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A new Red List of British butterflies

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Abstract. 1. Over the last century butterflies have undergone substantial changes in abundance and range in Great Britain and monitoring has improved markedly. These changes, together with a major revision of International Union for Conservation of Nature (IUCN) criteria, render previous Red List assessments outdated.

2. A new Red List assessment of all 62 resident and regularly breeding butterfly species in Britain was undertaken. The current IUCN criteria were applied for the first time to British butterflies using data from the Butterflies for the New Millennium recording scheme and the UK Butterfly Monitoring Scheme.

3. The state of knowledge and nature of the data available from these two schemes enabled assessment to be based upon two quantitative IUCN criteria: A2 (rate of population decline) and B2 (area of occupancy).

4. Twenty-three species (37% of the total) qualified as Regionally Extinct (RE) or threatened: 4 species were listed as RE and 19 as threatened (two Critically Endangered, eight Endangered and nine Vulnerable). A further 11 species were classified as Near Threatened. The remaining 28 species (45% of the total) were classified as Least Concern.

5. In comparison with previous assessments, we show that the number of species classified as threatened has increased. This is likely to be due to a combination of refined assessment criteria, improved data, and a real increase in the extinction threat as a result of human impacts.

6. The results confirm butterflies as a highly threatened group of insects in Great Britain and the Red List provides an important foundation to define conservation priorities.

Key words. Butterflies, conservation, extinction risk, IUCN Red List, monitoring, recording, threatened species.

Introduction

Human impacts on landscape and climate during the 20th and 21st centuries have led to rapid and substantial changes to the distribution and status of butterflies, both in Britain and elsewhere in Europe (e.g. Maes & Van Dyck, 2001; Warren *et al*., 2001; De Heer *et al*., 2005; Van Swaay *et al*., 2006; Wenzel *et al*., 2006; Wilson *et al*., 2007; Van Swaay *et al*., 2008; Van Dyck *et al*., 2009). These changes have prompted concern about butterfly declines and calls for a conservation response (New, 1997; Thomas *et al*., 2004; Van Swaay *et al*., 2009).

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Red Lists and Red Data Books (hereafter, just called Red Lists) have been important tools in biodiversity conservation for many decades (Lamoreux *et al*., 2003; Rodrigues *et al*., 2006). Instigated by the International Union for Conservation of Nature (IUCN), they provide a means of identifying, in a standardised way, species threatened with extinction (Mace *et al*., 2008). Although Red Lists do not contain conservation objectives or actions, they often serve to promote the development, prioritisation and monitoring of conservation policies (Butchart *et al*., 2005; Fitzpatrick *et al*., 2007; Warren *et al*., 2007).

Red Lists of butterflies have been produced in many countries and also at the pan-European scale (Van Swaay & Warren, 1999; Van Swaay *et al*., 2010). Two previous Red List assessments of butterflies have been carried out in Great Britain (Shirt, 1987; Warren *et al*., 1997). The IUCN criteria used for these

assessments differed from each other (principally with the inclusion of rate of decline as a quantitative measure of extinction risk in the later Red List) and from those used in this study. Importantly, both previous assessments pre-dated a major revision of the IUCN criteria in 2000 (IUCN, 2001). This revision, which is still in use today, introduced more quantitative and precise criteria (IUCN, 2001, 2003) and guidance on their use at the regional level (Gärdenfors *et al*., 2001).

Since the last Red List in 1997, considerable advances have been made in monitoring British butterflies. Thousands of skilled volunteers are now involved annually in a range of national schemes co-ordinated by Butterfly Conservation and the Centre for Ecology and Hydrology. As a result, comprehensive new data have become available on both distribution and population trends (Asher *et al*., 2001; Fox *et al*., 2006). It was established that butterflies had declined more rapidly over the last 30–50 years in Britain than other well-studied taxa (vascular plants and birds; Thomas *et al*., 2004); the rate of decline among macro-moths, however, has been comparable with that measured for butterflies (Conrad *et al*., 2006).

