# Butterflies for the new millennium: mapping butterfly distributions in Britain (Lepidoptera)

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## Abstract

Butterflies for the New Millennium is the largest and most comprehensive survey of butterfly distribution ever undertaken in Britain and Ireland. The number of contributing recorders, the coverage achieved and the number and quality of distribution records generated far exceed those available for any other invertebrate taxon. The data thus provide a unique insight into the effects of habitat degradation and climate change on a high profile insect group.

The results of the first five years of the survey (1995-1999) have been analysed to assess broad-scale distribution changes over the past two decades and the past two centuries. In both time periods, the British distributions of most butterfly species have shown substantial change. The trends affecting habitat specialist and habitat generalist (wider countryside) species differ significantly. The distributions of half of the habitat generalists have increased (consistent with an expected positive response to observed climate change), whereas most habitat specialists declined (consistent with habitat degradation). The opposing forces of climate change and habitat degradation are thought to be the main driving forces. The decline of specialist species indicates a reduction in overall biodiversity, whilst mobile and widespread generalists increasingly dominate biological communities. These patterns of change are thought to be representative of many other invertebrate groups in Britain and demonstrate the use of butterflies as indicators of environmental change.

Key words: Lepidoptera, butterfly recording, butterfly distribution, habitat degradation, climate change, biodiversity, conservation, indicator species.

## Introduction

Butterflies have a special place in people's experience and vision of the countryside. No other invertebrates have the same popular appeal. This popularity, together with the ease with which most species can be identified and recorded, accounts for a long history of butterfly recording in Britain and Ireland (Harding et al. 1995).

The Butterflies for the New Millennium (BNM) project was launched in 1995 by Butterfly Conservation and the Biological Records Centre at the Centre for Ecology and Hydrology, because it was clear that the distributions of many butterflies had changed substantially since the only previous national survey (1970-1982).

Up-to-date distribution information is essential to inform decisions in nature conservation. The main aims of the BNM project were to provide such data to support conservation and land-use policy, inform the development planning system and guide direct conservation efforts. Since the survey was to be an inclusive project, utilizing members of the public and volunteers from a wide range of organisations, other aims were to develop the numbers and expertise of people recording butterflies and to promote the conservation of butterflies to a wider audience. Data from the first five years of the survey (1995-1999) have been analysed and published in a major new book, The Millennium Atlas of Butterflies in Britain and Ireland (Asher et al. 2001).

## The BNM survey

The survey was achieved by mobilizing volunteers across Britain and Ireland. Participants were issued with standard recording forms and instructions, but records were not gathered systematically (with respect to geography or time). However, considerable efforts were made to target recording to ensure the best possible coverage of the survey area with the available resources. Records were collected, verified and computerised by volunteer county co-ordinators and local data sets then collated annually in a central database.

After five years of recording, the success of the survey was clear. Between 1995 and 1999, over

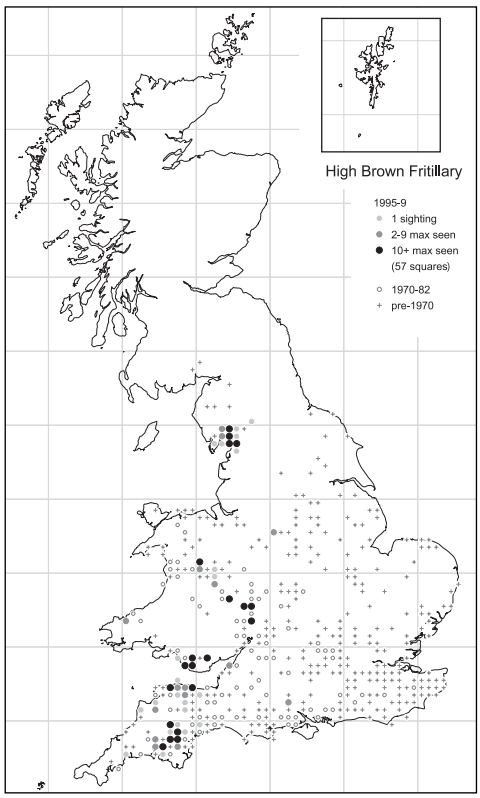



Figure 1
The high brown fritillary was once widespread in England and Wales in coppiced woodlands and bracken habitats. It has declined severely since the 1950s due to habitat deterioration, and is now one of the rarest and most threatened butterflies in Britain.

