded Buff** *Diacrisia sannio* (below left) by 64% R.Thompson

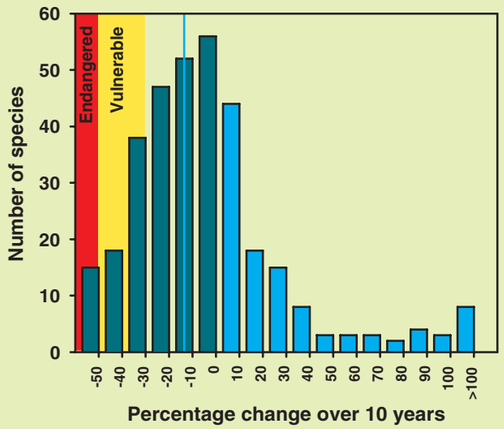
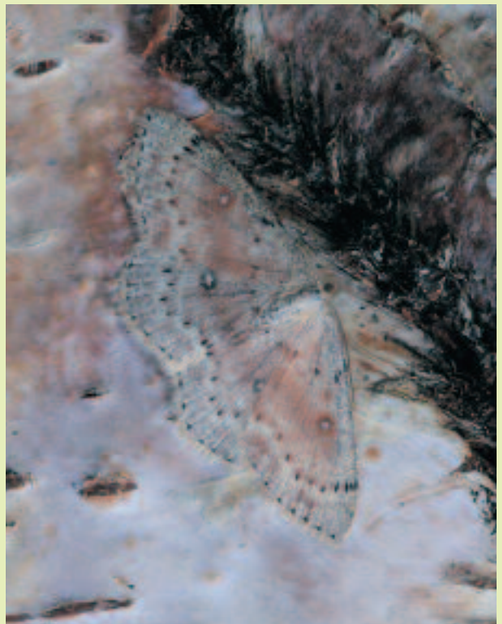



**Figure 4** Frequency distributions of population change of 337 British moth species. The size of population change is the percentage change over a 10 year period, calculated from the annual rate of change estimated from long-term trends from 1968-2002. The blue vertical line shows the median 10 year change. X-axis labels are the upper limits of each class. Shaded areas correspond with the IUCN criteria thresholds for the Endangered and Vulnerable status.



## Trends of common moths

### Analysis of the Rothamsted data

In 2003, Butterfly Conservation and Rothamsted Research launched a collaborative project to assess population trends in individual moth species from the light-trap data set. The Esmée Fairbairn Foundation provided funding for the project. Long-term (35 year) trends were obtained for 337 common, larger moths based on annual indices of abundance calculated using the TRIM modelling procedure[16]. In this context, 'common' relates to species with sufficient captures for the calculation of national trends. Some of these 'common' species may be absent or scarce in parts of Britain.

### Common moths in decline

- Most species are declining, some at very alarming rates (Figure 4). Two thirds (226 species) show a decreasing population trend and one third (111 species) show an increase in population over the 35 year study.

**Twice as many common larger moth species have declined as increased over the past three decades**

- 75 species decreased by over 70% between 1968 and 2002 (listed in Table 1 on p.14).

- Another 57 species decreased by over 50% and a further 60 species decreased by over 25%.

As a result of these declines, many common moths now meet the selection criteria for the UK Biodiversity Action Plan 2006 review (see Table 1 on p.14). Butterfly Conservation has put most of these species forward for consideration as Priority Species for conservation action.

[16] Conrad *et al*. 2004
[17] IUCN 2001
[18] Conrad *et al*. in prep.

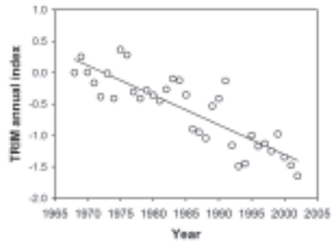
### New Red Data Book species

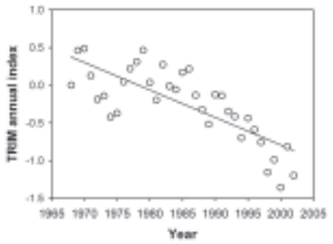
The Red Data Book criteria developed by IUCN (the World Conservation Union) are used around the world to determine the conservation priority level of species[17].

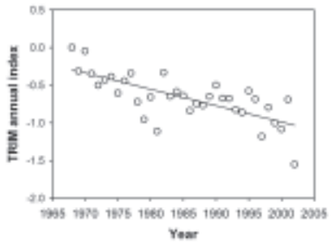
If the IUCN criteria are applied to the national population trends generated from the Rothamsted data, 71 common British moths would be considered threatened (see Table 1 on p.14). 15 species would qualify as Endangered and 56 as Vulnerable[18]. None of these have been listed as Red Data Book species before in Britain and none were previously thought to warrant any conservation priority in the UK BAP. Although there are considerable annual fluctuations in the abundance of many species, the trends show a steady decline through the 1970s, 80s and 90s.

These findings are extremely alarming. Few naturalists would have noticed or predicted the dramatic declines of many of these larger moths, with the possible exception of species such as the V-moth *Macaria wauaria* and Spinach *Eulithis mellinata* (see p.25). Moth recorders, conservationists and the public will probably be surprised and shocked that so many common species have declined to such a great extent in recent decades. There are obvious parallels with the dramatic and well-publicised declines of common birds such as the Skylark, House Sparrow and Starling, although none of these species have declined by as much as the 75 larger moths in Table 1. It is well known that there are many threatened and scarce species in Britain, but this is the clearest signal yet that our common species, which underpin the food chains and ecosystems that maintain our biodiversity, are also undergoing catastrophic change.

**71 common British moths (21% of the species assessed in this research) now qualify as Endangered or Vulnerable as a result of rapid declines over recent decades**

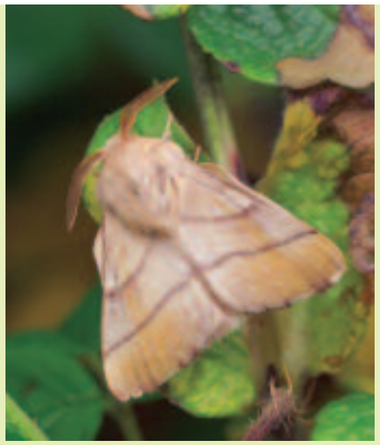



Severlely declining common moths (1968-2002).