The revision of the IUCN criteria and availability of new monitoring data, together with known changes in butterfly distributions and populations, highlighted the need for an updated butterfly Red List and revised conservation priorities. The aim of this article is to undertake a revised assessment of British butterflies.

Methods and data sources

All resident and regularly breeding species (species that breed in Great Britain every year) were assessed. These included three migratory species (Clouded Yellow *Colias croceus*, Red Admiral *Vanessa atalanta* and Painted Lady *Vanessa cardui*) that are common summer breeding species but which do not maintain substantial year-round populations in Britain (although see Fox & Dennis, 2010 for a recent evaluation of the Red Admiral). Other immigrant species were classified as vagrants according to IUCN guidelines (Gärdenfors *et al*., 2001), since they occur only occasionally within Britain, and were not considered. Butterflies that formerly occurred as regular breeding species were assessed. In total, 62 species were included. All taxa were assessed at the species level.

Data sources

The Red List assessment was carried out using data from two different, but complementary schemes that exist to monitor butterflies in Britain: a national distribution recording scheme (Butterflies for the New Millennium, BNM) and a population monitoring scheme (UK Butterfly Monitoring Scheme, UKBMS).

The BNM scheme was launched by Butterfly Conservation in 1995 and has provided the impetus for 15 years of the most intensive butterfly recording ever undertaken in Britain (and Ireland). Data from the first 10 years of the BNM scheme (1995–2004) were used to develop the new Red List. In this period, approximately 10 000 observers contributed 3.2 million butterfly distribution records for Great Britain, representing 99.4% of the 10 km × 10 km grid squares in the Ordnance Survey national grid (Fox *et al*., 2006). In addition, historical butterfly records for the period 1970–1982 (Heath *et al*., 1984) were used in the assessment to provide a baseline against which to measure distribution change.

The BNM data were used to calculate area of occupancy (AOO), a measure of distribution size, for each species, and also to assess long-term trends by comparing species' distributions in different time periods. However, such trends have to be constructed and interpreted with care as the intensity and geographical coverage of recording has varied over time (Dennis *et al*., 1999). We calculated distribution change at the 10 km grid square resolution between the survey periods 1970–1982 and 1995–2004 (duration between mid-points of surveys = 25 years) by using a sub-sampling analysis (Thomas *et al*., 2004; Fox *et al*., 2006). This technique reduced the bias resulting from differences in recording intensity in the two periods, producing an approximate equalisation of recording effort. The sub-sampling method has been validated by comparison with population monitoring trends (Warren *et al*., 2001; Thomas, 2005) and alternative analysis techniques (Fox *et al*., 2010).

Since 1976, the UKBMS has undertaken detailed population monitoring of butterflies, primarily using a line transect method (Pollard & Yates, 1993). To date, the UKBMS has collated data from over 1500 site transects, representing nearly 170 000 weekly walks and records of over 12.5 million individual butterflies.

The UKBMS provides a standardised annual measure (index) of butterfly populations at transect sites. Transect indices relate closely to other, more intensive, measures of population size such as mark/release/recapture methods (Pollard *et al*., 1986). Indices from different sites can be combined to derive regional and national collated indices, which can be used to generate long- and short-term population trends. Collated indices of abundance were calculated for each species that had been recorded from a minimum of five sites per year. Abundance indices and temporal trends in the indices for each species were analysed by poisson regression, as implemented in the freeware program Trends and Indices for Monitoring Data (TRIM) (Pannekoek & van Strien, 1996). The direction, magnitude and significance of trends were calculated using the time effects model within TRIM, incorporating year and site effects and adjustments for overdispersion and serial correlation. Trends were calculated for 49 species over two time periods: (i) 10 years (1995–2004) and (ii) long-term (typically 1976–2004).

Although these distribution and population data on butterflies are more comprehensive than for any other invertebrate group in Britain, they do have limitations for use in Red List assessment (see next).

Application of IUCN criteria

The *new* IUCN criteria were used for the current assessment (IUCN, 2001), following guidance for their use at the regional scale (Gärdenfors *et al*., 2001). Species at risk of regional

extinction in Britain were assigned to the categories Regionally Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT). Species not assigned to one of these categories were classed as Least Concern (LC). Three additional IUCN categories (Extinct in the Wild, Data Deficient and Not Assessed) were not used in this assessment.

