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# Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis

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ABSTRACT

A fundamental problem in estimating biodiversity loss is that very little quantitative data are available for insects, which comprise more than two-thirds of terrestrial species. We present national population trends for a species-rich and ecologically diverse insect group: widespread and common macro-moths in Britain. Two-thirds of the 337 species studied have declined over the 35 yr study and 21% (71) of the species declined >30% 10 $yr^{-1}$. If IUCN (World Conservation Union) criteria are applied at the national scale, these 71 species would be regarded as threatened. The declines are at least as great as those recently reported for British butterflies and exceed those of British birds and vascular plants. These results have important and worrying implications for species such as insectivorous birds and bats, and suggests as-yet undetected declines may be widespread among temperate-zone insects.



## 1. Introduction

Insects are a vital component of terrestrial ecosystems and form a substantial proportion of terrestrial biodiversity. Despite this, knowledge of endangered insects lags behind that of vertebrates and vascular plants (New, 2004; Thomas et al., 2004). Whether recent extinction rates of insects are as great as for other groups has been debated keenly (Thomas and Morris, 1994; Lawton and May, 1995; McKinney, 1999). Most early estimates of insect extinction rates were much lower than those of birds, large mammals and plants, but attempts to quantify losses amongst insects were hampered by a lack of suitable data (Thomas and Morris, 1994; McKinney, 1999; New, 2004; Thomas et al., 2004).

Recently, Thomas et al. (2004) compared similarly measured changes in native butterfly, bird, and plant species and concluded that butterflies had declined more rapidly than these other groups in Britain; the first time such a comparison has been achieved for an insect taxon at the national scale. They proposed that if other insect groups are similarly sensitive to recent environmental change, then the unmeasured or under-recorded extinction rates of insects may rival or exceed those documented for vertebrates and plants (McKinney, 1999; Thomas et al., 2004). Furthermore, Thomas et al. (2004) argued that such high rates of extinction for insects would signal the 'sixth great extinction' (Wilson, 1992).

Here, we report severe national population declines among another intensively recorded insect group: the larger British moths, or 'macro-moths'. Thomas (2005) noted that long time series of species abundance should provide sensitive indicators of environmental change and cited the British marco-moths as one of three long-term datasets suitable for this purpose. In a previous paper (Conrad et al., 2004) we have described and validated our methodology for

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estimating long-term population trends for British macro-moths and outlined some general patterns in the trends based on ecological characteristics of the moth species. In this paper we apply IUCN (IUCN World Conservation Union, 2001) criteria to identify nationally threatened species and compare macro-moth species declines to those reported for UK butterflies (Thomas and Clarke, 2004; Thomas, 2005). While the utility of butterflies as indicators of insect biodiversity has been questioned (Hambler and Speight, 2004; but see Thomas and Clarke, 2004; Thomas, 2005), moths form a much more ecologically diverse and species-rich group and are thus more likely to represent a greater range of terrestrial insects in Britain. We suggest, therefore, that declines in common and widespread moths provide further evidence of wider declines in British terrestrial insects.

## 2. Methods

### 2.1. Data source and selection criteria

Population data on British macro-moths were extracted from the Rothamsted Insect Survey (RIS, Woiwod and Harrington, 1994), one of the longest-running and spatially extensive datasets of a species-rich insect group anywhere in the world (Conrad et al., 2004). Established in the early 1960s to provide information on the spatial variation of insect abundance, the RIS has operated a national network of approximately 100 standard light-traps (Williams, 1948) annually since 1968. These traps provide standardized, nightly counts of individual moth species from a wide range of habitats (Woiwod and Harrington, 1994; Conrad et al., 2004). Catches are small, but consistent and representative, making the traps suitable for long-term monitoring of common and widespread species without affecting the moth populations being sampled (Williams, 1952; Taylor and French, 1974; Conrad et al., 2004). We analysed data for 337 species, each of which was represented by more than 500 individuals captured over the 35-yr sampling period (1968–2002), and derived annual national indices of abundance from the 199 sites that operated for a minimum of 48 weeks a year for 5 yr (Conrad et al., 2004).

### 2.2. Estimates of abundance and population change

We estimated indices of annual abundance, allowing for differences between sites, by fitting a generalised linear model with Poisson errors and logarithmic link, using version 3.2 of the TRIM (TRends and Indices for Monitoring data) software package (Pannekoek and Van Strien, 2001). By convention, the estimated abundance in the first year is set to one and each annual index, $A_i$, for year $i$, is calculated relative to the first, $A_1$. $T$, the 'TRIM trend index' is the overall slope of the regression of annual indices on a logarithmic scale (Pannekoek and Van Strien, 2001). $T$ is a reliable and robust estimator of long-term trends that is suitable for comparisons across a range of species (Van Strien et al., 2001; Conrad et al., 2004). Annual rates of population change were calculated from $T$ and 10-yr percentage declines were estimated from the annual rates of change (Van Strien et al., 2001).

We considered species population decline rates >30% 10 $yr^{-1}$ to be of significant conservation concern. We further divided these rapidly declining species into two categories: vulnerable (30–50% 10 $yr^{-1}$) and endangered (>50% 10 $yr^{-1}$), according to the criteria and time period used to identify globally Vulnerable and Endangered species (IUCN World Conservation Union, 2001). Following the guidelines of Gardenfors et al. (2001), we applied the IUCN thresholds unaltered at the national level because the British populations can be regarded as effectively isolated, insular populations and their extinction risk is unlikely to be affected by populations in continental Europe (i.e., there is unlikely to be any significant 'rescue effect').

### 2.3. Regional variation

In order to assess geographical variation in population trends for common macro-moths we divided Great Britain into two regions along the 4500 N gridline of the British national grid system. The region to the north of 4500 N was called 'North' (N), and the region to the south of 4500 N was called 'South' (S). This division into regions was arbitrary but gave a reasonable number and distribution of sites for analysis in each region. More importantly, it provides the first steps in examining a number of species trends for the influences of climate change and changes in land-use already demonstrated to affect the decline of the once-common moth, *Arctia caja* (Conrad et al., 2002, 2003).

### 2.4. Comparison of short-term and long-term trap data

While the core number and geographical distribution of traps never changes significantly from year to year, there has been turnover of trapping sites during the 35 yr of our study (Conrad et al., 2004). In order to examine the effect of this turnover on our population trend estimates we calculated 10-yr percentage population changes using only traps that operated for 15 or more years and compared the results with those from our standard 'all sites' analysis, which used trapping sites that had operated for five or more years.

### 2.5. Light competition

'Astronomical light pollution' results from the cumulative effects of artificial lighting sources increasing the illumination of the night-time sky (Longcore and Rich, 2004) and may compete with light-traps and decrease their effectiveness. An increase in astronomical light pollution during our study period could thus decrease trap catches and lead to overestimates of downward population trends.

To examine the effects of 'light competition' on our trap catches, we obtained 'world change pair' images of the night-time sky from the Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS) dataset, provided by the US The National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Centre (NGDC) (http://dmsp.ngdc.noaa.gov/html/download_world_change_pair.html). These images provide estimates of average annual night-time illumination of the earth's surface for the years 1992/93 and 2000. Illumination is recorded as pixels on a linear scale from 0 (dark) to 63 (instrument light saturation) (Elvidge et al., 2001). We selected the 116 RIS light-traps running between 1992 and 2000, and extracted the night-time

illumination of the ~1 km$^2$ pixel containing each trap in 1992/93 and 2000. We divided the traps into two groups: 'dark', which included 35 trapping sites which scored 0 in 1992/93 and remained 0, or scored >0 in 1992/93 but were darker in 2000, and 'light' which comprised 81 sites that were >0 in 1992/93 and were lighter in 2000 (no sites initially >0 remained unchanged). We then estimated, for each of the two groups, the annual rate of change in total trap catch of the 337 moth species in this study for the period 1992–2000.

## 3. Results

### 3.1. *Rates of change of moth abundance and regional variation*

We found alarming declines in the overall abundance of widespread marco-moths. The annual total number of all macro-moths caught by the RIS light-trap network decreased by 31% over the 35-yr sampling period (Fig. 1). The majority of this decrease occurred in southern Britain, while the north showed no significant trend over time (Fig. 1). Year-to-year fluctuations in abundance are very similar in both the north and south despite the difference in overall trends (Fig. 1).

Two-thirds (0.66 ± 0.05, proportion ±95% CI) of the 337 individual moth species declined (Fig. 2). The median 10-yr population change was a decrease of 12% with a greater median decrease in the south (17%) than in the north (5%; Fig. 2). Of even greater concern, 21% ($N = 71$) of species displayed declines placing them in the vulnerable or endangered categories (Fig. 2). The total catch of each species and the trend index, $T$, were not correlated ($r = 0.020$, $N = 337$, $P = 0.714$; Fig. 3), so the total number of individuals captured did not affect whether a species was likely to increase or decline. Overall, 75% of species in the south declined compared to 55% in the north (Fig. 2).