**Autumnal Rustic** *Eugnorisma glareosa* **92% decline** R.Leverton
**Ghost Moth** *Hepialus humuli* **73% decline** R.Leverton
**Blood-vein** *Timandra comae* **79% decline** R.Thompson
**Lackey** *Malacosoma neustria* **90% decline** P.Pugh
**Oak Hook-tip** *Watsonalla binaria* **81% decline** R.Leverton
**White Ermine** *Spilosoma lubricipeda* **77% decline** R.Thompson



**ENDANGERED:**

The **Dusky Thorn** *Ennomos fuscantaria* shows the greatest decline of all 337 larger moth species analysed. It has decreased by 98% over the 35 year study. This distinctive geometrid moth is readily attracted to light traps and flies during the late summer and autumn. Its distribution is described as "...occurs, not uncommonly, throughout England and Wales"[19] and "Common. Fairly generally distributed and often frequent in England and Wales"[20]. Despite the abundance of the main caterpillar foodplant, ash, the moth has undergone an extraordinary and unexplained decline.

P.Pugh

**ENDANGERED:**

The **Figure of Eight** *Diloba caeruleocephala* is a woodland, hedgerow and garden moth described as "Common. Well distributed throughout most of England, Wales and southern Scotland"[20]. It has declined by 95% over 35 years and qualifies as a Red Data Book Endangered species. This moth was caught in over 30% of Rothamsted traps in the early years of this study, but had declined to only around 10% during the final years of the twentieth century.

R.Thompson

**VULNERABLE:**

The **Cinnabar** *Tyria jacobaeae* is one of the most familiar larger moths on account of its attractive black and red wings and because of its distinctive orange and black banded caterpillars found on ragwort. It is widespread and common in southern Britain, becoming more local and coastal in Scotland. Between a third and half of Rothamsted traps catch this species and this proportion has not changed much during the study period. However, its populations have suffered a long-term decrease of 83% over 35 years, marking the species Vulnerable according to IUCN criteria.

D.Green

[19] Skinner 1998
[20] Waring and Townsend 2003

## Table 1 Larger moth species that have declined by ≥70% over 35 years and their IUCN Red List categories.

# Identifications confirmed by examination of internal anatomy
† Selection of candidate species for UK BAP Priority status is made on the basis of a >50% decline over 25 years
* The IUCN classifications are based on 10 year population trends of the larger British moths estimated from the Rothamsted data. The 10 year moth population trends were calculated from the annual rate of decline across the whole 35 year study period (i.e. they are not the trends from the most recent 10 years). When, as in this case, the causes of trends are not understood or the declines are likely to be ongoing, IUCN criteria define species with 10 year decreases of 50% or greater as Endangered and those with 30% or greater as Vulnerable.

| Species | | % change over 35 years | % change over 25 years† | IUCN category* |
|---|---|---|---|---|
| Dusky Thorn | *Ennomos fuscantaria* | -98 | -93 | Endangered |
| Hedge Rustic | *Tholera cespitis* | -97 | -92 | Endangered |
| V-moth | *Macaria wauaria* | -97 | -92 | Endangered |
| Double Dart | *Graphiphora augur* | -97 | -92 | Endangered |
| Garden Dart | *Euxoa nigricans* | -97 | -92 | Endangered |
| Grass Rivulet | *Perizoma albulata* | -96 | -91 | Endangered |
| Dark Spinach | *Pelurga comitata* | -95 | -89 | Endangered |
| Spinach | *Eulithis mellinata* | -95 | -89 | Endangered |
| Figure of Eight | *Diloba caeruleocephala* | -95 | -88 | Endangered |
| Anomalous | *Stilbia anomala* | -93 | -86 | Endangered |
| Dusky-lemon Sallow | *Xanthia gilvago* | -92 | -84 | Endangered |
| Autumnal Rustic | *Eugnorisma glareosa* | -92 | -84 | Endangered |
| White-line Dart | *Euxoa tritici* | -92 | -83 | Endangered |
| Dark-barred Twin-spot Carpet | *Xanthorhoe ferrugata* | -92 | -83 | Endangered |
| September Thorn | *Ennomos erosaria* | -91 | -83 | Endangered |
| Feathered Gothic | *Tholera decimalis* | -90 | -81 | Vulnerable |
| Beaded Chestnut | *Agrochola lychnidis* | -90 | -81 | Vulnerable |
| Deep-brown Dart | *Aporophyla lutulenta* | -90 | -81 | Vulnerable |
| Lackey | *Malacosoma neustria* | -90 | -80 | Vulnerable |
| Brindled Ochre | *Dasypolia templi* | -90 | -80 | Vulnerable |
| Garden Tiger | *Arctia caja* | -89 | -80 | Vulnerable |
| Haworth's Minor | *Celaena haworthii* | -89 | -80 | Vulnerable |
| Dot Moth | *Melanchra persicariae* | -88 | -78 | Vulnerable |
| Large Nutmeg | *Apamea anceps* | -88 | -77 | Vulnerable |
| Flounced Chestnut | *Agrochola helvola* | -88 | -77 | Vulnerable |
| Latticed Heath | *Chiasmia clathrata* | -87 | -77 | Vulnerable |
| Pretty Chalk Carpet | *Melanthia procellata* | -87 | -76 | Vulnerable |
| Large Wainscot | *Rhizedra lutosa* | -86 | -75 | Vulnerable |
| Pale Eggar | *Trichiura crataegi* | -86 | -75 | Vulnerable |
| Rosy Rustic | *Hydraecia micacea* | -86 | -75 | Vulnerable |
| Small Square-spot | *Diarsia rubi* | -85 | -74 | Vulnerable |
| Heath Rustic | *Xestia agathina* | -84 | -73 | Vulnerable |
| Broom-tip | *Chesias rufata* | -84 | -73 | Vulnerable |
| Oblique Carpet | *Orthonama vittata* | -83 | -72 | Vulnerable |
| Cinnabar | *Tyria jacobaeae* | -83 | -71 | Vulnerable |
| Sprawler | *Asteroscopus sphinx* | -83 | -71 | Vulnerable |
| Small Emerald | *Hemistola chrysoprasaria* | -82 | -71 | Vulnerable |
| Sallow | *Xanthia icteritia* | -82 | -71 | Vulnerable |
| Crescent | *Celaena leucostigma* | -82 | -71 | Vulnerable |
| Oak Lutestring | *Cymatophorima diluta* | -82 | -70 | Vulnerable |
| Neglected Rustic | *Xestia castanea* | -82 | -70 | Vulnerable |
| Oak Hook-tip | *Watsonalla binaria* | -81 | -70 | Vulnerable |
| August Thorn | *Ennomos quercinaria* | -81 | -70 | Vulnerable |
| Rosy Minor | *Mesoligia literosa* | -81 | -70 | Vulnerable |
| Brindled Beauty | *Lycia hirtaria* | -81 | -69 | Vulnerable |
| Red Carpet | *Xanthorhoe decoloraria* | -81 | -69 | Vulnerable |
| Knot Grass | *Acronicta rumicis* | -80 | -68 | Vulnerable |
| Grey Mountain Carpet | *Entephria caesiata* | -79 | -67 | Vulnerable |
| Green-brindled Crescent | *Allophyes oxyacanthae* | -79 | -67 | Vulnerable |
| Blood-vein | *Timandra comae* | -79 | -67 | Vulnerable |
| Dark Brocade | *Blepharita adusta* | -78 | -66 | Vulnerable |
| The Streak | *Chesias legatella* | -78 | -66 | Vulnerable |
| Small Phoenix | *Ecliptopera silaceata* | -77 | -65 | Vulnerable |
| Grey Dagger# | *Acronicta psi* | -77 | -65 | Vulnerable |
| Broom Moth | *Melanchra pisi* | -77 | -65 | Vulnerable |
| White Ermine | *Spilosoma lubricipeda* | -77 | -65 | Vulnerable |
| Mullein Wave | *Scopula marginepunctata* | -76 | -64 | Vulnerable |
| Galium Carpet | *Epirrhoe galiata* | -76 | -64 | Vulnerable |
| Powdered Quaker | *Orthosia gracilis* | -76 | -64 | Vulnerable |
| Dusky Brocade | *Apamea remissa* | -76 | -63 | Vulnerable |
| Brown-spot Pinion | *Agrochola litura* | -76 | -63 | Vulnerable |
| Rustic | *Hoplodrina blanda* | -75 | -63 | Vulnerable |
| Centre-barred Sallow | *Atethmia centrago* | -74 | -62 | Vulnerable |
| Mouse Moth | *Amphipyra tragopogonis* | -73 | -61 | Vulnerable |
| Mottled Rustic | *Caradrina morpheus* | -73 | -61 | Vulnerable |
| Shaded Broad-bar | *Scotopteryx chenopodiata* | -73 | -61 | Vulnerable |
| Buff Ermine | *Spilosoma luteum* | -73 | -61 | Vulnerable |
| Minor Shoulder-knot | *Brachylomia viminalis* | -73 | -61 | Vulnerable |
| Ghost Moth | *Hepialus humuli* | -73 | -60 | Vulnerable |
| Shoulder-striped Wainscot | *Mythimna comma* | -72 | -60 | Vulnerable |
| Ear Moth# | *Amphipoea oculea* | -71 | -59 | Vulnerable |
| July Belle/Lead Belle | *Scotopteryx luridata/S. mucronata* | -71 | -59 | - |
| Light Arches | *Apamea lithoxylaea* | -71 | -59 | - |
| Buff Arches | *Habrosyne pyritoides* | -71 | -58 | - |
| Dark Umber | *Philereme transversata* | -70 | -58 | - |