The state of knowledge and nature of the data available on British butterflies permitted species to be assessed quantitatively against two IUCN criteria: A2 (reduction in population size) and B2 (AOO).

The 10-year population trends generated from the UKBMS data set were directly applicable to the Red List assessment under criterion A2(b). However, inappropriate classification of species can occur if short-term population trends do not accurately reflect the longer term trend (Dunn, 2002). This is a particular concern for taxa, including British butterflies, with rapidly fluctuating population dynamics. The long time series of data in the UKBMS enabled short-term (i.e. 10 year) trends to be interpreted in the context of two- or threefold longer time periods. We assessed 10-year trends against the IUCN thresholds but also used long-term trends (which varied across species from 13 to 29 years, mean = 27.7 years, $n = 49$) to downgrade the initial categorisation, where there was inconsistency between short- and long-term trends.

Distribution (AOO) trends derived from the BNM data were used, with modification, under criterion A2(c). Modification was required on two fronts. First, trends were measured at 10 km grid square scale, whereas the IUCN criteria relate to population level change. Distribution trends measured at 10 km square resolution correlate with trends from butterfly population monitoring, suggesting that distribution change can be a valid surrogate for population change (Warren *et al*., 2001; Thomas, 2005). However, trends at 10 km square resolution underestimate trends at a finer spatial scale (which more closely resemble population level change), and this relationship is non-linear and taxon-specific (Thomas & Abery, 1995; Cowley *et al*., 1999). Thomas and Abery (1995) estimated that losses of species of intermediate rarity were underestimated by 35% on average when plotted at the 10 km square scale compared with losses at the 2 km grid square scale. To account for this, thresholds required to qualify for threat categories in this assessment were initially set 35% lower than those defined for population decline by IUCN. This 35% rule has been used in other recent assessments of the status of British butterflies (e.g. Warren *et al*., 1997; Bourn *et al*., 2005).

Second, distribution trends were measured over 25 years whilst IUCN thresholds specify 10 years. Consequently, the threshold values were further adjusted by calculating the annual rate of change using the equation $(1 - x)^n$ = proportion of population remaining (where x is the annual rate of change and n is the number of years over which the change has taken place) and solving for the altered time periods and threshold values. The resultant thresholds, adjusted for both geographical resolution and time scale, used in this assessment are shown in Table 1.

We defined a quantitative threshold for the NT category, so as to permit objective classification across species. This was set as a 31.9% decline in AOO (i.e. a 10% band below the threshold for VU, see Table 1).

IUCN criterion B2 (AOO) was derived for each species directly from the BNM data for 1995–2004. AOO values (and resultant Red List classifications) are influenced by the spatial resolution at which they are calculated (Gaston & Fuller, 2009). In accordance with recommended practice, AOO was calculated at the 2 km × 2 km grid resolution by totalling the number of grid squares occupied by each species at any point during the time period and converting to area (km^2) (Hartley & Kunin, 2003; IUCN, 2003; Eaton *et al*., 2005). Although using this geographical resolution provides a better estimate of the true range of a taxon than the coarser 10 km square resolution, in reality many butterfly species will occupy only a proportion of the land area within each 2 km × 2 km grid square (Cowley *et al*., 1999). Thus, the AOO values used in this study are likely to overestimate the amount of land occupied by species and potentially underestimate the IUCN threat category to which taxa should be assigned.

During previous Red List assessments of British butterflies, small geographical range was sufficient for species to be classified as at risk of extinction. This is not the case under the current IUCN criteria. For this study, butterfly species only qualified as threatened under criterion B2 if the measured AOO met threshold values plus at least two of three IUCN-defined *sub-criteria* (severe fragmentation, continuing decline, extreme fluctuations) were satisfied (IUCN, 2001). Species were classified as NT if

Table 1. The IUCN threshold values for classification under criterion A2 and the equivalent values used in this assessment.