### 3.2. *Land-use categories represented*

Although the light-trap network originated from an agricultural research station (Woiwod and Harrington, 1994), it was not intended to monitor agricultural pest species and a wide range of land-use categories have been sampled (Fig. 4). Because of trap turnover, the relative numbers of different types of biotope sampled each year varies over time (Fig. 4). The mean annual proportions of sites used corresponded with the following categories: coastal (8.9%); farmland (13.5%); mixed (15.3%); moorland (3.1%); parkland (22.8%); scrubland (2.6%); urban (15.9%) and woodland (17.8%). Only the proportion of scrubland changed significantly over time ($F_{1,33} = 30.34$, $P < 0.001$), and this is largely because no traps were sited in areas that were categorised as scrubland in the early years of the study. Annual variation in biotopes sampled was not systematically biased in any way.

### 3.3. *Comparison of short-term and long-term trap data*

Estimates for 222 decreasing species were obtained from sites that ran 15 or more years. These estimates were highly correlated with those from the 'all sites' analysis ($r = 0.95$, $N = 222$, $P = <0.001$), suggesting that light-trap turnover did not bias the results. Using only long-term trap sites to calculate trends had little impact on assigning species to the vulnerable and endangered categories (Fig. 5). A similar result was obtained when sites running 20 or more years were used (Conrad et al., 2004). Therefore, the all-sites analysis was used because it provides greater spatial coverage, larger sample sizes for individual species and enables estimates for a greater number of less common species.

### 3.4. *Light competition*

Contrary to expectation, the annual index of total trap catch (slope ± SE) at 'dark' sites (−0.044 ± 0.007) decreased marginally more than at 'light' sites (−0.035 ± 0.005) although the difference between these slopes was not significant ($t_{38} = 0.97$, $P = 0.34$). The decrease in total macro-moths captured was therefore as great or greater at sites that remained dark or became darker than at those where night-time illumination increased between 1992 and 2000. In addition, annual estimates

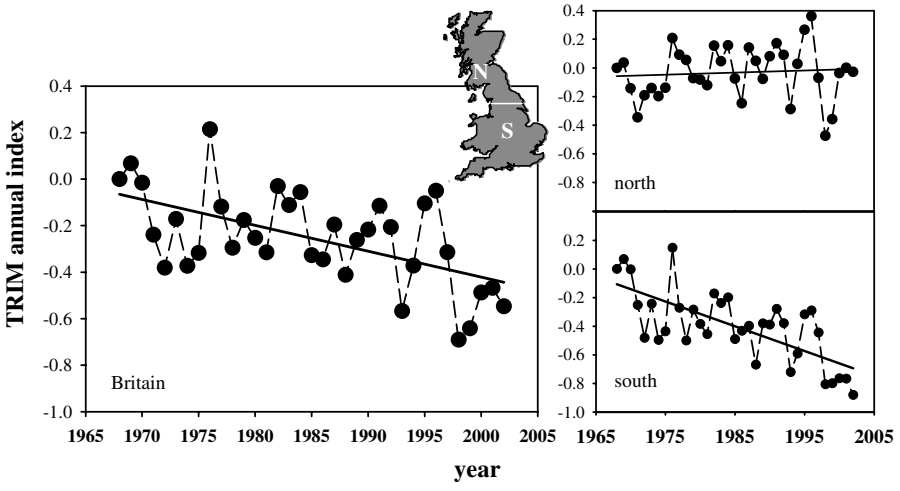


**Fig. 1 – Decreases in total annual trap catches for all species. The decrease for Great Britain is significant ($t_{33} = 8.83$, $P < 0.001$), as is the decrease in the south ($t_{33} = 10.9$, $P < 0.001$), and represent 31% and 44% decreases in total macro-moths caught, respectively. Trap catches have increased by 5% in the north, but this trend is not significant ($t_{33} = 0.67$, $P = 0.51$).**

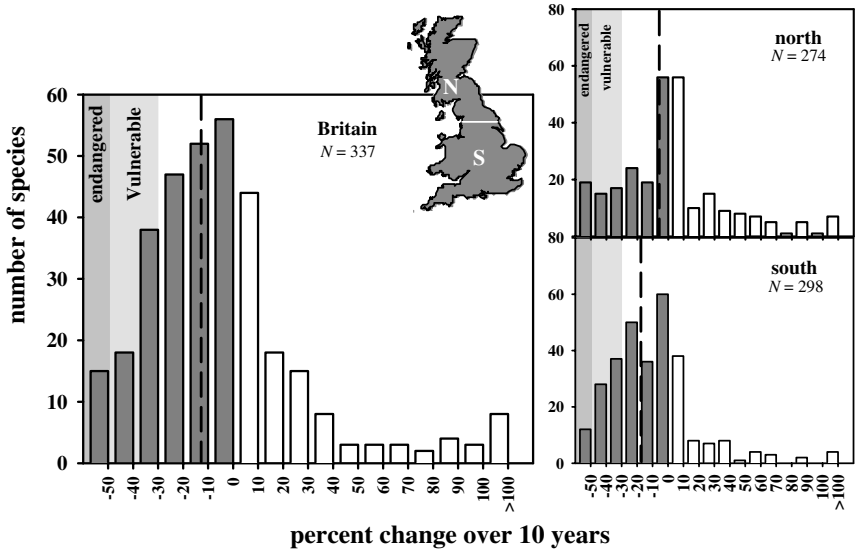


**Fig. 2 – Frequency distributions of changes in abundance of British macro-moths. The figures plotted are the percentage changes over a 10-yr period, calculated from the annual rate of change estimated from long-term trends from 1968–2002. The vertical dashed line shows the median 10-yr change. *X*-axis labels are the upper limits of each class. Shaded areas correspond with the criteria thresholds for threatened species in the vulnerable and endangered categories.**

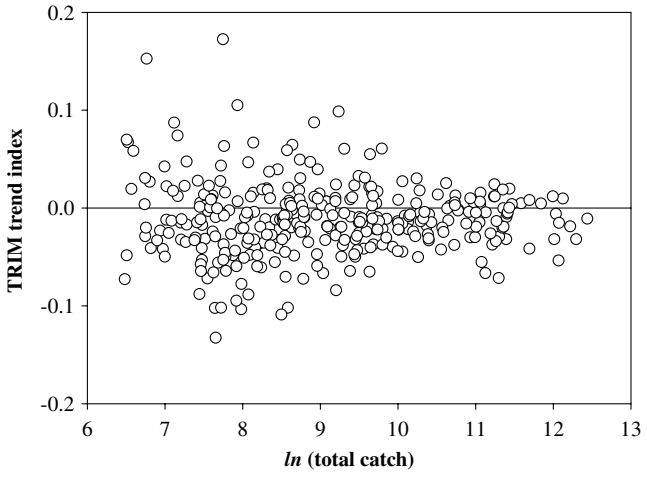


**Fig. 3 – TRIM trend index versus the natural logarithm of total trap catch for each of the 337 species in the study. Frequently captured species are no more or less likely to decline or increase than less common species.**

of abundance were very similar between groups. This indicates that the declines in moth abundance observed over the course of our study are not caused by decreased effectiveness of RIS light-traps due to increasing light competition, but does not preclude the possibility that light pollution has been a cause of moth population declines (Frank, 1988).

## 4. Discussion

This study has, for the first time, shown that the so-called "common and widespread" macro-moth species in Britain are undergoing severe population declines. These estimates of population change represent a wide variety of biotopes, are robust to trap turnover, are not affected by light competition and are independent of total catches for individual species.

The overall pattern of decline for so many species points to a widespread deterioration of suitable environmental conditions across the country. The deterioration has been most severe in the south of England where the rapid intensification of agriculture and forestry already has been implicated in the decline of butterflies, especially in the southeast (Warren et al., 2001). However, the fact that a large proportion of species are declining rapidly in both north and south Britain (Fig. 2) indicates that adverse environmental changes are impacting moth populations across the country.

The IUCN categories of threat are widely used to prepare 'Red lists' of threatened species and have become an important tool to identify ecological problems and guide conservation action (Mace and Lande, 1991; IUCN World Conservation Union, 2001; Dunn, 2002). While the quantitative data on population dynamics demanded by IUCN categories are lacking for almost all moths and other insects that are currently of conservation concern around the world (New, 2004), the extensive RIS dataset did allow us to determine, quantitatively, 10-yr rates of population change of a large group of British macro-moths. Following the criteria of the IUCN categories in our study provides a well-recognized scale of the severity of moth population declines.

In this study we found 71 common moth species that are declining at rates that should see them designated as endangered or vulnerable if the quantitative IUCN criteria are applied at the national scale (Gardenfors et al., 2001; Eaton et al., 2005). None of the threatened species is known for long-distance migrations and it is unlikely that the declining populations can be "rescued" by continental migrants.