**Buff Arches** *Habrosyne pyritoides* and **Magpie** *Abraxas grossulariata* populations have declined rapidly R.Thompson while the number of **Smoky Wainscot** *Mythimna impura* has remained stable R.Leverton

**Peacock Moth** *Macaria notata* R.Leverton


**Figure 5** Maps showing locations of Rothamsted light traps that caught a) Least Carpet *Idaea rusticata* and b) Blair's Shoulder-knot *Lithophane leautieri*1968-2002 (solid dots). Crosses indicate location of other Rothamsted traps.

## Other rapidly declining species

Many other moths have significant population declines, but do not quite meet the Red Data Book criteria. Examples include the Light Arches, Buff Arches and Dark Umber. All three of these moths have declined by 70% or more in the 35 year study, but just below the 30% decline threshold over 10 years necessary for Vulnerable status. Many other familiar moths are also declining rapidly, including the Garden Carpet *Xanthorhoe fluctuata*, Small Seraphim *Pterapherapteryx sexalata* and Magpie *Abraxas grossulariata* (each with a 69% decline over 35 years) and the Turnip Moth *Agrotis segetum*, Purple Thorn *Selenia tetralunaria* and Black Rustic *Aporophyla nigra* (each with a 68% decline).

The presence of many common garden moths, such as Garden Carpet, Heart and Dart *Agrotis exclamationis* (67% decline), Scalloped Oak *Crocallis elinguaria* (66% decline) and Common Wainscot *Mythimna pallens* (64% decline), amongst all these rapidly decreasing species is particularly worrying for biodiversity conservation, as the decline of such common insects suggests very widespread and pervasive environmental degradation.

## Relatively stable species

The population levels of the Smoky Wainscot *Mythimna impura* have changed least over the 35 year study period. This grass-feeding species is typically caught by over 90% of Rothamsted traps every year and is found in good numbers. Other stable species include the very widespread Flame Shoulder *Ochropleura plecta*, Uncertain *Hoplodrina alsines*, Mottled Umber *Erannis defoliaria* and Dun-bar *Cosmia trapezina*.

**Table 2 The 20 larger moths with greatest increases in population 1968-2002.**

| Species | | % change over 35 years |
|---|---|---|
| Least Carpet | *Idaea rusticata* | 41,696 |
| Blair's Shoulder-knot | *Lithophane leautieri* | 20,798 |
| Satin Beauty | *Deileptenia ribeata* | 3856 |
| Treble Brown Spot | *Idaea trigeminata* | 3061 |
| Scarce Footman | *Eilema complana* | 2035 |
| Peacock Moth | *Macaria notata* | 2022 |
| Juniper Carpet | *Thera juniperata* | 1241 |
| Grey Shoulder-knot | *Lithophane ornitopus* | 1055 |
| Broad-bordered Yellow Underwing | *Noctua fimbriata* | 954 |
| Devon Carpet | *Lampropteryx otregiata* | 937 |
| Spruce Carpet | *Thera britannica* | 861 |
| Buff Footman | *Eilema depressa* | 815 |
| Dingy Footman | *Eilema griseola* | 737 |
| Dotted Carpet | *Alcis jubata* | 732 |
| Least Black Arches | *Nola confusalis* | 689 |
| Red-green Carpet | *Chloroclysta siterata* | 587 |
| Marbled Beauty | *Cryphia domestica* | 467 |
| Blue-bordered Carpet | *Plemyria rubiginata* | 426 |
| Dwarf Cream Wave | *Idaea fuscovenosa* | 419 |
| Vine's Rustic | *Hoplodrina ambigua* | 413 |

## Common moths on the increase

Although the majority of population trends for larger moths from the Rothamsted network are negative, some species have increased spectacularly over recent decades (Table 2). 46 species have more than doubled their population levels (i.e. increased by at least 100%) and a further 23 species have increased by more than 50% over the 35 year period. Several of these species breed on non-native plants or have colonised Britain recently. Others may be responding to climate change.