10 000 participants had generated more than 1.6 million butterfly records. This represents a twelve-fold increase over the number of records compiled by the previous survey (Heath et al. 1984) and in less than half the survey time period. Coverage was also more comprehensive with 99% coverage achieved at the 10 km square level in Britain (and 98% in Ireland). The precision and detail of the records gathered also represented a great improvement over the previous survey. For example, over 90% of the BNM records had a 1 km square or 100 m square grid reference, compared to 51% of 1970-1982 records.

The current distribution of each species, determined by the BNM survey, has been compared with that recorded in 1970-1982 and historical information dating back to 1800. Recording effort bias complicates the interpretation of distribution change in Ireland. Therefore, this paper considers only the changes that have occurred in Britain.

## Patterns of change since 1970-1982

Many resident butterflies continued to decline in the final decades of the 20th century. The pattern of change among different species has been considered using the ecological concept of island and matrix species (Pollard & Eversham 1995). This concept has been modified using the terms habitat specialist and wider countryside species.

British butterflies can be divided relatively easily into these two groups based on their ecological attributes. Habitat specialists have 'narrow' niches and tend to be sedentary, univoltine and use only one or two species of larval foodplant. Wider countryside species tend to have 'wide' niches and many are mobile, bivoltine or trivoltine and polyphagous. The British butterfly fauna consists of approximately equal numbers of habitat specialists and wider countryside species, yet there are clear differences between the distribution changes of the two groups over the last 20 years.

Most habitat specialists have suffered substantial decreases in their distributions at the 10 km square scale. The high brown fritillary *Argynnis adippe* (Denis & Schiffermüller, 1775), for example, was once widespread in woodlands across England and Wales, where the traditional practice of coppicing created a regular supply of sunny clearings. These provided a warm, sheltered microclimate essential for the larvae. Each clearing would remain suitable for only a few years before the trees regrew, but the butterfly was able to persist by colonising new clearings nearby. However, the high brown fritillary has undergone the most severe decline of any extant species and has been lost from 77% of the 10 km squares in which it was recorded in the 1970-1982 survey (fig. 1, 2). It is now restricted to only 50 sites, mainly in bracken (*Pteridium aquilinum*) dominated habitats.

Other butterflies have suffered similarly spectacular declines in Britain. The distributions of the wood white *Leptidea sinapis* (Linnaeus, 1758) and pearl-bordered fritillary *Boloria euphrosyne*

Figure 2
The high brown fritillary *Argynnis adippe*.

(Linnaeus, 1758), both specialist butterflies of woodland clearings, have decreased by 62% and 60%, respectively, in Britain since 1970-1982. The marsh fritillary *Euphydryas aurinia* (Rottemburg, 1775), a habitat specialist of unimproved damp or chalk grasslands that is classified as vulnerable in Europe (van Swaay & Warren 1999), has undergone a 55% decrease in Britain in the last two decades. The recent declines of several other species are causing concern. Examples include the large heath *Coenonympha tullia* (Müller, 1764), silver-studded blue *Plebeius argus* (Linnaeus, 1758), duke of burgundy *Hamearis lucina* (Linnaeus, 1758), dingy skipper *Erynnis tages* (Linnaeus, 1758) and small pearl-bordered fritillary *Boloria selene* (Denis and Schiffermüller, 1775). Only one habitat specialist species (the white admiral *Limenitis camilla* (Linnaeus, 1764) has undergone a substantial expansion of its distribution at the 10 km grid square scale.

It is recognised that the comparison of distributions at coarse geographical scales (e.g. 10 km grid squares) greatly under-estimates population level declines (Thomas & Abery 1995). High rates of population decline and colony extinction may exist within a 10 km square, but only the final loss from the square will be registered on distribution maps at this resolution. Therefore, the national distribution declines measured by the BNM survey are minimum estimates of population loss and many species have probably declined even more severely at the local level (Cowley et al. 1999).

In contrast, the distributions of many wider countryside species have expanded or remained stable. The comma *Polygonia c-album* (Linnaeus, 1758) is one of a group of 14 wider countryside species that have undergone substantial range expansions in Britain. Since the 1970-1982 survey, its range margin has moved 220 km northwards (fig. 3, 4). In addition, vagrant commas have been recorded recently in Scotland, where the species became extinct in the 19th century, and on the Isle of Man and in Northern Ireland, where the species has never been resident.