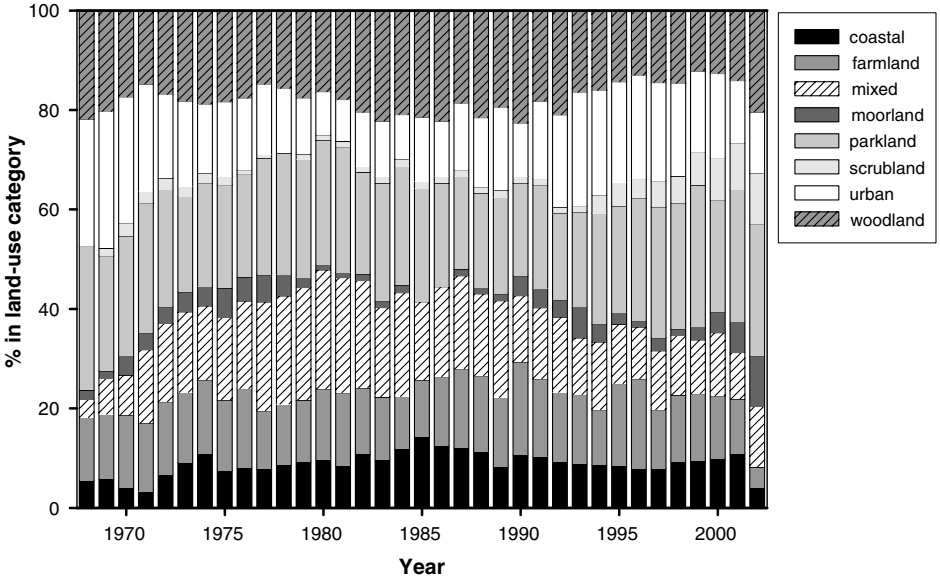


**Fig. 4 – Annual proportions of land-use categories for light-traps used in the study.**

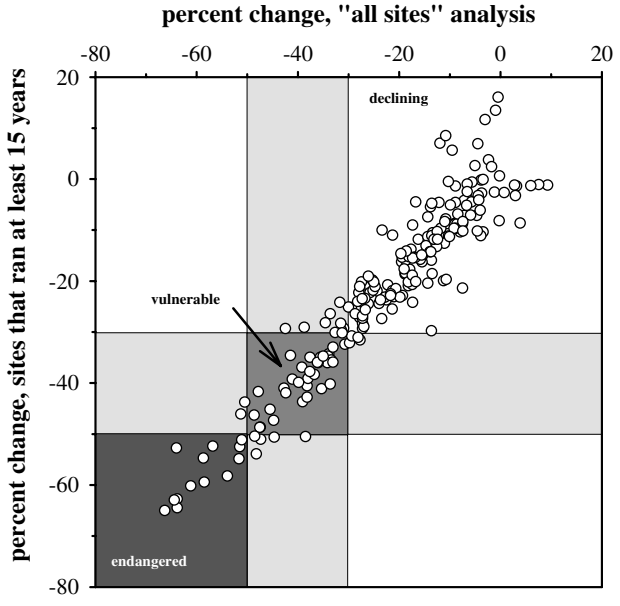


**Fig. 5 – Comparison of 10-yr trends estimated by analysis of all light-trap sites and only using sites that operated for at least 15 yr. The four areas shaded pale grey delineate regions of assignment of rapid-decline categories between the two methods of estimating trends.**

Even so, it is more important that the magnitude of the declines are sufficient that the species *could* be considered for threatened status. The number of potentially threatened species in this study is more than double the published British Red Data Book list of 33 species (Shirt, 1987), none of which was included in our analysis. This finding suggests we may be seriously underestimating the proportion of threatened British insects.

Designation of threatened status for common and widespread species on the basis of population decline rates alone has been criticized (Dunn, 2002) and the method of applying IUCN criteria at national rather than global scales is still being formalised, although their utility has been recognised (Gardenfors et al., 2001; Dunn, 2002; Eaton et al., 2005). Nevertheless, it is important that monitoring effort is directed toward understanding population changes among common species as well as rare ones (Conrad et al., 2002; Dunn, 2002). Common species may undergo dramatic population changes that go largely unnoticed by recorders and conservation managers, but which could provide valuable information for conservation and ecological studies (Thomas and Abery, 1995; Cowley et al., 1999; Leon-Cortes et al., 1999). Common species should represent a greater variety of habitats and species interactions and therefore play an important role in ecosystem functioning.

A brief examination of moth population trends in relation to ecological and life-history traits identified few significant associations and declines are taking place in a wide variety of biotopes (Conrad et al., 2004). While widely distributed species are more likely to be declining, increasing species are likely to be those that are expanding their range as well as increasing in abundance, and are often species apparently benefiting from human activity, such as those feeding on ornamental conifers (Conrad et al., 2004). The causes of long-term trends identified in this study are yet to be assessed in detail, and are likely to be a complex mixture of factors influencing the quantity, quality and spatial distribution of suitable habitat (e.g., land management, chemical and light pollution, climatic conditions). Causes of decline will also undoubtedly vary from species to species.

All of the moth species in our study are common and widespread. Truly specialised species, such as have been described for British butterflies (Warren et al., 2001) are too uncommon and too locally distributed (Quinn et al., 1997) to have been caught in sufficient numbers to be used in our analysis and are therefore under-represented. If, like specialist butterflies (Warren et al., 2001), these species are more

likely to be declining, then we have underestimated the overall proportions of declining macro-moths.

Half of the species we studied experienced a 10-yr decline of at least 12%, and while the precise comparison of trends between different sampling methods is difficult and may give misleading results (Thomas, 1996) our results suggest that British macro-moths have undergone declines at least as severe as British butterflies (Thomas et al., 2004). Moreover, the percentage of moth species declining (66%) was similar to the proportion of butterflies declining (71%), and greater than the proportion of birds (54%) or plants declining (28%) (Thomas et al., 2004; Eaton et al., 2005). Thus, our findings support the view that insect biodiversity is declining very rapidly in Britain and probably at a greater rate than vertebrates and vascular plants (Thomas et al., 2004), with potentially serious consequences for ecosystem services.

Common macro-moths have undergone widespread and serious declines in Britain. Environmental changes that affect common and widespread herbivores, such as the macro-moths reported here, signal strong impacts on the wider ecosystem and at higher trophic levels such as predacious insects, insectivorous spiders, birds and bats (Pollard and Yates, 1993; Ormerod and Watkinson, 2000; Donald et al., 2001; Wickramasinghe et al., 2004). Compared to UK butterflies (Thomas et al., 2004), the macro-moths in this study include a greater number of species from a wider range of habitats and, therefore are more likely to be representative of terrestrial insect biodiversity. However, the observed declines of macro-moths, taken together with those of butterfly species, signal a biodiversity crisis for Britain and are a strong indicator that insects may be facing great losses in other temperate-zone industrialised countries. As yet, even correlative evidence of factors driving long-term moth population trends is lacking, but having identified so many decreasing trends, the next priority is to examine the relative roles of climate, chemical and light pollution, and changes in land-use in greater detail.

## Acknowledgements

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## Appendix A. List of species studied with rates of annual population change

Number = "Bradley number", from Checklist of Lepidoptera recorded from the British Isles (Bradley, 2000); annual change rate = annual rate of population change estimated from the 35-yr time series (see methods); 95% CI = 95% confidence interval for the annual change rate; change status: increasing = change rate >0, declining = change rate <0, vulnerable = greater than 30% · 10 $yr^{-1}$ decline, endangered = greater than 50% 10 $yr^{-1}$ decline.

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 14 | Ghost Swift | *Hepialus humuli* | −0.036 | −0.027, −0.046 | Vulnerable |
| 15 | Orange Swift | *Hepialus sylvina* | 0.023 | 0.031, 0.015 | Increasing |
| 17 | Common Swift | *Hepialus lupulinus* | −0.005 | 0.003, −0.013 | Declining |
| 18 | Map-Winged Swift | *Hepialus fusconebulosa* | −0.014 | −0.007, −0.022 | Declining |
| 1631 | December Moth | *Poecilocampa populi* | −0.030 | −0.025, −0.034 | Declining |
| 1632 | Pale Eggar | *Trichiura crataegi* | −0.054 | −0.042, −0.065 | Vulnerable |
| 1634 | The Lackey | *Malacosoma nuestria* | −0.063 | −0.044, −0.082 | Vulnerable |
| 1640 | The Drinker | *Euthrix potatoria* | −0.007 | 0.000, −0.015 | Declining |
| 1645 | Scalloped Hook-Tip | *Falcaria lacertinaria* | −0.021 | −0.013, −0.028 | Declining |
| 1646 | Oak Hook-Tip | *Drepana binaria* | −0.047 | −0.033, −0.061 | Vulnerable |
| 1648 | Pebble Hook-Tip | *Drepana falcataria* | −0.020 | −0.012, −0.027 | Declining |
| 1651 | Chinese Character | *Cilix glaucata* | −0.018 | −0.011, −0.024 | Declining |
| 1652 | Peach Blossom | *Thyatira batis* | −0.028 | −0.020, −0.036 | Declining |
| 1653 | Buff Arches | *Habrosyne pyritoides* | −0.034 | −0.026, −0.043 | Declining |
| 1657 | Common Lutestring | *Ochropacha duplaris* | 0.031 | 0.044, 0.018 | Increasing |
| 1658 | Oak Lutestring | *Cymatophorima diluta* | −0.048 | −0.023, −0.072 | Vulnerable |
| 1659 | Yellow-Horned | *Achlya flavicornis* | 0.015 | 0.022, 0.008 | Increasing |
| 1663 | March Moth | *Alsophila aescularia* | −0.013 | −0.008, −0.019 | Declining |
| 1665 | Grass Emerald | *Pseudoterpna pruinata* | −0.030 | −0.016, −0.044 | Declining |
| 1666 | Large Emerald | *Geometra papilionaria* | 0.009 | 0.016, 0.002 | Increasing |
| 1667 | Blotched Emerald | *Comibaena bajularia* | −0.008 | 0.013, −0.029 | Declining |
| 1669 | Common Emerald | *Hemithea aestivaria* | −0.008 | −0.002, −0.014 | Declining |