Two species have been particularly successful, the Least Carpet and Blair's Shoulder-knot, both of which have increased by many thousand-fold. The Least Carpet occurs in southern England and is only caught in a small (but increasing) proportion of Rothamsted traps (Figure 5). However, the number of individuals caught has increased very significantly over recent decades. Conversely, Blair's Shoulder-knot has only ever been caught in small numbers in the traps, but the proportion of Rothamsted sites where this species is found has increased dramatically since the mid-1980s (Figure 5). Prior to that, hardly any traps caught this moth (less than 5% of traps), but this rose to almost 40% in 1996, before settling to 20-30% each year since then.

Blair's Shoulder-knot is a recent colonist and successful invader: from the first recorded resident individual on the Isle of Wight in 1951, the species has spread northwards to reach Scotland by 2001[21]. This moth is associated primarily with non-native cypress trees (including the ubiquitous Leyland Cypress) and Britain's gardens and parks provide a large area of potential habitat for the species to colonise.

[21] Agassiz 2004

**Scarce Footman**
*Eilema complana* R.Leverton
**Vestal**
*Rhodometra sacraria* R.Leverton
**Green Silver-lines**
*Pseudoips prasinana* R.Thompson

## Patterns of abundance change amongst common larger moths

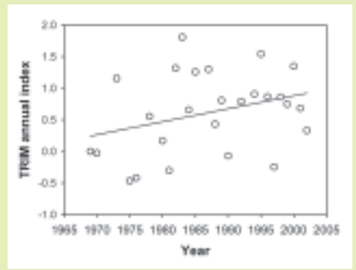
### Footmen on the march

The footman moths (subfamily *Lithosiinae*) have done very well as a group. Eight species are included in the analysis of which all have increased:

| Species | | % change over 35 years |
|---|---|---|
| Scarce Footman | *Eilema complana* | 2035 |
| Buff Footman | *Eilema depressa* | 815 |
| Dingy Footman | *Eilema griseola* | 737 |
| Rosy Footman | *Miltochrista miniata* | 299 |
| Muslin Footman | *Nudaria mundana* | 115 |
| Round-winged Muslin | *Thumatha senex* | 56 |
| Common Footman | *Eilema lurideola* | 40 |
| Four-dotted Footman | *Cybosia mesomella* | 17 |

### The Vestal

The Vestal *Rhodometra sacraria*, an immigrant moth, shows a very large increase in captures by the Rothamsted network: 674% (1968-2002). Although there is much annual fluctuation in the population index, as would be expected for an immigrant, the Vestal does appear to have become significantly more frequent in Britain (possibly as a result of climate change). See graph right >




Below the top 20 greatest increases, come several species that can be categorised broadly as woodland moths, including the Pine Beauty *Panolis flammea* (+354%), Brindled Green *Dryobotodes eremita* (+299%), Pine Carpet *Thera firmata* (+268%), Common Lutestring *Ochropacha duplaris* (+191%) and Green Silver-lines *Pseudoips prasinana* (+157%) and some of the most common moths caught at both Rothamsted sites and garden light traps within their ranges (e.g. the Large Yellow Underwing +134%, Lunar Underwing *Omphaloscelis lunosa* +100%, July Highflier *Hydriomena furcata* +52%, Angle Shades *Phlogophora meticulosa* +47% and Shuttle-shaped Dart *Agrotis puta* +36%).

### Ecological patterns

The causes of these changes in population levels of common moths are likely to be numerous and complex, and will vary from species to species. Teasing out the main causes of declines and increases will be the focus of further research. Initial analyses have provided some intriguing findings both positive and negative[22].

- Obligately single brooded species tend to have fared worse on average than obligately double or multiple brooded ones (though this was not statistically significant).
- Only moths that survive the winter as adults (either in hibernation or as part of their flight period) have increased on average (Figure 6) whereas, on average, all of the other species have declined.
- Species that overwinter in the egg stage, such as the Spinach, Pale Eggar and Scalloped Oak, have fared particularly badly.

### Flight period

- Species that fly through the winter from autumn into spring (e.g. the Spring Usher *Agriopis leucophaearia*) have on average increased.
- Species with all other flight periods have on average decreased.
- Moths that fly in the autumn, such as the Beaded Chestnut, appear to be faring worst of all.

It is worth noting, however, that flight period season and overwintering stage are not independent. Many of the autumn flying moths that have declined severely also overwinter as eggs. Examples include Flounced Chestnut (-88%), Green-brindled Crescent (-79%), Feathered Thorn *Colotois pennaria* (-58%), Pink-barred Sallow *Xanthia togata* (-48%) and Autumnal Moth *Epirrita autumnata* (-31%).

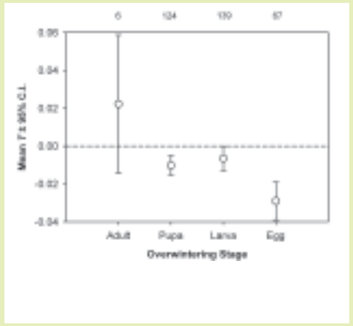



**Figure 6** Relationship between moth species population trend (*T*) and overwintering stage. The number of larger moth species in each category is given across the top of the figure.

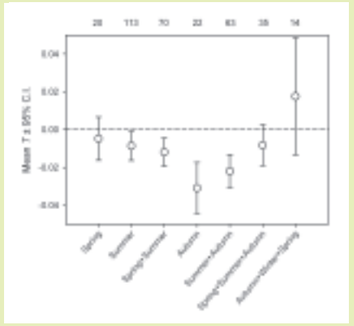



**Figure 7** Relationship between moth species population trend (*T*) and flight period season. The number of larger moth species in each category is given across the top of the figure. Spring equates to March-May; Summer June-August; Autumn September-November and Winter December-February.

**Pale Eggar larvae** *Trichiura crataegi* R.Leverton

[22] Conrad *et al*. 2004

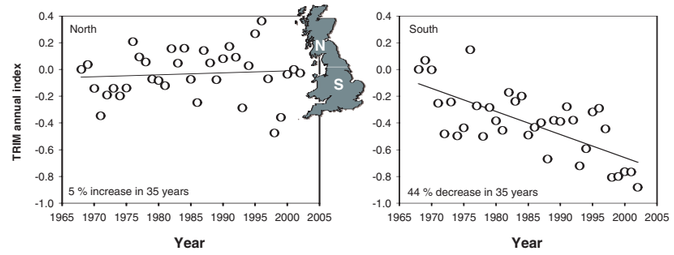



**Figure 9** Total larger moth catches in the Rothamsted light-trap network 1968-2002 in northern and southern areas.

## Habitats and foodplants

- Moths that are relatively specialised, in that they occur in only one or two broad habitat types[23] (e.g. woodland, grassland, heathland, wetland etc.), have declined on average.
- However, no significant differences were found between groups of moths occupying different broad habitat types.
- Moths specialising on four foodplant categories[23] (deciduous trees, grasses, shrubs and low-growing herbs) all declined on average (see Figure 8).
- Species feeding on lichens/algae and coniferous trees generally increased. The differences between the increasing groups and each of the declining groups are statistically significant.