Threat class	IUCN criteria (A2) for population decline over 10 years (%)	Equivalent AOO 25-year decline measured at 10 km square scale (%)
CR	≥80	≥84.0
EN	50–79	62.6–83.9
VU	30–49	41.9–62.5
NT	–	31.9–41.8

AOO, area of occupancy; CR, Critically Endangered; EN, Endangered; IUCN, International Union for Conservation of Nature; VU, Vulnerable; NT, Near Threatened.

Table 2. The IUCN thresholds for classification under criterion B2.

Threat class	AOO (based on occupied 2 km grid squares)
CR	< 10 km^2 + two of three sub-criteria (a–c)
EN	< 500 km^2 + two of three sub-criteria (a–c)
VU	< 2000 km^2 + two of three sub-criteria (a–c)
NT	< 2000 km^2 + one of three sub-criteria (a–c)

AOO, area of occupancy; CR, Critically Endangered; EN, Endangered; IUCN, International Union for Conservation of Nature; VU, Vulnerable; NT, Near Threatened.

AOO values met the threshold for VU status but only one of the sub-criteria was satisfied.

The threshold values of area occupied were not modified and the classification was made according to Table 2.

Regional assessment

IUCN recommend that regional Red List classifications (regional being any level below global) are carried out as a two stage process (Gärdenfors *et al*., 2001; Keller *et al*., 2005). Stage 1 is the application of IUCN criteria to taxon data at the regional level. Stage 2 involves an assessment of whether the regional extinction threat determined in Stage 1 is affected by the existence of populations outside of the region in question by providing potential for a *rescue effect*.

The two stage process was adopted in this regional assessment of British butterflies. In Stage 1, species were assessed against IUCN criteria using national data sources. For most taxa, three variables (AOO, distribution trend and population trend) were available for the assessment against the quantitative thresholds (as discussed before). A precautionary approach was applied during the assessment, such that the highest threat category justified by the data (with expert interpretation) was applied.

For the second part of the assessment, the likely impact of populations outside of Britain was appraised. Whilst the British population of some butterfly species is interconnected with populations in neighbouring countries (e.g. for highly mobile resident species, such as Large White *Pieris brassicae*, Small White *P. rapae* and Small Tortoiseshell *Aglais urticae*, as well as for the migrant species that only breed in Britain during the summer), in all cases these taxa had been classified as LC and therefore no downgrading of threat category was required. Conversely, all British taxa afforded a threat category, and those classified as NT, were considered to be unaffected by the presence of conspecific populations elsewhere. The latter judgement was made primarily on the grounds of limited dispersal capability (Pollard & Yates, 1993), although it is also true that many of the species qualifying for high extinction risk categories in Britain are also declining in neighbouring countries (Van Swaay & Warren, 1999).

Results

Using the three data variables (AOO, distribution trend and population trend) and expert opinion, all 62 butterfly species that regularly breed in Britain were classified using IUCN criteria (modified where necessary as documented above). The available data and the assessment are shown in Table 3 and summarised in Table 4 and Figure 1.

The new Red List of British butterflies identified 23 species (37% of the total) as extinct or threatened to some degree: 4 species were listed as RE and 19 species were considered threatened. Among the 19 threatened species, two were classified as CR (Large Blue *Glaucopsyche arion* and High Brown Fritillary *Argynnis adippe*), eight as EN and nine as VU. A further 11 species were listed as NT. All of the remaining species (45% of the total) were classified as LC.

Discussion

The new Red List assessment was based on the most comprehensive monitoring data ever available for British butterflies. The results are consistent with previous evidence of butterfly trends and confirm that butterflies are a highly threatened group in Britain (Warren *et al*., 2001; Thomas *et al*., 2004). This study found 37% of regularly breeding species (or 39% of permanently resident species) either RE or threatened (CR, EN or VU). This compares with 21% of Odonata (Daguet *et al*., 2008), 20% of vascular plants (Cheffings & Farrell, 2005) and 29% of birds (Eaton *et al*., 2005), although the latter proportion does not include RE species.

A comparison with previous Red List assessments of butterflies shows that the number of species considered to be threatened has grown rapidly (Table 5).