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 1673 | Small Emerald | *Hemistola chrysoprasaria* | −0.049 | −0.023, −0.074 | Vulnerable |
| 1674 | Little Emerald | *Jodis lactearia* | −0.002 | 0.007, −0.010 | Declining |
| 1677 | Birch Mocha | *Cyclophora albipunctata* | −0.020 | −0.002, −0.038 | Declining |
| 1680 | Maiden's Blush | *Cyclophora punctaria* | 0.028 | 0.046, 0.011 | Increasing |
| 1682 | Blood-Vein | *Timandra griseata* | −0.043 | −0.037, −0.049 | Vulnerable |
| 1689 | Mullein Wave | *Scopula marginepunctata* | −0.040 | −0.021, −0.059 | Vulnerable |
| 1690 | Small Blood-Vein | *Scopula imitaria* | −0.028 | −0.021, −0.035 | Declining |
| 1692 | Lesser Cream Wave | *Scopula immutata* | −0.003 | 0.023, −0.029 | Declining |
| 1693 | Cream Wave | *Scopula floslactata* | −0.009 | −0.003, −0.015 | Declining |
| 1694 | Smoky Wave | *Scopula ternata* | −0.006 | 0.017, −0.030 | Declining |
| 1699 | Least Carpet | *Idaea vulpinaria* | 0.188 | 0.248, 0.128 | Increasing |
| 1702 | Small Fan-Footed Wave | *Idaea biselata* | −0.006 | −0.001, −0.011 | Declining |
| 1705 | Dwarf Cream Wave | *Idaea fuscovenosa* | 0.048 | 0.062, 0.034 | Increasing |
| 1707 | Small Dusty Wave | *Idaea seriata* | 0.013 | 0.022, 0.003 | Increasing |
| 1708 | Single-Dotted Wave | *Idaea dimidiata* | 0.013 | 0.019, 0.007 | Increasing |
| 1709 | Satin Wave | *Idaea subsericeata* | −0.012 | −0.001, −0.023 | Declining |
| 1711 | Treble Brown-Spot | *Idaea trigeminata* | 0.104 | 0.117, 0.090 | Increasing |
| 1712 | Small Scallop | *Idaea emarginata* | −0.009 | −0.001, −0.017 | Declining |
| 1713 | Riband Wave | *Idaea aversata* | 0.005 | 0.009, 0.001 | Increasing |
| 1715 | Plain Wave | *Idaea straminata* | 0.043 | 0.079, 0.008 | Increasing |
| 1716 | The Vestal | *Rhodometra sacraria* | 0.060 | 0.120, 0.000 | Increasing |
| 1719 | Oblique Carpet | *Orthonama vittata* | −0.050 | −0.034, −0.065 | Vulnerable |
| 1722 | Flame Carpet | *Xanthorhoe designata* | 0.018 | 0.026, 0.010 | Increasing |
| 1723 | Red Carpet | *Xanthorhoe munitata* | −0.046 | −0.035, −0.057 | Vulnerable |
| 1724 | Red Twin-Spot Carpet | *Xanthorhoe spadicearia* | −0.016 | −0.010, −0.022 | Declining |
| 1725 | Dark-Barred Twin-Spot | *Xanthorhoe ferrugata* | −0.069 | −0.062, −0.076 | Endangered |
| 1726 | Large Twin-Spot Carpet | *Xanthorhoe quadrifasiata* | −0.010 | 0.001, −0.021 | Declining |
| 1727 | Silver-Ground Carpet | *Xanthorhoe montanata* | −0.015 | −0.010, −0.020 | Declining |
| 1728 | Garden Carpet | *Xanthorhoe fluctuata* | −0.033 | −0.028, −0.038 | Declining |
| 1732 | Shaded Broad-Bar | *Scotopteryx chenopodiata* | −0.037 | −0.029, −0.045 | Vulnerable |
| 1738 | Common Carpet | *Epirrhoe alternata* | −0.004 | 0.002, −0.010 | Declining |
| 1739 | Wood Carpet | *Epirrhoe rivata* | 0.001 | 0.017, −0.014 | Increasing |
| 1740 | Galium Carpet | *Epirrhoe galiata* | −0.040 | −0.019, −0.062 | Vulnerable |
| 1742 | Yellow Shell | *Camptogramma bilineata* | 0.019 | 0.029, 0.009 | Increasing |
| 1744 | Grey Mountain Carpet | *Entephria caesiata* | −0.044 | −0.024, −0.064 | Vulnerable |
| 1745 | The Mallow | *Larentia clavaria* | −0.009 | 0.001, −0.020 | Declining |
| 1746 | Shoulder Stripe | *Anticlea badiata* | −0.032 | −0.026, −0.038 | Declining |
| 1747 | The Streamer | *Anticlea derivata* | −0.019 | −0.012, −0.026 | Declining |
| 1748 | Beautiful Carpet | *Mesoleuca albicillata* | 0.004 | 0.024, −0.016 | Increasing |
| 1749 | Dark Spinach | *Pelurga comitata* | −0.085 | −0.061, −0.108 | Endangered |
| 1750 | Water Carpet | *Lampropteryx suffumata* | 0.005 | 0.012, −0.002 | Increasing |
| 1751 | Devon Carpet | *Lampropteryx otregiata* | 0.069 | 0.118, 0.020 | Increasing |
| 1752 | Purple Bar | *Cosmorhoe ocellata* | −0.007 | −0.001, −0.012 | Declining |
| 1753 | Striped Twin-Spot Carpet | *Nebula salicata* | −0.010 | 0.010, −0.030 | Declining |
| 1754 | The Phoenix | *Eulithis prunata* | 0.012 | 0.026, −0.002 | Increasing |
| 1755 | The Chevron | *Eulithis testata* | −0.015 | −0.007, −0.022 | Declining |
| 1756 | Northern Spinach | *Eulithis populata* | 0.019 | 0.023, 0.015 | Increasing |
| 1757 | The Spinach | *Eulithis mellinata* | −0.084 | −0.060, −0.108 | Endangered |
| 1758 | Barred Straw | *Eulithis pyraliata* | −0.020 | −0.014, −0.026 | Declining |
| 1759 | Small Phoenix | *Ecliptopera silaceata* | −0.042 | −0.035, −0.049 | Vulnerable |
| 1760 | Red–green Carpet | *Chloroclysta siterata* | 0.057 | 0.067, 0.047 | Increasing |
| 1761 | Autumn Green Carpet | *Chloroclysta miata* | −0.014 | −0.005, −0.023 | Declining |
| 1762 | Dark Marbled Carpet | *Chloroclysta citrata* | 0.012 | 0.019, 0.005 | Increasing |
| 1764 | Common Marbled Carpet | *Chloroclysta truncata* | −0.019 | −0.014, −0.024 | Declining |
| 1765 | Barred Yellow | *Cidaria fulvata* | −0.010 | −0.003, −0.018 | Declining |

(*continued on next page*)