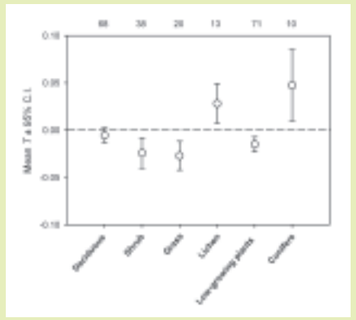



**Figure 8** Relationship between moth species population trend (*T*) and caterpillar foodplant type. The number of larger moth species in each category is given across the top of the figure.

**Satin Beauty** *Deileptenia ribeata* R.Leverton

### Lichen for lunch?

The main group of species whose caterpillars feed on lichens or algae are the footman moths. All eight of these for which trends have been produced increased over the 35 year study period (see p. 18). Other lichen-feeders that have undergone large population increases are the Dotted Carpet (+732%) and Marbled Beauty (+467%). Not all lichen feeding moths have increased though. For example, the population of the Beautiful Hook-tip *Laspeyria flexula* has decreased by 64% and that of the Brussels Lace *Cleorodes lichenaria* by 33%.

### Conifer feeders

Most conifer feeding moths have also done well. This group includes both recent colonists, such as Blair's Shoulder-knot (+20,798%) (see p. 17), and long-term residents, such as the Satin Beauty (+3,856%) and the aptly named Juniper Carpet (+1,241%), Spruce Carpet (+861%), Pine Beauty (+354%) and Pine Carpet (+268%). The Grey Pine Carpet *Thera obeliscata*, Tawny-barred Angle *Macaria liturata* and Barred Red *Hylaea fasciaria* have also shown small increases in population levels. The Bordered White *Bupalus piniaria* was the only conifer specialist found to have declined in the study (-33% over 35 years).

## Geographical patterns

Overall, the average change for species with northern distributions was not significantly different from the average of southern species, and neither group differed significantly from ubiquitous species. However, the comparison suggested that species with southern distributions (i.e. those with a northern limit to their range in Britain) have been more likely to increase over recent decades than either northerly or widely distributed species.

Comparison of the total numbers of moths caught in Rothamsted traps in northern and southern Britain showed a dramatic difference (Figure 9). Whilst overall numbers of moths had decreased significantly in southern traps since 1968, a 44% decline, there was a small (but not statistically significant) increase of 5% in captures in northern Britain.

Population trends in southern Britain were calculated for 298 larger moths from the light-trap network data and northern trends for 274 species (Figure 10)[24]. A similar proportion of species had declined severely in both regions. In northern Britain, 58 species (21%) met the standard IUCN criteria for Red Data Book listing as Endangered (23 species) or Vulnerable (35 species), whilst in southern Britain 78 larger moths (26%) qualified, with 12 Endangered and 66 Vulnerable. The top 10 most rapidly declining species in each area are shown in Table 3 overleaf.

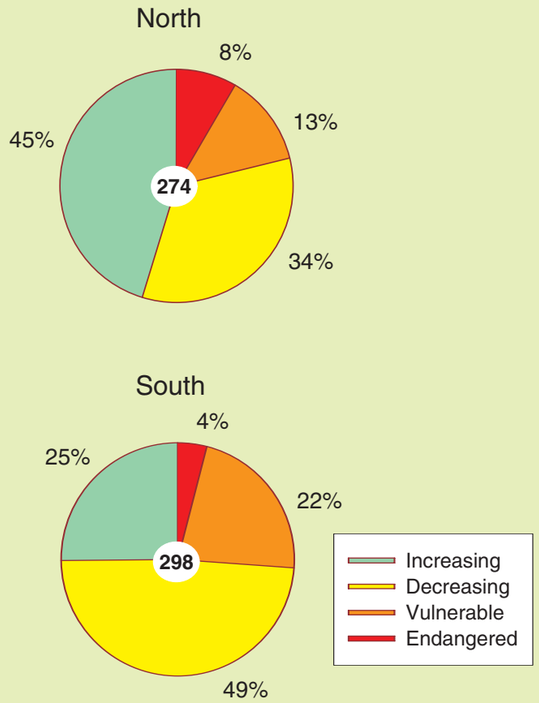



**Figure 10** Moth population changes in northern and southern Britain. Categories are based on percentage population changes over a 10 year period, calculated from annual rates of change estimated from long-term trends from 1968-2002. Endangered: decline > 50%; Vulnerable: decline 30-49% ; Decreasing: decline > 0% and < 30%; Increasing: increase > 0%. Numbers at the centre of each chart indicate the total number of species in each analysis.

[23] Classified according to Emmet 1991

[24] Conrad *et al*. in prep

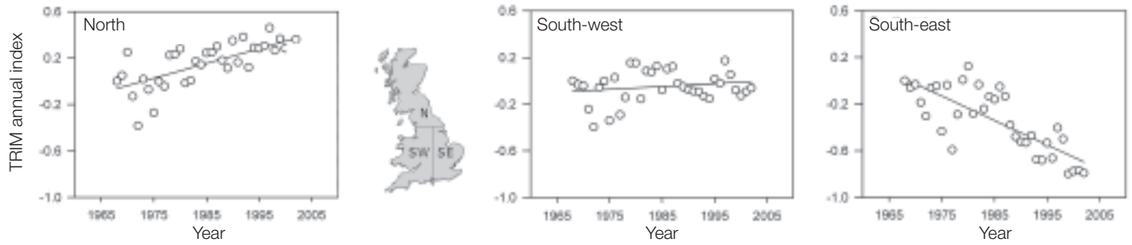



**Table 3 The 10 larger moths with greatest decreases in population 1968-2002 in northern and southern Britain.**

| Species and % change over 35 years | | | |
|---|---|---|---|
| **Northern Britain*** | | **Southern Britain*** | |
| Spinach | -99 | Double Dart | -98 |
| White-line Dart | -99 | Dark Spinach | -98 |
| Grass Emerald | -99 | Dusky Thorn | -98 |
| Hedge Rustic | -99 | Garden Dart | -97 |
| Large Wainscot | -99 | Hedge Rustic | -97 |
| Feathered Gothic | -99 | Figure of Eight | -95 |
| Dusky Thorn | -98 | September Thorn | -95 |
| Grass Rivulet | -97 | Dusky-lemon Sallow | -94 |
| Figure of Eight | -97 | Anomalous | -93 |
| Beaded Chestnut | -96 | Garden Tiger | -92 |

*Species trends for northern and southern Britain were calculated from Rothamsted light traps operating to the north and south respectively of the 4500 N grid line of the Ordnance Survey National Grid, which runs through York and just to the south of Lancaster.