Some of these expansions represent the continuation of trends that began many decades earlier (as is the case for the comma, which has been expanding sporadically since the 1920s), while others are recent events. An extreme case is the brown argus *Aricia agestis* (Denis & Schiffermüller, 1775). At the time of the 1970-1982 survey its distribution was decreasing, but recently the butterfly has

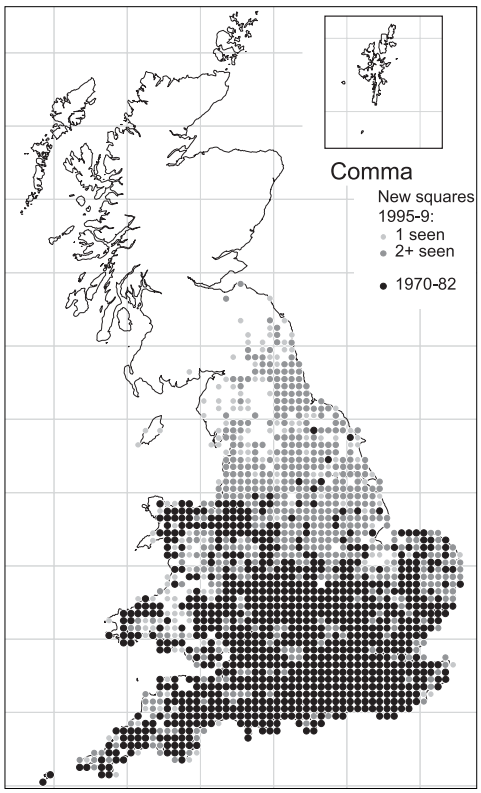



Figure 3
Since the 1970s, improving climatic conditions have allowed the comma to colonise much of northern England. Its distribution has increased by almost 80% at the 10 km square scale.

increased the range of habitat types in which it can breed and has spread into many new areas (C.D. Thomas et al. 2001). This decline has since been reversed and its distribution has more than doubled (108% increase in recorded 10 km squares).

Many of these wider countryside species are re-expanding following previous declines in the late 19th and early 20th centuries. Examples include the orange-tip *Anthocharis cardamines* (Linnaeus, 1758), peacock *Inachis io* (Linnaeus, 1758), comma and speckled wood *Pararge aegeria* (Linnaeus, 1758). The distributions of these butterflies have increased by 43%, 34%, 79% and 54% respectively. The main direction of all distribution expansions has been northwards.

At the 10 km square scale, only one wider countryside species, the wall *Lasiommata megera* (Linnaeus 1767), has undergone a substantial decline.

## Patterns of change since 1800

Historical records dating back over 200 years, show that more than half of the 59 resident butterflies in the British fauna have disappeared from over 20% of their range. This includes five species that have become extinct during the period (the black-veined white *Aporia crataegi* (Linnaeus, 1758), large copper *Lycaena dispar* (Haworth, 1802), mazarine blue *Polyommatus semiargus* (Rottemburg, 1775), large blue *Maculinea arion* (Linnaeus, 1758), and large tortoiseshell *Nymphalis polychloros* (Linnaeus, 1758). A number of 15 species (25% of the total fauna) have suffered decreases in distribution of greater than 50% at the 10 km square scale (fig. 5).

## The causes of distribution change

Human activities caused massive changes in the landscape of Britain during the 20th century. These changes have been largely detrimental to wildlife and three main factors have led to the historical and recent declines of butterflies. First is the destruction of semi-natural habitats. Huge amounts of butterfly habitat have been lost to intensive agriculture and forestry and to urban and infrastructure development. For example, 80% of chalk and limestone grassland has been destroyed in Britain since the 1940s (see Asher et al. 2001 for references and further examples of habitat loss). This is a key habitat for butterflies, providing conditions for 12 habitat specialist species and the sole habitat for four: the lulworth skipper *Thymelicus acteon* (Rottemburg, 1775), silver-spotted skipper *Hesperia comma* (Linnaeus, 1758), chalkhill blue *Polyommatus coridon* (Poda, 1761) and adonis blue *Polyommatus bellargus* (Rottemburg, 1775).