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 1766 | Blue-Bordered Carpet | *Plemyria rubiginata* | 0.049 | 0.065, 0.032 | Increasing |
| 1767 | Pine Carpet | *Thera firmata* | 0.038 | 0.051, 0.025 | Increasing |
| 1768 | Grey Pine Carpet | *Thera obeliscata* | 0.005 | 0.011, −0.002 | Increasing |
| 1769 | Spruce Carpet | *Thera britannica* | 0.067 | 0.090, 0.044 | Increasing |
| 1771 | Juniper Carpet | *Thera juniperata* | 0.077 | 0.120, 0.034 | Increasing |
| 1773 | Broken-Barred Carpet | *Electrophaes corylata* | −0.007 | 0.004, −0.018 | Declining |
| 1775 | Mottled Grey | *Colostygia multistrigaria* | −0.026 | −0.019, −0.034 | Declining |
| 1776 | Green Carpet | *Colostygia pectinataria* | 0.026 | 0.033, 0.018 | Increasing |
| 1777 | July Highflyer | *Hydriomena furcata* | 0.012 | 0.018, 0.006 | Increasing |
| 1778 | May Highflyer | *Hydriomena impluviata* | −0.005 | 0.010, −0.020 | Declining |
| 1781 | Small Waved Umber | *Horisme vitalbata* | 0.014 | 0.033, −0.005 | Increasing |
| 1782 | The Fern | *Horisme tersata* | −0.015 | 0.003, −0.032 | Declining |
| 1784 | Pretty Chalk Carpet | *Melanthia procellata* | −0.056 | −0.038, −0.074 | Vulnerable |
| 1789 | Scallop Shell | *Rheumaptera undulata* | −0.017 | −0.002, −0.031 | Declining |
| 1792 | Dark Umber | *Philereme transversata* | −0.034 | −0.021, −0.048 | Declining |
| 1794 | Sharp-Angled Carpet | *Euphyia unangulata* | −0.031 | −0.019, −0.042 | Declining |
| 1795 | November Moth | *Epirrita dilutata* | −0.031 | −0.027, −0.036 | Declining |
| 1797 | Autumnal Moth | *Epirrita autumnata* | −0.011 | −0.001, −0.020 | Declining |
| 1798 | Small Autumnal Moth | *Epirrita filigrammaria* | −0.022 | 0.040, −0.084 | Declining |
| 1799 | Winter Moth | *Operophtera brumata* | −0.004 | 0.003, −0.012 | Declining |
| 1800 | Northern Winter Moth | *Operophtera fagata* | −0.011 | −0.001, −0.020 | Declining |
| 1802 | The Rivulet | *Perizoma affinitata* | −0.015 | −0.006, −0.024 | Declining |
| 1803 | Small Rivulet | *Perizoma alchemillata* | −0.003 | 0.009, −0.014 | Declining |
| 1807 | Grass Rivulet | *Perizoma albulata* | −0.090 | −0.067, −0.113 | Endangered |
| 1808 | Sandy Carpet | *Perizoma flavofasciata* | −0.005 | 0.003, −0.013 | Declining |
| 1809 | Twin-Spot Carpet | *Perizoma didymata* | 0.028 | 0.036, 0.019 | Increasing |
| 1858 | V-Pug | *Chloroclystis v-ata* | 0.009 | 0.022, −0.004 | Increasing |
| 1864 | The Streak | *Chesias legatella* | −0.042 | −0.033, −0.051 | Vulnerable |
| 1865 | Broom-Tip | *Chesias rufata* | −0.052 | −0.022, −0.081 | Vulnerable |
| 1867 | Treble-Bar | *Aplocera plagiata* | −0.032 | −0.021, −0.044 | Declining |
| 1873 | Welsh Wave | *Venusia cambrica* | 0.005 | 0.021, −0.010 | Increasing |
| 1874 | Dingy Shell | *Euchoeca nebulata* | 0.020 | 0.065, −0.026 | Increasing |
| 1875 | Small White Wave | *Asthena albulata* | 0.001 | 0.030, −0.028 | Increasing |
| 1881 | Early Tooth-Striped | *Trichopteryx carpinata* | 0.032 | 0.041, 0.022 | Increasing |
| 1882 | Small Seraphim | *Pterapherapteryx sexalata* | −0.033 | −0.015, −0.051 | Declining |
| 1883 | Yellow-Barred Brindle | *Acasis viretata* | 0.023 | 0.036, 0.011 | Increasing |
| 1884 | The Magpie | *Abraxas grossulariata* | −0.033 | −0.025, −0.040 | Declining |
| 1887 | Clouded Border | *Lomaspilis marginata* | −0.004 | 0.001, −0.010 | Declining |
| 1888 | Scorched Carpet | *Ligdia adustata* | −0.020 | −0.011, −0.029 | Declining |
| 1889 | Peacock | *Semiothisa notata* | 0.091 | 0.132, 0.050 | Increasing |
| 1890 | Sharp-Angled Peacock | *Semiothisa alternaria* | −0.013 | 0.001, −0.027 | Declining |
| 1893 | Tawny-Barred Angle | *Semiothisa liturata* | 0.002 | 0.012, −0.008 | Increasing |
| 1894 | Latticed Heath | *Semiothisa clathrata* | −0.058 | −0.048, −0.067 | Vulnerable |
| 1897 | The V-Moth | *Semiothisa wauaria* | −0.097 | −0.072, −0.122 | Endangered |
| 1902 | Brown Silver-Lines | *Petrophora chlorosata* | −0.005 | 0.000, −0.009 | Declining |
| 1903 | Barred Umber | *Plagodis pulveraria* | 0.021 | 0.031, 0.011 | Increasing |
| 1904 | Scorched Wing | *Plagodis dolabraria* | 0.002 | 0.010, −0.005 | Increasing |
| 1906 | Brimstone Moth | *Opisthograptis luteolata* | −0.013 | −0.009, −0.017 | Declining |
| 1907 | Bordered Beauty | *Epione repandaria* | −0.008 | 0.000, −0.016 | Declining |
| 1910 | Lilac Beauty | *Apeira syringaria* | −0.031 | −0.023, −0.040 | Declining |
| 1912 | August Thorn | *Ennomos quercinaria* | −0.047 | −0.033, −0.061 | Vulnerable |
| 1913 | Canary-Shouldered Thorn | *Ennomos alniaria* | −0.030 | −0.024, −0.036 | Declining |
| 1914 | Dusky Thorn | *Ennomos fuscantaria* | −0.103 | −0.088, −0.119 | Endangered |
| 1915 | September Thorn | *Ennomos erosaria* | −0.068 | −0.056, −0.080 | Endangered |
| 1917 | Early Thorn | *Selenia dentaria* | −0.026 | −0.022, −0.030 | Declining |
| 1918 | Lunar Thorn | *Selenia lunularia* | −0.015 | −0.005, −0.026 | Declining |

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 1919 | Purple Thorn | *Selenia tetralunaria* | −0.032 | −0.024, −0.041 | Declining |
| 1920 | Scalloped Hazel | *Odontopera bidentata* | −0.004 | 0.001, −0.009 | Declining |
| 1921 | Scalloped Oak | *Crocallis elinguaria* | −0.031 | −0.026, −0.035 | Declining |
| 1922 | Swallow-Tail Moth | *Ourapteryx sambucaria* | −0.024 | −0.018, −0.031 | Declining |
| 1923 | Feathered Thorn | *Colotois pennaria* | −0.024 | −0.019, −0.029 | Declining |
| 1926 | Pale Brindled Beauty | *Apocheima pilosaria* | −0.022 | −0.012, −0.032 | Declining |
| 1927 | Brindled Beauty | *Lycia hirtaria* | −0.046 | −0.038, −0.055 | Vulnerable |
| 1930 | Oak Beauty | *Biston strataria* | −0.003 | 0.004, −0.011 | Declining |
| 1931 | Peppered Moth | *Biston betularia* | −0.027 | −0.018, −0.035 | Declining |
| 1932 | Spring Usher | *Agriopis leucophaearia* | 0.010 | 0.034, −0.015 | Increasing |
| 1933 | Scarce Umber | *Agriopis aurantiaria* | −0.028 | −0.018, −0.039 | Declining |
| 1934 | Dotted Border | *Agriopis marginaria* | −0.022 | −0.017, −0.027 | Declining |
| 1935 | Mottled Umber | *Erannis defoliaria* | 0.000 | 0.012, −0.012 | Increasing |
| 1937 | Willow Beauty | *Peribatodes rhomboidaria* | −0.015 | −0.009, −0.022 | Declining |
| 1940 | Satin Beauty | *Deileptenia ribeata* | 0.111 | 0.153, 0.069 | Increasing |
| 1941 | Mottled Beauty | *Alcis repandata* | 0.010 | 0.015, 0.005 | Increasing |
| 1942 | Dotted Carpet | *Alcis jubata* | 0.062 | 0.077, 0.048 | Increasing |
| 1944 | Pale Oak Beauty | *Serraca punctinalis* | 0.007 | 0.022, −0.009 | Increasing |
| 1945 | Brussels Lace | *Cleorodes lichenaria* | −0.011 | 0.011, −0.034 | Declining |
| 1947 | The Engrailed | *Ectropis bistortata* | 0.003 | 0.009, −0.003 | Increasing |
| 1950 | Brindled White-Spot | *Paradarisa extersaria* | −0.008 | 0.014, −0.029 | Declining |
| 1951 | Grey Birch | *Aethalura punctulata* | 0.000 | 0.019, −0.020 | Declining |
| 1954 | Bordered White | *Bupalus piniaria* | −0.011 | 0.004, −0.027 | Declining |
| 1955 | Common White Wave | *Cabera pusaria* | 0.016 | 0.021, 0.011 | Increasing |
| 1956 | Common Wave | *Cabera exanthemata* | 0.006 | 0.011, 0.000 | Increasing |
| 1957 | White-Pinion Spotted | *Lomographa bimaculata* | 0.010 | 0.031, −0.011 | Increasing |
| 1958 | Clouded Silver | *Lomographa temerata* | −0.018 | −0.012, −0.025 | Declining |
| 1961 | Light Emerald | *Campaea margaritata* | 0.007 | 0.011, 0.002 | Increasing |
| 1962 | Barred Red | *Hylaea fasciaria* | 0.003 | 0.010, −0.005 | Increasing |
| 1981 | Poplar Hawk-Moth | *Laothoe populi* | −0.007 | −0.001, −0.012 | Declining |
| 1994 | Buff-Tip | *Phalera bucephala* | −0.022 | −0.012, −0.031 | Declining |
| 2000 | Iron Prominent | *Notodonta dromedarius* | −0.012 | 0.001, −0.025 | Declining |
| 2003 | Pebble Prominent | *Eligmodonta ziczac* | −0.021 | −0.011, −0.031 | Declining |
| 2005 | Great Prominent | *Peridea anceps* | 0.016 | 0.028, 0.003 | Increasing |
| 2006 | Lesser Swallow Prominent | *Pheosia gnoma* | −0.019 | −0.013, −0.026 | Declining |
| 2007 | Swallow Prominent | *Pheosia tremula* | 0.012 | 0.027, −0.003 | Increasing |
| 2008 | Coxcomb Prominent | *Ptilodon capucina* | −0.025 | −0.019, −0.030 | Declining |
| 2011 | Pale Prominent | *Pterostoma palpina* | −0.009 | −0.002, −0.017 | Declining |
| 2014 | Marbled Brown | *Drymonia dodonaea* | −0.011 | 0.000, −0.023 | Declining |
| 2015 | Lunar Marbled Brown | *Drymonia ruficornis* | 0.022 | 0.039, 0.006 | Increasing |
| 2020 | Figure of Eight | *Diloba caeruleocephala* | −0.081 | −0.071, −0.090 | Endangered |
| 2028 | Pale Tussock | *Calliteara pudibunda* | −0.015 | −0.005, −0.024 | Declining |
| 2030 | Yellow-Tail | *Euproctis similis* | −0.006 | 0.000, −0.013 | Declining |
| 2033 | Black Arches | *Lymantria monacha* | 0.020 | 0.036, 0.005 | Increasing |
| 2035 | Round-Winged Muslin | *Thumatha senex* | 0.013 | 0.039, −0.014 | Increasing |
| 2037 | Rosy Footman | *Miltochrista miniata* | 0.040 | 0.054, 0.026 | Increasing |
| 2038 | Muslin Footman | *Nudaria mundana* | 0.022 | 0.034, 0.010 | Increasing |
| 2040 | Four-Dotted Footman | *Cybosia mesomella* | 0.004 | 0.014, −0.005 | Increasing |
| 2044 | Dingy Footman | *Eilema griseola* | 0.063 | 0.076, 0.049 | Increasing |
| 2047 | Scarce Footman | *Eilema complana* | 0.091 | 0.112, 0.070 | Increasing |
| 2049 | Buff Footman | *Eilema deplana* | 0.065 | 0.104, 0.027 | Increasing |
| 2050 | Common Footman | *Eilema lurideola* | 0.010 | 0.016, 0.004 | Increasing |
| 2057 | Garden Tiger | *Arctia caja* | −0.062 | −0.054, −0.071 | Vulnerable |
| 2059 | Clouded Buff | *Diacrisia sannio* | −0.028 | −0.007, −0.050 | Declining |
| 2060 | White Ermine | *Spilosoma lubricipeda* | −0.041 | −0.035, −0.046 | Vulnerable |