**Grass Emerald** *Pseudoterpna pruinata* R.Leverton

As well as highlighting species that have fared very badly in northern or southern Britain, this geographical breakdown shows which region contributes most to the overall trends for species in Britain. Of the 15 species classified nationally as Endangered (Table 1, p.14), four are Endangered in both northern and southern areas (Dusky Thorn, Hedge Rustic, Figure of Eight and Anomalous) and six are Endangered in one and Vulnerable in the other area (V-moth, Double Dart, Garden Dart, Dark Spinach, Spinach and Autumnal Rustic). Therefore 10 of the most rapidly decreasing species appear to be declining across the whole of Britain. Of the remaining species, two do not occur in sufficient numbers in southern Britain to generate a separate index (Grass Rivulet and White-line Dart) and three are only declining rapidly enough to meet IUCN criteria in southern Britain (Dusky-lemon Sallow, Dark-barred Twin-spot Carpet and September Thorn). Nevertheless, the Dusky-lemon Sallow and Dark-barred Twin-spot Carpet have declined in the north (by -42% and -66% respectively), while the September Thorn has increased slightly (+17%).

Although there is much consistency between northern and southern Britain with regards to the most rapidly declining species, there are substantial differences amongst other species (i.e. that have declined less severely or increased in population levels). In northern Britain 45% of species assessed have increased, whereas in southern Britain this proportion is only 25% (see Figure 10). It is this difference that accounts for the stability in the overall numbers of moths caught in the north (i.e. declines have been balanced out by increases) and the sharply decreasing trend in the south (where declining species are driving the overall trend).

**Lilac Beauty** *Apeira syringaria* R.Leverton

The difference also means that there are many species that have different trends in the north and south. The September Thorn mentioned opposite is one example. Others include the Lilac Beauty *Apeira syringaria* (+697% in north, -77% in south), Scorched Wing *Plagodis dolabraria* (+472% in north, -52% in south), Clouded Silver *Lomographa temerata* (+258% in north, -58% in south) and Buff-tip *Phalera bucephala* (+100% in north, -63% in south).

The national increases of some common moths are also being driven by changes in northern Britain. For example, the Satin Beauty has only increased by 32% in southern Britain but by 2438% in the north, Common Footman by 32% in the south and 1678% in the north.

- **Total numbers of moths have declined in southern Britain (44% decrease over 35 years) but have remained more or less stable in northern Britain.**
- **More common moths are declining in the south (75% of species) than the north (55%).**
- **Similar proportions of moths qualify for Endangered and Vulnerable status (26% in south and 21% in north).**
- **South-east Britain had the greatest number of declining species.**

**East versus West** *see graphs above*

A further geographical division of the southern area was made to look for differences between eastern and western parts. This was done along the 4500 E grid line of the Ordnance Survey National Grid, which runs through the Isle of Wight, Oxford and Nottingham. Population indices and trends were recalculated for species in these south-west and south-east regions:

- Northern Britain had the greatest proportion of increases, with the south-west and south-east approximately equal.
- South-west Britain had the greatest proportion of species with relatively stable populations.
- South-east Britain had the greatest proportion of moths displaying substantial declines.
- Many species showed different trends in different regions. 44 species, 20% of those used for this three-area comparison, declined substantially in south-east Britain, whilst remaining stable or increasing in south-west and northern areas. For example, the Scalloped Hazel *Odontopera bidentata* increased in the north, remained stable in the south-west and declined severely in the south-east (trends shown above).

**Scalloped Hazel** *Odontopera bidentata* A.Barnes

# Causes of change for common moths

### Habitat change

Over the last 50 years, agricultural intensification, commercial forestry and urban development have wrought massive change upon the British landscape. The effect on semi-natural habitats, such as ancient woodland, heathland and chalk grassland, and the wildlife that inhabits them, has been devastating. The widespread destruction (see box), modification and fragmentation of these habitats have had a severe impact on many specialist moths[25], butterflies[26] and other animals and plants[27]. Many organisms have been listed in Red Data Books and in the UK Biodiversity Action Plan as a result (see p. 8 for further discussion).

**Loss of important wildlife habitats in Britain**
**(taken from Asher *et al*. 2001)**

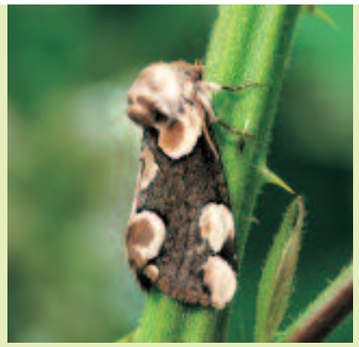
| **Habitat and approximate loss since the 1940s** | |
|---|---|
| Lowland flower-rich grassland | 97% |
| Fenland (East Anglia) | 90% |
| Chalk and limestone grassland | 80% |
| Actively coppiced woodland | 75% |
| Lowland raised bogs | 60% |
| Ancient broad-leaved woodland | 50% |
| Hedgerows (England) | 67% |
| Hedgerows (Scotland) | 54% |
| Lowland heathland | 40% |

There is insufficient evidence at present to determine the level of impact of habitat change on the declines of common moths. However, the substantial loss of hedgerows, destruction of field margins and reseeding and fertilization of pastures etc. is likely to have been a major factor. A recent comparison of organic and conventional mixed farms in southern Britain found significantly more moths on the organic farms[28].

**Intensive farming** G.Jeffcoate

This supports a previous analysis of data from a very long-running light trap on the Rothamsted Farm, which found that agricultural intensification during the 1950's had caused a significant decrease in moth numbers and diversity[29].

However for some declining species, habitat loss alone seems unlikely to be the main driving force of change. For example, the amount of broad-leaved woodland in Britain increased by 20% between 1800 and 1980 and by a further 5% since 1990. A lack of woodland *per se* cannot be causing the declines of common species found in woodland, such as the Buff Arches (-71%), December Moth *Poecilocampa populi* (-65%), Peach Blossom *Thyatira batis* (-63%) and Purple Clay *Diarsia brunnea* (-47%). However, the declines of woodland species might be related to the changing structure, management and composition of woods (e.g. increasing shade, fewer open spaces, loss of plant species diversity) as has been found for many butterflies (e.g. the woodland fritillaries[26]). Increasing broad-leaved woodland cover may have helped other species (see p.18 for examples), and the increase of many conifer feeding moths is hardly surprising given the massive expansion of conifer plantations (a twenty-fold increase in Britain 1800-1980).