The rapid intensification of farming and forestry has had a profound effect on the way that the remaining semi-natural habitats are managed, as these generally represent small, economically marginal fragments of land. Most habitat specialist butterflies are sensitive to subtle changes in their habitats and can decline rapidly if management regimes become unsuitable. Many are also adapted to early successional habitats, which have been maintained (unwittingly) for centuries by

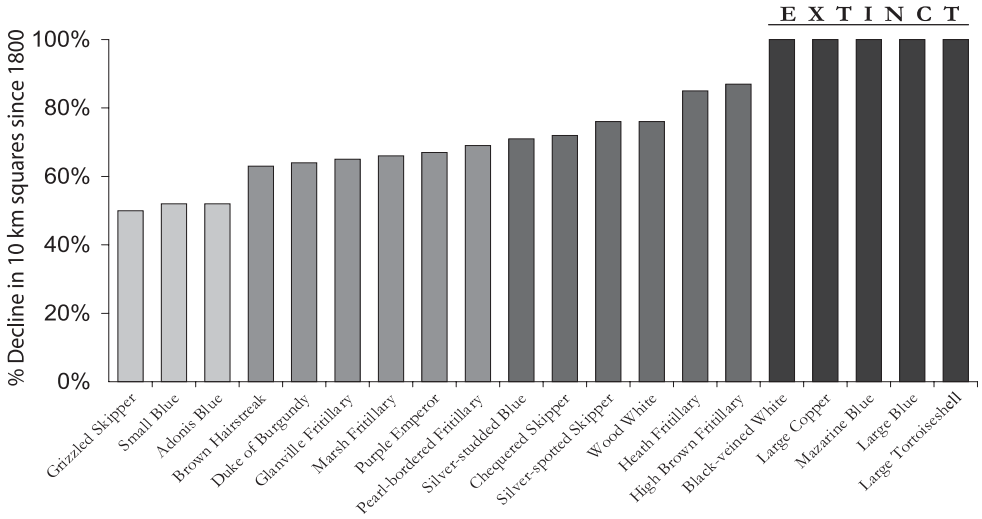
Figure 4
The comma *Polygonia c-album*.

practices such as low intensity livestock grazing on grasslands and coppicing in woods. The decline of such traditional forms of land management during the 20th century is the second major factor that has led to the severe declines of butterflies. For example, semi-natural grasslands in some lowland areas have been abandoned by farmers and graziers, leading to an immediate loss of the short turf conditions (and very warm microclimates) needed by specialist butterflies such as the large blue, silver-spotted skipper, silver-studded blue, adonis blue and grayling *Hipparchia semele* (Linnaeus, 1758). A few species that require longer grass may have benefited in the short-term (e.g. the lulworth skipper) but eventually decline as scrub invades the grassland. At the other extreme, overgrazing has adversely affected some butterfly habitats, particularly in upland areas. Subsidies available under the EU Common Agricultural Policy have encouraged a substantial increase in numbers of livestock, especially sheep, and specialist butterflies such as the pearl-bordered fritillary and marsh fritillary have declined as a result of increased grazing pressure.

Many woodland specialist butterflies have suffered declines, as their habitats have become more shaded and overgrown following the abandonment of coppicing in most broad-leaved woodlands. On the other hand, this reduced level of management has facilitated the spread of the white admiral, a specialist butterfly of shady woodland.

The third major cause of butterfly declines is the fragmentation of remaining habitat. Although fragmentation is a consequence of habitat destruction and deterioration due to changing management, it places surviving butterfly populations at further risk as patches of semi-natural habitats become smaller and more isolated from each other. Small habitat patches tend to support small populations of butterflies that are susceptible to extinction because of stochastic events, like fire or disease, or demographic and genetic effects. Increasing isolation reduces the probability of a habitat patch being recolonised by butterflies (Thomas et al. 1992, 1998). The relative importance of habitat quality and fragmentation effects on butterfly declines has recently been described empirically by J.A. Thomas et al. (2001).