Three main factors may be responsible for this trend, acting singly or in combination and exerting a different effect on different species; continued decline, improved data and the revision of IUCN criteria.

There is no doubt that the majority of butterfly species are in decline in Britain, as shown by the distribution trends listed in Table 3, and so have an increasing risk of extinction (Warren *et al*., 2001; Thomas *et al*., 2004; Fox *et al*., 2006). It is also clear that the quality and quantity of data available from recording and monitoring schemes have improved substantially in recent years. Some species, which were not generally considered to be in decline during the 1980s (upon which the 1987 and 1997 Red Lists were based), have since been shown to be so because of continued decline coupled with improved quantity and quality of data (e.g. Wall *Lasiommata megera*, White Admiral *Limenitis camilla*). Although many of the species classified as threatened in this assessment had already been identified as extinct or having undergone major contractions of range by the time the previous Red Lists were produced (e.g. Heath *et al*., 1984), ongoing declines and improved ability to detect trends undoubtedly contributed to the large increase in threatened species, particularly between the 1997 Red List and the current assessment.

In contrast, the increase in the number of butterflies listed as threatened or NT between the 1987 Red List and the subsequent assessments owes more to the revision of IUCN criteria. The first Red List assessment excluded many species now considered threatened or NT because the IUCN criteria did not then include criteria for the rate of population decline (Shirt, 1987). In this assessment, 17 species qualify on this criterion alone and it formed part of the classification for a further three species. Restricting our assessment to *rarity* (i.e. limited range or population size) only, as was used by Shirt (1987), would have resulted in 17 species qualifying as currently threatened, compared with 11 in 1987.

Table 3. New Red List of British butterflies, showing available data and qualifying criteria.

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Chequered Skipper	*Carterocephalus palaemon*	424	EN	−38		–	–		**EN**	B2 ab(ii)	AOO highly restricted (< 500 km^2), severely fragmented and continuing decline of AOO
Small Skipper	*Thymelicus sylvestris*	60 680		4		–	–		LC		
Essex Skipper	*Thymelicus lineola*	26 640		46		–	–		LC		
Lulworth Skipper	*Thymelicus acteon*	252	NT	−15		−13	79		**NT**	B2 b(iii)	AOO highly restricted (< 500 km^2) and continuing decline in quantity and quality of habitat, but not severely fragmented and no extreme fluctuations
Silver-spotted Skipper	*Hesperia comma*	672	NT	4		1524***	2		**NT**	B2 a	AOO restricted (< 2000 km^2), severely fragmented, but no continuing decline (recent expansion) or extreme fluctuations
Large Skipper	*Ochlodes sylvanus*	54 136		−12		12	−38*	VU	LC		VU downgraded to LC because 10-year population decline not supported by long-term trend or AOO trend
Dingy Skipper	*Erynnis tages*	8668		−48	VU	−37**	−26		**VU**	A2 c	AOO trend suggests a population decline of 30–49%
Grizzled Skipper	*Pyrgus malvae*	5636		−49	VU	−34	−42	VU	**VU**	A2 bc	AOO trend, and 10-year population trend suggest a population decline of 30–49%
Swallowtail	*Papilio machaon*	128	NT	−5		–	–		**NT**	B2 b(iii)	AOO highly restricted (< 500 km^2) and continuing decline in quantity and quality of habitat, but not severely fragmented and no extreme fluctuations

Table 3. (*continued*).