**Peach Blossom** *Thyatira batis* is declining despite an overall increase in woodland. R.Thompson

The **Juniper Carpet** *Thera juniperata* has successfully colonised ornamental junipers in gardens. R.Leverton

The **V-moth** *Macaria wauaria*, one of our most rapidly declining common species, may be suffering because fewer people grow its caterpillar foodplants (currants) and because of greater use of insecticides in gardens. R.Leverton

In some specific cases, it is tempting to speculate about the impacts of habitat change on common larger moths. For example, two of the most rapidly declining species (the V-moth and Spinach) utilise currants as their caterpillar foodplants, and their declines may be due to fewer people growing these plants in their gardens[30]. Whilst many declining moths use native foodplants that are unlikely to be affected by trends in gardening, the success of some rapidly increasing moths is strongly related to their ability to make use of exotic garden plants. Blair's Shoulder-knot is a prime example (see p.17) as its caterpillars feed primarily on cypresses, which are not native to Britain. Another example is the Juniper Carpet, which was formerly restricted to semi-natural habitats where its foodplant Juniper grows. However, in recent decades, the moth has successfully colonised many gardens in which ornamental juniper varieties have been planted.

### Pesticides

Another garden trend that may have had a significant impact on moth populations is the massive increase in pesticide (insecticide and herbicide) use. The total weight of pesticides sold for use in domestic gardens increased by 70% between 1992 and 1997 alone[31]. Whilst this might have hastened the decline of garden specialists such as the V-moth and Spinach, and may have caused substantial declines of moths in individual gardens, it cannot account for the vast majority of negative population trends found in the Rothamsted data, simply because most light traps in the network do not sample garden habitats.

Agricultural use of pesticides increased enormously as a key part of agricultural intensification during the twentieth century, and may have played an important role in the declines of many common moths. Nowadays, insecticide use may be having less influence in this respect, as modern chemicals are less persistent than previously. However, herbicides have enabled farmers to reduce weed populations greatly, no doubt having a profound effects on the availability of foodplants for many common moths.

### Pollution

Eutrophication (increased fertility of soil and water) is altering the plant composition and vegetation structure of many habitats, with unknown impacts on herbivores such as moths. The increases seen amongst lichen feeding moths, such as the Marbled Beauty, may be linked to increases in some lichen species, which are in turn attributed to the reduction of air pollution and hence acid rain in many areas[32].

[25] Young 1997
[26] Asher *et al*. 2001
[27] Hawksworth 2001
[28] Wickramasinghe *et al*. 2004
[29] Woiwod 1991
[30] Waring and Townsend 2003
[31] Ansell *et al*. 2001
[32] Gilbert 1992

Moth traps with mercury-vapour bulbs are used commonly by recorders. Such traps are much more attractive to moths than the standard Rothamsted design. P.Pugh

**Garden Tiger** *Arctia caja* A.Barnes

### Vehicles

Moth recorders have speculated whether moths killed by collision with cars and other vehicles could be a significant cause of mortality. However, there is little evidence at present to suggest that this cause of mortality has contributed significantly to moth population trends. Air pollution generated by vehicles, particularly the emission of greenhouse gasses, may be a more important problem in the longer term. Conversely, vehicles might also assist the range expansion of species when moths hitchhike inadvertently.

### Light pollution

Increasing light pollution is another potential cause of change to moth populations. Outdoor lighting can have many disruptive effects on moth behaviour and increase exposure to predators. However, such effects seem to vary between species, populations and even individuals, as well as with the type of lighting used[33]. More importantly, it is very difficult to separate out the direct impact of light pollution on moth populations from the other impacts of urbanisation and development that usually accompany an increase in lighting levels. This potentially serious problem would benefit from further research using manipulative experiments.

### Light pollution and moth trapping

The attractiveness of moth trap lights depends partly upon the level of background lighting, as well as the type of bulb used. For example, catches generally decline when there is a full moon on a clear night. Increased light pollution over recent decades may thus have decreased the efficiency of Rothamsted light traps, resulting in spurious population trends for common moths. This was investigated using satellite data on the change in illumination levels of each 1km square in Britain between 1992 and 2000. Rothamsted light traps were divided into two groups, depending whether they were located in squares that remained 'dark' throughout the period or became darker or in squares that had become brighter by 2000.

- the decrease in total moths captured was as great or greater at traps in areas that remained unaffected by increasing background light levels than at sites that had become measurably brighter.
- the changes in moth abundance presented in this report have not been biased significantly by decreasing effectiveness of light traps due to increasing light competition from light pollution.

See Conrad *et al*. in prep. for more details.

### Climate change

Over the period that the Rothamsted network has been operating, climate change has become evident. Numerous impacts are already apparent on the distribution and phenology of Britain's wildlife. Major range expansions have been noted for many insects including some butterflies, dragonflies and bush-crickets. Negative impacts have been less well documented, but many studies warn of the future threat of human-induced climate change to biodiversity[34]. There have been many recent observations of 'early' or 'late' moths and changing moth phenology (e.g. single brooded species producing partial second broods), always consistent with a climatic explanation. Given this background, it seems highly likely that climate change is also exerting a profound influence on common moths, although this requires further research.

Several results from our analysis of common moths suggest a climatic cause. The group of 56 species classified as having southern distributions (i.e. a northern range margin in Britain) had increased on average, whereas northern species and ubiquitous species had declined. However, this finding was not quite statistically significant. Similarly, the observed relationship between positive population trend and species with winter flight periods hints at an underlying climatic cause (e.g. warmer winters are favouring these species). Furthermore, in the one example that has been examined in considerable detail, the Garden Tiger, climate seems to be playing a significant role[35].

### Tigers like it cold and dry

Detailed investigation has been carried out into the population decrease of the Garden Tiger (89% over the period 1968-2002). This has shown that the moth declines after wet winters and warm springs and that its population levels are strongly correlated with a large-scale climatic pattern in the Atlantic basin, which is thought to influence winter weather in Britain[35]. This species is predicted to decline further in many areas as climate change continues.