All three of these factors have combined to cause an overall degradation of semi-natural habitats and consequent decline of resident butterfly species. This habitat degradation has had a disproportional-

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|---|---|---|---|---|---|---|---|
| Adonis Blue | 52% | Pearl-bordered Fritillary | 69% | High Brown Fritillary | 87% | Large Tortoiseshell | 100% |
| Small Blue | 52% | Purple Emperor | 67% | Heath Fritillary | 85% | Large Blue | 100% |
| Grizzled Skipper | 50% | Marsh Fritillary | 66% | Wood White | 76% | Mazarine Blue | 100% |
| | | Glanville Fritillary | 65% | Silver-spotted Skipper | 76% | Large Copper | 100% |
| | | Duke of Burgundy | 64% | Chequered Skipper | 72% | Black-veined White | 100% |
| | | Brown Hairstreak | 63% | Silver-studded Blue | 71% | | |

Figure 5
The most serious losses of range amongst British butterflies since 1800.

ly large negative effect on habitat specialist butterflies in Britain relative to wider countryside species. The main factor causing wider countryside species to expand their distributions appears to be climate change. Average spring and summer temperatures in central England have increased by 1.5 and 1°C respectively in the past 25 years (Roy & Sparks 2001), a substantial increase for climatically-sensitive insects such as butterflies, many of which reach their European range margin in Britain. The evidence for the role of climate change in range expansions comes from the simultaneous spread of species, counter to the downward trend in extent of most butterfly habitats, and also from northward range shifts elsewhere in Europe (Parmesan et al. 1999). Most of these expanding species use habitats that are still relatively common, such as hedgerows, roadside verges and woodland edges. They are relatively mobile butterflies and have been able to move through the modern landscape, tracking climatic change and capitalising on recent favourable weather.

## BNM and nature conservation

The BNM survey has generated an unprecedented amount of data with many potential applications. Of particular importance in nature conservation is the opportunity to reassess UK Biodiversity Action Plan (BAP) priorities and targets for butterflies (UK Biodiversity Group 1998). The severity of declines recorded for some BAP species, such as the wood white and duke of burgundy, was unexpected and suggests that they require increased priority. Other rapidly declining species, including the dingy skipper, grizzled skipper *Pyrgus malvae* (Linnaeus, 1758) and dark green fritillary *Argynnis aglaja* (Linnaeus, 1758) now warrant consideration for inclusion in the UK BAP (Fox et al. 2001).

The BNM data give the precise locations of key butterfly populations. This is vital in local nature conservation, feeding into local government policies (such as Local Biodiversity Action Plans), informing the planning process and allowing direct conservation action through, for example,

habitat management and site designation. Moreover, because recording effort has increased, many thousands of new sites for declining species have been identified. This has been particularly notable in Scotland, where many previously unknown colonies of species such as the chequered skipper *Carterocephalus palaemon* (Pallas, 1771), northern brown argus *Aricia artaxerxes* (Fabricius, 1793) and pearl-bordered fritillary have been discovered.

## BNM and research

The data set provides a powerful tool for a wide range of ecological and biogeographic research. It is clear that the distributions of butterflies are changing rapidly, perhaps more rapidly than other well studied taxa such as birds and higher plants. This speed of response (a consequence of short life-cycles, close dependence on climate and, in many cases, specific habitat and microclimate requirements) coupled with ease of recording and popularity amongst the public make butterflies good potential indicator species for studying and assessing environmental change.

BNM data are already being used in research to predict the responses of British butterflies to climate change. Climate response surface models have been developed to assess the extent of climatically suitable habitat potentially available to butterflies under various scenarios of climate change. Most butterfly species might be expected to benefit from rising temperatures, at least in the short- or medium-term. However, when measures of habitat availability were incorporated into the models, they indicated that the range expansions of even wider countryside species (such as speckled wood and ringlet *Aphantopus hyperantus* (Linnaeus, 1758)) have lagged behind climatic changes because of habitat fragmentation (Hill et al. 2001a). This finding has been reinforced by further work using a spatially explicit model to simulate the migration of butterflies within areas of range expansion. This also strongly suggested that landscape structure (i.e. habitat fragmentation) accounted for different rates of expansion of the speckled wood in different parts of Britain (Hill et al. 2001b).

These findings have implications for the long-term conservation of the British butterfly fauna. Many populations of habitat specialists already appear to be isolated on remaining (often small) patches of suitable habitat, and will be unable to track shifting patterns of climate and vegetation. The fact that habitat fragmentation is also limiting the responses of wider countryside species to climate change is of great concern.