(*continued on next page*)

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 2061 | Buff Ermine | *Spilosoma luteum* | −0.037 | −0.031, −0.042 | Vulnerable |
| 2063 | Muslin Moth | *Diaphora mendica* | 0.007 | 0.015, −0.001 | Increasing |
| 2064 | Ruby Tiger | *Phragmatobia fuliginosa* | 0.007 | 0.015, −0.001 | Increasing |
| 2069 | Cinnabar | *Tyria jacobaeae* | −0.049 | −0.035, −0.063 | Vulnerable |
| 2077 | Short-Cloaked Moth | *Nola cucullatella* | −0.021 | −0.011, −0.030 | Declining |
| 2078 | Least Black Arches | *Nola confusalis* | 0.061 | 0.082, 0.040 | Increasing |
| 2081 | White-Line Dart | *Euxoa tritici* | −0.069 | −0.051, −0.088 | Endangered |
| 2082 | Garden Dart | *Euxoa nigricans* | −0.097 | −0.067, −0.126 | Endangered |
| 2085 | Archer's Dart | *Agrotis vestigialis* | −0.031 | −0.016, −0.046 | Declining |
| 2087 | Turnip Moth | *Agrotis segetum* | −0.032 | −0.022, −0.042 | Declining |
| 2088 | Heart & Club | *Agrotis clavis* | −0.002 | 0.012, −0.016 | Declining |
| 2089 | Heart & Dart | *Agrotis exclamationis* | −0.031 | −0.023, −0.040 | Declining |
| 2091 | Dark Sword-Grass | *Agrotis ipsilon* | −0.025 | −0.003, −0.047 | Declining |
| 2092 | Shuttle-Shaped Dart | *Agrotis puta* | 0.009 | 0.019, −0.001 | Increasing |
| 2098 | The Flame | *Axylia putris* | −0.021 | −0.014, −0.029 | Declining |
| 2102 | Flame Shoulder | *Ochropleura plecta* | −0.001 | 0.005, −0.007 | Declining |
| 2107 | Large Yellow Underwing | *Noctua pronuba* | 0.025 | 0.030, 0.019 | Increasing |
| 2109 | Lesser Yellow Underwing | *Noctua comes* | 0.017 | 0.024, 0.011 | Increasing |
| 2110 | Broad-Bordered Yellow Underwing | *Noctua fimbriata* | 0.070 | 0.094, 0.046 | Increasing |
| 2111 | Lesser Broad-Bordered Yellow Underwing | *Noctua janthe* | 0.008 | 0.015, 0.002 | Increasing |
| 2114 | Double Dart | *Graphiphora augur* | −0.097 | −0.084, −0.110 | Endangered |
| 2117 | Autumnal Rustic | *Paradiarsa glareosa* | −0.070 | −0.060, −0.079 | Endangered |
| 2118 | True Lover's Knot | *Lycophotia porphyrea* | −0.029 | −0.023, −0.036 | Declining |
| 2120 | Ingrailed Clay | *Diarsia mendica* | −0.031 | −0.026, −0.036 | Declining |
| 2121 | Barred Chestnut | *Diarsia dahlii* | 0.033 | 0.045, 0.021 | Increasing |
| 2122 | Purple Clay | *Diarsia brunnea* | −0.018 | −0.012, −0.025 | Declining |
| 2123 | Small Square-Spot | *Diarsia rubi* | −0.052 | −0.045, −0.060 | Vulnerable |
| 2126 | Setaceous Hebrew Character | *Xestia c-nigrum* | 0.004 | 0.010, −0.003 | Increasing |
| 2127 | Triple-Spotted Clay | *Xestia ditrapezium* | −0.020 | 0.002, −0.041 | Declining |
| 2128 | Double Square-Spot | *Xestia triangulum* | −0.014 | −0.008, −0.019 | Declining |
| 2130 | Dotted Clay | *Xestia baja* | −0.014 | −0.007, −0.021 | Declining |
| 2132 | Neglected or Grey Rustic | *Xestia castanea* | −0.047 | −0.029, −0.065 | Vulnerable |
| 2133 | Six-Striped Rustic | *Xestia sexstrigata* | −0.021 | −0.012, −0.029 | Declining |
| 2134 | Square-Spot Rustic | *Xestia xanthographa* | 0.005 | 0.011, −0.001 | Increasing |
| 2135 | Heath Rustic | *Xestia agathina* | −0.052 | −0.029, −0.074 | Vulnerable |
| 2136 | The Gothic | *Naenia typica* | −0.032 | −0.012, −0.051 | Declining |
| 2138 | Green Arches | *Anaplectoides prasina* | 0.019 | 0.031, 0.007 | Increasing |
| 2139 | Red Chestnut | *Cerastis rubricosa* | −0.021 | −0.014, −0.029 | Declining |
| 2145 | The Nutmeg | *Discestra trifolii* | −0.017 | 0.001, −0.035 | Declining |
| 2147 | The Shears | *Hada plebeja* | 0.010 | 0.020, 0.001 | Increasing |
| 2150 | Grey Arches | *Polia nebulosa* | −0.015 | −0.001, −0.029 | Declining |
| 2154 | Cabbage Moth | *Mamestra brassicae* | −0.015 | −0.006, −0.025 | Declining |
| 2155 | Dot Moth | *Melanchra persicariae* | −0.059 | −0.044, −0.073 | Vulnerable |
| 2158 | Pale-Shouldered Brocade | *Lacanobia thalassina* | 0.003 | 0.011, −0.005 | Increasing |
| 2160 | Bright-Line Brown-Eye | *Lacanobia oleracea* | −0.011 | −0.004, −0.018 | Declining |
| 2163 | Broom Moth | *Ceramica pisi* | −0.041 | −0.032, −0.049 | Vulnerable |
| 2173 | The Lychnis | *Hadena bicruris* | −0.024 | −0.010, −0.037 | Declining |
| 2176 | Antler Moth | *Cerapteryx graminis* | −0.031 | −0.024, −0.038 | Declining |
| 2177 | Hedge Rustic | *Tholera cespitis* | −0.098 | −0.087, −0.110 | Endangered |
| 2178 | Feathered Gothic | *Tholera decimalis* | −0.065 | −0.052, −0.077 | Vulnerable |
| 2179 | Pine Beauty | *Panolis flammea* | 0.044 | 0.057, 0.032 | Increasing |
| 2182 | Small Quaker | *Orthosia cruda* | 0.008 | 0.021, −0.004 | Increasing |
| 2186 | Powdered Quaker | *Orthosia gracilis* | −0.040 | −0.030, −0.050 | Vulnerable |
| 2187 | Common Quaker | *Orthosia cerasi* | 0.006 | 0.013, −0.002 | Increasing |
| 2188 | Clouded Drab | *Orthosia incerta* | −0.008 | −0.002, −0.014 | Declining |
| 2189 | Twin-Spotted Quaker | *Orthosia munda* | −0.001 | 0.009, −0.011 | Declining |