- **The precise causes of the decline or increase of most common moths are unknown. However, it seems very likely that agricultural intensification and other land-use changes will have had significant impacts on many moths of the wider countryside, and that climate change and other factors will be influencing some species at the same time.**
- **Further research is needed urgently to determine the underlying causes of the widespread declines of larger moths and suggest ways of reversing the trend.**

[33] Frank 1988

[34] e.g. for European butterflies Hill *et al*. 2002

[35] Conrad *et al*. 2002, 2003

The decline of common moths may have a significant impact on predators such as the **Barbastelle bat,** a UK Biodiversity Action Plan Priority Species.
H.Clark / Bat Conservation Trust

Declining common moths
**Burnished Brass** *Diachrysia chrysitis*
**57% decline** P.Pugh

**Scalloped Hook-tip** *Falcaria lacertinaria*
**52% decline** R.Thompson

**Implications of the trends of common moths**
Insects make up the largest portion of UK biodiversity, comprising over half of terrestrial species[36]. The analysis of common moths presented in this report is therefore important as it is the first time that population trends have been available for such a large group of insects in Britain.

The declines uncovered by the analysis of Rothamsted light-trap data are dramatic and alarming. The total number of moths caught by the traps has decreased by a third in 35 years and two thirds of the 337 common, larger moth species examined have declined. The findings support other research that showed that 71% of butterfly species have declined since the 1970s, substantially more than the declines recorded for British birds (54% over 20 years) and plants (28% over 40 years)[37]. Moreover, our results for moths are even more startling because they relate only to trends in widespread, common species and exclude rarer moths, for which we do not have long-term population data but which may have undergone even more severe declines.

**Together, the declines of so many common moths, and of butterflies, signal a severe crisis for British biodiversity.**

In addition to acting as an indicator of wider change, the moth declines may have other serious implications. Moths are important in ecosystems (see p. 4) and such widespread declines are likely to have detrimental knock-on effects on other organisms. Although the link between the decline of common moths and their predators and parasitoids has not been proven conclusively, there is a growing body of research that demonstrates such links amongst farmland birds and their insect prey[38].

[36] UK Biodiversity Action Group 1998
[37] Thomas *et al*. 2004

Another recent study found a strong correlation between farmland moth abundance and the activity of bats that feed mainly on moths[39]. The researchers suggest that increasing the numbers of key insect groups, such as moths, would increase numbers of bat predators. They also conclude that agricultural intensification has probably been a factor causing declines of moths and other insects that are key components in bat diets, and that this has led to reduced bat activity in the farmed countryside.

Common moths are part of the fabric of the British countryside. They occur in countless millions across the landscape from urban gardens to wild stretches of moor or coast, forming the biodiversity that we take for granted. And yet, like the House Sparrow and other common species that we once took for granted, we now know that many larger moths are declining at alarming rates and overall numbers are decreasing rapidly, with unforeseen but potentially serious consequences for ecosystems throughout Britain.

[38] Vickery *et al*. 2001, Benton *et al*. 2002, Barker 2004
[39] Wickramasinghe *et al*. 2004

The decline of common moths demands further research and conservation action. However, this cannot be achieved through standard conservation activities developed to protect rare and localised species (e.g. nature reserves). The fact that so many common and widespread species are declining so rapidly points strongly to patterns of large-scale environmental deterioration that will require large-scale solutions.

**Only measures that act at the landscape scale and improve agricultural and woodland habitats over large areas are likely to be successful. It is crucial, therefore, that measures to conserve moths and other widespread insects are integrated into Habitat Action Plans and new agri-environment schemes such as Entry Level Stewardship in England and Tir Cynnal in Wales.**

**The importance of long-term data sets**
The results presented in this report highlight the value of long-term biodiversity programmes such as the Rothamsted light-trap network. Although the use of skilled volunteers makes such schemes highly cost-effective, they still require ongoing commitment and resources. This is increasingly difficult against an ever-changing financial and political background and consequently long-term monitoring is rare. The Rothamsted network provides one of the longest-running and geographically extensive data sets of a species -rich insect group anywhere in the world.

**The revelation of such widespread moth declines merits increased investment in the Rothamsted monitoring network and further analysis to determine the causes of change. It also provides strong support for the development of a comprehensive national recording scheme for larger moths to underpin and target conservation effort.**

## Conclusions

How many moths will be left for future generations to enjoy? P.Pugh

Moths are an important part of our natural heritage; culturally, biologically and ecologically. Everyone can recognise moths; many have stunning colours and patterns and their study has been popular for over 300 years. There are many amateur recorders and interest in moths is growing rapidly. Moths are a diverse group of insects (around 2500 species) that make a significant contribution to our biodiversity. They are the only large group of insects for which it is feasible to assess trends and, therefore, moths are important indicators for the quality of natural heritage. Moths are important in ecosystems. Most birds, including the familiar garden species, and all bats feed on moths, as do many other mammals, insects and spiders.

The moth fauna of Britain is constantly changing, with small numbers of species colonising the country or becoming extinct each decade. Set against this small turnover of species is the dramatic new evidence, presented in this report, of a severe and widespread decline of moths. The unique data set available from the long-term monitoring of the Rothamsted light-trap network shows that the total number of moths captured nationally declined by almost a third between 1968 and 2002. Two thirds of the 337 individual species of common larger moth examined in detail had declined in abundance during that period. Over 20% of these common species have decreased so severely that they qualify as nationally threatened species under internationally-recognised criteria. Such widespread declines are likely to have serious detrimental knock-on effects on other organisms, and signal a wider biodiversity crisis.

A range of conservation actions are required to tackle the decline of Britain's moths, whether rare and threatened or common but rapidly declining. Above all, more information is needed on the distributions, trends and ecology of species. In addition to maintaining the Rothamsted network, a new national macro-moth recording scheme (see www.mothrecording.org.uk), covering all 900 or so larger moth species in the UK, is urgently needed to underpin efforts to reverse these significant declines.



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**Rosy Footman** *Miltochrista miniata* R.Leverton

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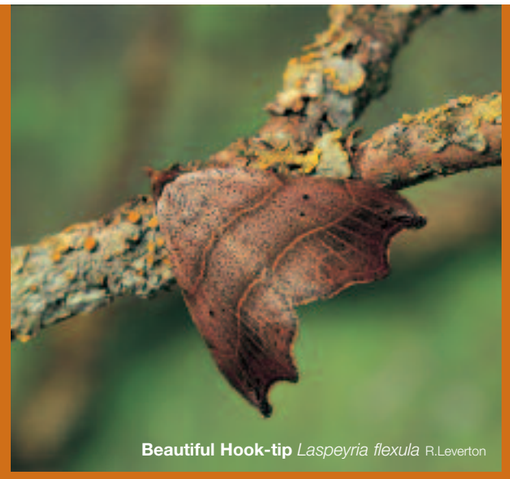
Butterfly Conservation
Saving butterflies, moths and their habitats

ROTHAMSTED RESEARCH

Funded by Esmée Fairbairn FOUNDATION

**Argent & Sable** *Rheumaptera hastata* D.Green



**Beautiful Hook-tip** *Laspeyria flexula* R.Leverton

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