## Conclusions

In summary, the BNM survey has been a great success in assessing the recent and long-term trends in the distribution of resident butterfly species. The data provide a unique insight into the effects of habitat degradation and climate change on a high profile insect group. Most butterflies should have responded positively to climate change over recent decades and yet many species have declined. Certainly for habitat specialist butterflies, the detrimental effects of habitat loss have outweighed the beneficial impacts of a warming climate. Therefore, without substantial conservation intervention, butterfly communities will be driven towards lower species richness and increasing dominance by widespread generalist species.

The data set generated by the survey will form a vital tool for nature conservation and research and a new baseline against which to measure future change, including the success of conservation initiatives such as the BAP. British butterflies constitute a very small group – there are ten times as many butterfly species in continental Europe and nearly 500 times as many other invertebrate species in Britain. Nevertheless it is almost certainly the best studied insect fauna in the world and the BNM project has shown how butterflies can and should be used as flagship species, not only to raise the profile of insect conservation but also to involve members of the public in biological recording.

## Acknowledgements

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## References


Asher, J., M. Warren, R. Fox, P. Harding, G. Jeffcoate & S. Jeffcoate 2001. The Millennium Atlas of Butterflies in Britain and Ireland. – Oxford University Press, Oxford.

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

Fox, R., M.S. Warren, P.T. Harding, I.F.G. McLean, J. Asher, D. Roy & T. Brereton 2001. The State of Britain's Butterflies. – Butterfly Conservation, CEH and JNCC, Wareham.

Harding, P.T., J. Asher & T.J. Yates 1995. Butterfly monitoring 1- recording the changes. – In: Pullin, A.S. (ed.), Ecology and Conservation of Butterflies. Chapman & Hall, London: 3-22.

Heath, J., E. Pollard & J.A. Thomas 1984. Atlas of Butterflies in Britain and Ireland. – Viking, Harmondsworth.

Hill, J.K., C.D. Thomas, R. Fox, D. Moss & B. Huntley 2001a. Analysing and modelling range changes in UK butterflies. – In: Woiwod, I.P., D.R. Reynolds & C.D. Thomas (Eds.), Insect movement: mechanisms and consequences. CABI, London: 415-441.

Hill, J.K., Y.C. Collingham, C.D. Thomas, D.S. Blakeley, R. Fox, D. Moss & B. Huntley 2001b. Impacts of landscape structure on butterfly range expansion. – Ecology Letters 4: 313-321.

Parmesan, C., N. Ryrholm, C. Stefanescu, J.K. Hill, C.D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru, J. Tennant, J.A. Thomas & M.S. Warren 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. – Nature 399: 579-583.

Pollard, E. & B.C. Eversham 1995. Butterfly monitoring 2 - interpreting the changes. – In: Pullin, A.S. (Ed.), Ecology and Conservation of Butterflies. Chapman & Hall, London: 23-36.

Roy, D.B. & T.H. Sparks 2000. Phenology of British butterflies and climate change. – Global Change Biology 6: 407-416.

Swaay, C. van & M.S. Warren 1999. Red data book of European Butterflies (Rhopalocera). – Council of Europe, Strasbourg. [Nature and Environment, No. 99]

Thomas, C.D. & J.C.G. Abery 1995. Estimating rates of butterfly decline from distribution maps: the effect of scale. – Biological Conservation 73: 59-65.

Thomas, C.D., J.A. Thomas & M.S. Warren 1992. Distribution of vacant and occupied habitats in fragmented landscapes. – Oecologia 92: 563–567.

Thomas, C.D., J.K. Hill & O.T. Lewis 1998. Evolutionary consequences of habitat fragmentation in a localized butterfly. – Journal of Animal Ecology 67: 485–497.

Thomas, C.D., E.J. Bodsworth, R.J. Wilson, A.D. Simmons, Z.G. Davies, M. Musche & L. Conradt 2001. Ecological and evolutionary processes at expanding range margins. – Nature 411: 577-581.

Thomas, J.A., N.A.D. Bourn, R.T. Clarke, K.E.J. Stewart, D.J. Simcox, G.S. Pearman, R. Curtis & B. Goodger 2001. The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. – Proceedings of the Royal Society B 268: 1791-1796.

UK Biodiversity Group 1998. Tranche 2 Action Plans. Volume I - vertebrates and vascular plants. – English Nature, Peterborough.



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