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 2190 | Hebrew Character | *Orthosia gothica* | −0.011 | −0.006, −0.015 | Declining |
| 2192 | Brown-Line Bright-Eye | *Mythimna conigera* | −0.023 | −0.012, −0.035 | Declining |
| 2193 | The Clay | *Mythimna ferrago* | −0.009 | −0.004, −0.015 | Declining |
| 2198 | Smoky Wainscot | *Mythimna impura* | 0.000 | 0.006, −0.006 | Declining |
| 2199 | Common Wainscot | *Mythimna pallens* | −0.029 | −0.021, −0.036 | Declining |
| 2205 | Shoulder-Striped Wainscot | *Mythimna comma* | −0.036 | −0.024, −0.048 | Vulnerable |
| 2225 | Minor Shoulder-Knot | *Brachylomia viminalis* | −0.037 | −0.025, −0.048 | Vulnerable |
| 2227 | The Sprawler | *Brachionycha sphinx* | −0.049 | −0.040, −0.057 | Vulnerable |
| 2229 | Brindled Ochre | *Dasypolia templi* | −0.063 | −0.040, −0.085 | Vulnerable |
| 2231 | Deep-Brown Dart[a] | *Aporophyla lutulenta* | −0.064 | −0.044, −0.084 | Vulnerable |
| 2232 | Black Rustic | *Aporophyla nigra* | −0.032 | −0.019, −0.044 | Declining |
| 2237 | Grey Shoulder-Knot | *Lithophane ornitopus* | 0.072 | 0.101, 0.044 | Increasing |
| 2240 | Blair's Shoulder-Knot | *Lithophane leautieri* | 0.165 | 0.243, 0.087 | Increasing |
| 2241 | Red Sword-Grass | *Xylena vetusta* | −0.013 | 0.002, −0.028 | Declining |
| 2243 | Early Grey | *Xylocampa areola* | 0.004 | 0.013, −0.005 | Increasing |
| 2245 | Green-Brindled Crescent | *Allophyes oxyacanthae* | −0.044 | −0.038, −0.050 | Vulnerable |
| 2247 | Merveille Du Jour | *Dichonia aprilina* | 0.005 | 0.020, −0.009 | Increasing |
| 2248 | Brindled Green | *Dryobotodes eremita* | 0.040 | 0.058, 0.023 | Increasing |
| 2250 | Dark Brocade | *Mniotype adusta* | −0.043 | −0.027, −0.058 | Vulnerable |
| 2254 | Grey Chi | *Antitype chi* | −0.023 | −0.005, −0.041 | Declining |
| 2255 | Feathered Ranunculus | *Eumichtis lichenea* | −0.007 | 0.003, −0.018 | Declining |
| 2256 | The Satellite | *Eupsilia transversa* | 0.024 | 0.035, 0.014 | Increasing |
| 2258 | The Chestnut | *Conistra vaccinii* | 0.012 | 0.017, 0.007 | Increasing |
| 2259 | Dark Chestnut | *Conistra ligula* | −0.019 | −0.009, −0.029 | Declining |
| 2262 | The Brick | *Agrochola circellaris* | −0.028 | −0.021, −0.035 | Declining |
| 2263 | Red-Line Quaker | *Agrochola lota* | 0.007 | 0.016, −0.001 | Increasing |
| 2264 | Yellow-Line Quaker | *Agrochola macilenta* | 0.014 | 0.020, 0.007 | Increasing |
| 2265 | Flounced Chestnut | *Agrochola helvola* | −0.058 | −0.043, −0.072 | Vulnerable |
| 2266 | Brown-Spot Pinion | *Agrochola litura* | −0.039 | −0.031, −0.048 | Vulnerable |
| 2267 | Beaded Chestnut | *Agrochola lychnidis* | −0.064 | −0.057, −0.072 | Vulnerable |
| 2269 | Centre-Barred Sallow | *Atethmia centrago* | −0.038 | −0.029, −0.046 | Vulnerable |
| 2270 | Lunar Underwing | *Omphaloscelis lunosa* | 0.020 | 0.027, 0.013 | Increasing |
| 2272 | Barred Sallow | *Xanthia aurago* | −0.017 | −0.005, −0.029 | Declining |
| 2273 | Pink-Barred Sallow | *Xanthia togata* | −0.018 | −0.012, −0.025 | Declining |
| 2274 | The Sallow | *Xanthia icteritia* | −0.048 | −0.040, −0.056 | Vulnerable |
| 2275 | Dusky-Lemon Sallow | *Xanthia gilvago* | −0.070 | −0.036, −0.104 | Endangered |
| 2284 | Grey Dagger | *Acronicta psi* | −0.041 | −0.028, −0.054 | Vulnerable |
| 2289 | Knot Grass | *Acronicta rumicis* | −0.045 | −0.035, −0.054 | Vulnerable |
| 2293 | Marbled Beauty | *Cryphia domestica* | 0.051 | 0.062, 0.039 | Increasing |
| 2299 | Mouse Moth | *Amphipyra tragopogonis* | −0.037 | −0.030, −0.044 | Vulnerable |
| 2302 | Brown Rustic | *Rusina ferruginea* | −0.015 | −0.010, −0.019 | Declining |
| 2303 | Straw Underwing | *Thalpophila matura* | −0.031 | −0.022, −0.040 | Declining |
| 2305 | Small Angle Shades | *Euplexia lucipara* | −0.019 | −0.011, −0.027 | Declining |
| 2306 | Angle Shades | *Phlogophora meticulosa* | 0.011 | 0.018, 0.004 | Increasing |
| 2312 | The Olive | *Ipimorpha subtusa* | 0.031 | 0.061, 0.001 | Increasing |
| 2318 | The Dun-Bar | *Cosmia trapezina* | 0.000 | 0.007, −0.008 | Declining |
| 2319 | Lunar-Spotted Pinion | *Cosmia pyralina* | −0.026 | −0.010, −0.042 | Declining |
| 2321 | Dark Arches | *Apamea monoglypha* | −0.009 | −0.004, −0.014 | Declining |
| 2322 | Light Arches | *Apamea lithoxylaea* | −0.035 | −0.026, −0.043 | Declining |
| 2326 | Clouded-Bordered Brindle | *Apamea crenata* | −0.003 | 0.007, −0.014 | Declining |
| 2330 | Dusky Brocade | *Apamea remissa* | −0.039 | −0.028, −0.051 | Vulnerable |
| 2333 | Large Nutmeg | *Apamea anceps* | −0.058 | −0.034, −0.081 | Vulnerable |
| 2334 | Rustic Shoulder-Knot | *Apamea sordens* | −0.027 | −0.018, −0.036 | Declining |
| 2335 | Slender Brindle | *Apamea solopacina* | 0.016 | 0.038, −0.006 | Increasing |
| 2340 | Middle-Barred Minor | *Oligia fasciuncula* | −0.013 | −0.006, −0.019 | Declining |

(*continued on next page*)

**Appendix A – *continued***

| Number | Vernacular name | Species | Annual change rate | 95% CI | Change status |
|---|---|---|---|---|---|
| 2341 | Cloaked Minor | *Mesoligia furuncula* | 0.022 | 0.032, 0.012 | Increasing |
| 2342 | Rosy Minor | *Mesoligia literosa* | −0.047 | −0.035, −0.058 | Vulnerable |
| 2343 | Common Rustic | *Mesapamea secalis* | 0.004 | 0.009, −0.002 | Increasing |
| 2345 | Small Dotted Buff | *Photedes minima* | −0.020 | −0.015, −0.025 | Declining |
| 2350 | Small Wainscot | *Photedes pygmina* | −0.024 | −0.016, −0.031 | Declining |
| 2352 | Dusky Sallow | *Eremobia ochroleuca* | 0.009 | 0.022, −0.004 | Increasing |
| 2353 | Flounced Rustic | *Luperina testacea* | −0.019 | −0.013, −0.024 | Declining |
| 2357 | Large Ear | *Amphipoea lucens* | −0.019 | 0.006, −0.044 | Declining |
| 2360 | Ear Moth | *Amphipoea oculea* | −0.035 | −0.019, −0.051 | Vulnerable |
| 2361 | Rosy Rustic | *Hydraecia micacea* | −0.054 | −0.047, −0.060 | Vulnerable |
| 2364 | Frosted Orange | *Gortyna flavago* | −0.012 | −0.002, −0.022 | Declining |
| 2367 | Haworth's Minor | *Celaena haworthii* | −0.062 | −0.045, −0.079 | Vulnerable |
| 2368 | The Crescent | *Celaena leucostigma* | −0.048 | −0.030, −0.066 | Vulnerable |
| 2375 | Large Wainscot | *Rhizedra lutosa* | −0.054 | −0.042, −0.066 | Vulnerable |
| 2380 | Treble Lines | *Charanyca trigrammica* | 0.007 | 0.019, −0.004 | Increasing |
| 2381 | The Uncertain | *Hoplodrina alsines* | 0.002 | 0.009, −0.005 | Increasing |
| 2382 | The Rustic | *Hoplodrina blanda* | −0.039 | −0.030, −0.048 | Vulnerable |
| 2384 | Vine's Rustic | *Hoplodrina ambigua* | 0.048 | 0.077, 0.019 | Increasing |
| 2387 | Mottled Rustic | *Caradrina morpheus* | −0.037 | −0.030, −0.044 | Vulnerable |
| 2389 | Pale Mottled Willow | *Caradrina clavipalpis* | 0.023 | 0.038, 0.007 | Increasing |
| 2394 | The Anomalous | *Stilbia anomala* | −0.075 | −0.052, −0.097 | Endangered |
| 2410 | Marbled White-Spot | *Protodeltote pygarga* | 0.018 | 0.032, 0.005 | Increasing |
| 2422 | Green Silver-Lines | *Pseudoips prasinana* | 0.027 | 0.040, 0.015 | Increasing |
| 2425 | Nut-Tree Tussock | *Colocasia coryli* | 0.015 | 0.023, 0.007 | Increasing |
| 2434 | Burnished Brass | *Diachrysia chrysitis* | −0.024 | −0.018, −0.030 | Declining |
| 2439 | Gold Spot | *Plusia festucae* | 0.018 | 0.036, 0.000 | Increasing |
| 2441 | Silver Y | *Autographa gamma* | −0.019 | −0.014, −0.024 | Declining |
| 2442 | Beautiful Golden Y | *Autographa pulchrina* | −0.009 | −0.002, −0.015 | Declining |
| 2443 | Plain Golden Y | *Autographa jota* | −0.004 | 0.009, −0.017 | Declining |
| 2444 | Gold Spangle | *Autographa bractea* | 0.002 | 0.016, −0.012 | Increasing |
| 2450 | The Spectacle | *Abrostola tripartita* | 0.012 | 0.019, 0.005 | Increasing |
| 2473 | Beautiful Hook-Tip | *Laspeyria flexula* | −0.029 | −0.016, −0.041 | Declining |
| 2474 | Straw Dot | *Rivula sericealis* | 0.031 | 0.046, 0.016 | Increasing |
| 2475 | Waved Black | *Parascotia fuliginaria* | −0.004 | 0.009, −0.016 | Declining |
| 2477 | The Snout | *Hypena proboscidalis* | −0.006 | 0.000, −0.012 | Declining |
| 2489 | The Fan-Foot | *Herminia tarsipennalis* | −0.013 | −0.006, −0.021 | Declining |
| 2492 | Small Fan-Foot | *Herminia grisealis* | −0.016 | −0.011, −0.021 | Declining |
| – | Lead/July Belle Aggregate[b] | *Scotopteryx spp* | −0.035 | −0.024, −0.045 | Declining |

a Deep-brown dart *Aporophyla lutulenta*, and Northern deep-brown dart *A. luenerbergensis* were not initially recorded as separate species and appear in the table as an aggregate of counts of both species.
b After compiling the data we determined that Lead Belle (*Scotopteryx mucronata*, 1733) and July Belle (*S. luridata*, 1734) could not be reliably distinguished on the basis of external appearance, gross morphology, phenology or distribution, so the catches of the two species were combined.

## REFERENCES


Bradley, J.D., 2000. Checklist of Lepidoptera Recorded from the British Isles, second ed. Bradley & Bradley, Fordingbridge.

Conrad, K.F., Woiwod, I.P., Perry, J.N., 2002. Long-term decline in abundance and distribution of the garden tiger moth (*Arctia caja*) in Great Britain. Biological Conservation 106, 329–337.

Conrad, K.F., Woiwod, I.P., Perry, J.N., 2003. East Atlantic teleconnection pattern and the decline of a common arctiid moth. Global Change Biology 9, 125–130.

Conrad, K.F., Woiwod, I.P., Parsons, M., Fox, R., Warren, M.S., 2004. Long-term population trends in widespread British moths. Journal of Insect Conservation 8, 119–136.

Cowley, M.J.R., Thomas, C.D., Thomas, J.A., Warren, M.S., 1999. Flight areas of British butterflies: assessing species status and decline. Proceedings of the Royal Society of London Series B-Biological Sciences 266, 1587–1592.

Donald, P.F., Green, R.E., Heath, M.M., 2001. Agricultural intensification and collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London Series B-Biological Sciences 268, 25–29.

Dunn, E.H., 2002. Using decline in bird populations to identify needs for conservation action. Conservation Biology 16, 1632–1637.
Eaton, M.A., Gregory, R.D., Noble, D.G., Robinson, J.A., Hughes, J., Procter, D., Brown, A.F., Gibbons, D.W., 2005. Regional IUCN red listing: the process as applied to birds in the United Kingdom. Conservation Biology 19, 1557–1570.
Elvidge, C.D., Imhoff, M.L., Baugh, K.E., Hobson, V.R., Nelson, I., Safran, J., Dietz, J.B., Tuttle, B.T., 2001. Night-time lights of the world: 1994–1995. Isprs Journal of Photogrammetry and Remote Sensing 56, 81–99.
Frank, K.D., 1988. Impact of outdoor lighting on moths: an assessment. Journal of the Lepidopterists Society 42, 63–93.
Gardenfors, U., Hilton-Taylor, C., Mace, G.M., Rodriguez, J.P., 2001. The application of IUCN red list criteria at regional levels. Conservation Biology 15, 1206–1212.
Hambler, C., Speight, M.R., 2004. Extinction rates and butterflies. Science 305, 1563.
IUCN World Conservation Union. 2001. IUCN Red List categories and criteria: Version 3.1. IUCN Species Survival Commission, Gland, Switzerland and Cambridge, UK.
Lawton, J.H., May, R.M., 1995. Extinction Rates. Oxford University Press, oxford.
Leon-Cortes, J.L., Cowley, M.J.R., Thomas, C.D., 1999. Detecting decline in a formerly widespread species: how common is the common blue butterfly *Polyommatus icarus*? Ecography 22, 643–650.
Longcore, T., Rich, C., 2004. Ecological light pollution. Frontiers in Ecology and the Environment 2, 191–198.
Mace, G.M., Lande, R., 1991. Assessing extinction threats: toward re-evaluation of IUCN threatened species categories. Conservation Biology 5, 148–157.
McKinney, M.L., 1999. High rates of extinction and threat in poorly studied taxa. Conservation Biology 13, 1273–1281.
New, T.R., 2004. Moths (Insecta: Lepidoptera) and conservation: background and perspective. Journal of Insect Conservation 8, 79–94.
Ormerod, S.J., Watkinson, A.R., 2000. Editor's introduction: birds and agriculture. Journal of Applied Ecology 37, 699.
Pannekoek, J., Van Strien, A.J. 2001. TRIM 3 Manual (TRends & Indices for Monitoring data) Statistics Netherlands, Voorburg.
Pollard, E., Yates, T., 1993. Monitoring Butterflies for Ecology and Conservation, first ed. Chapman and Hall, London.
Quinn, R.M., Gaston, K.J., Blackburn, T.M., Eversham, B.C., 1997. Abundance-range size relationships of macrolepidoptera in Britain: the effects of taxonomy and life history variables. Ecological Entomology 22, 453–461.
Shirt, D.B., 1987British Red Data Books, vol. 2. Insects Nature Conservancy Council, Peterborough.
Taylor, L.R., French, R.A., 1974. Effects of light-trap design and illumination on samples of moths in an English woodland. Bulletin of Entomological Research 63, 583–594.
Thomas, L., 1996. Monitoring long-term population change: why are there so many analysis methods? Ecology 77, 49–58.
Thomas, J.A., 2005. Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions of the Royal Society B-Biological Sciences 360, 339–357.
Thomas, C.D., Abery, J.C.G., 1995. Estimating rates of butterfly decline from distribution maps – the effect of scale. Biological Conservation 73, 59–65.
Thomas, J.A., Clarke, R.T., 2004. Extinction rates and butterflies. Science 305, 1563–1564.
Thomas, J.A., Morris, M.G., 1994. Patterns, mechanisms and rates of extinction among invertebrates in the United Kingdom. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences 344, 47–54.
Thomas, J.A., Telfer, M.G., Roy, D.B., Preston, C.D., Greenwood, J.J.D., Asher, J., Fox, R., Clarke, R.T., Lawton, J.H., 2004. Comparative losses of British butterflies, birds, and plants and the global extinction crisis. Science 303, 1879–1881.
Van Strien, A.J., Pannekoek, J., Gibbons, D.W., 2001. Indexing European bird population trends using results of national monitoring schemes: a trial of a new method. Bird Study 48, 200–213.
Warren, M.S., Hill, J.K., Thomas, J.A., Asher, J., Fox, R., Huntley, B., Roy, D.B., Telfer, M.G., Jeffcoate, S., Harding, P., Jeffcoate, G., Willis, S.G., Greatorex-Davies, J.N., Moss, D., Thomas, C.D., 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. Nature 414, 65–69.
Wickramasinghe, L.P., Harris, S., Jones, G., Vaughan Jennings, N., 2004. Abundance and species richness of nocturnal insects on organic and conventional farms: effects of agricultural intensification on bat foraging. Conservation Biology 18, 1283–1292.
Williams, C.B., 1948. The Rothamsted light trap. Proceedings of the Royal Entomological Society of London A 23, 80–85.
Williams, C.B., 1952. Some notes on killing insects for collections and for scientific research. The Entomologist 85, 271–279.
Wilson, E.O., 1992. The Diversity of Life. Penguin Press, London.
Woiwod, I.P., Harrington, R., 1994. Flying in the face of change: The Rothamsted Insect Survey. In: Leigh, R., Johnston, A. (Eds.), Long-Term Experiments in Agricultural and Ecological Sciences. CAB International, Wallingford, pp. 321–342.