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Wood White	*Leptidea sinapis*	944	VU	−65	EN	−64	10		**EN**	A2 c	AOO trend suggests a population decline of 50–79%
Clouded Yellow	*Colias croceus*	26 368		144		1117	1877		LC		Regular breeding migrant
Brimstone	*Gonepteryx rhamni*	52 436		−3		22	−11		LC		
Black-veined White	*Aporia crataegi*	–		–		–	–		**RE**		Last record 1920s
Large White	*Pieris brassicae*	101 852		−7		−28	18		LC		
Small White	*Pieris rapae*	103 012		−7		15	−34	VU	LC		VU downgraded to LC because 10-year population decline is not supported by long-term trend or AOO trend
Green-veined White	*Pieris napi*	120 932		−1		11	7		LC		
Orange-tip	*Anthocharis cardamines*	86 376		7		22	−8		LC		
Green Hairstreak	*Callophrys rubi*	14 152		−29		−25	−25		LC		AOO trend close to NT
Brown Hairstreak	*Thecla betulae*	3704		−43	VU	–	–		**VU**	A2 c	AOO trend suggests a population decline of 30–49%
Purple Hairstreak	*Neozephyrus quercus*	22 784		−15		53	−23		LC		
White-letter Hairstreak	*Satyrium w-album*	9220		−53	VU	−71*	−63	EN	**EN**	A2 b	10-year population trend is between 50 and 79% decline
Black Hairstreak	*Satyrium pruni*	288	EN	−43	VU	–	–		**EN**	B2 ab(ii)	AOO highly restricted (< 500 km^2), severely fragmented and continuing decline in AOO
Small Copper	*Lycaena phlaeas*	60 936		−16		−8	−41	VU	LC		VU downgraded to LCbecause 10-year population decline not supported by long-term trend or AOO trend
Large Copper	*Lycaena dispar*	–		–		–	–		**RE**		Last record 1864. Reintroduction attempts failed

Table 3. (*continued*).

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Small Blue	*Cupido minimus*	3212		−38	NT	−6	121		**NT**	A2 c	AOO trend is close to VU
Silver-studded Blue	*Plebeius argus*	1660	VU	−43	VU	−1	−72*	EN	**VU**	A2 c + B2ab(ii,v)	AOO restricted (< 2000 km^2), population severely fragmented and declining, and decline in AOO. However, steep 10-year population decline not supported by long-term trend, hence EN downgraded to VU
Brown Argus	*Plebeius agestis*	17 528		16		16	−61*	EN	LC		EN downgraded to LC because10-year population trend not supported by long-term trend or AOO trend
Northern Brown Argus	*Plebeius artaxerxes*	1536	VU	18		−10	−30	VU	**VU**	A2 b + B2 ab(v)	10-year population trend is between 30 and 49%. AOO restricted (< 2000 km^2), severely fragmented, and continuing decline
Common Blue	*Polyommatus icarus*	69 000		−15		9	−21		LC		
Chalkhill Blue	*Polyommatus coridon*	3468		−36	NT	31	−34	VU	**NT**	A2 bc	VU downgraded to NT because 10-year population decline not supported by long-term trend. AOO trend is close to VU
Adonis Blue	*Polyommatus bellargus*	1820	NT	−19		28	63		**NT**	B2 c(iv)	AOO restricted (< 2000 km^2) and extreme fluctuations in population size, but not declining (recent expansion) or severely fragmented
Mazarine Blue	*Polyommatus semi-argus*	–		–		–	–		**RE**		Last record 1904

Table 3. (*continued*).

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Holly Blue	*Celastrina argiolus*	59 292		36		281	−30	VU	LC		VU downgraded to LC because 10-year population trend part of natural cycle and not supported by long-term trend or AOO trend
Large Blue	*Glaucopsyche arion*	< 10	CR	–		–	–		**CR**	B2 ac(iv)	Extinct in Britain 1979 but re-introduced since 1980s to c. 10 sites. Severely fragmented and extreme fluctuations in population size
Duke of Burgundy	*Hamearis lucina*	1288	VU	−52	VU	−28	−58*	EN	**EN**	A2 b	10-year population trend is between 50 and 79% decline
White Admiral	*Limenitis camilla*	6004		−31	NT	−62**	−36	VU	**VU**	A2 b	10-year population trend is between 30 and 49% decline
Purple Emperor	*Apatura iris*	1040	NT	−52	VU	−18	33		**NT**	A2 c + B2 b(ii)	VU downgraded to NT because AOO trend not reliable for this canopy dwelling species. AOO restricted (< 2000 km^2) and continuing decline in AOO but not severely fragmented or with extreme fluctuations
Red Admiral	*Vanessa atalanta*	95 840		25		350***	−38	VU	LC		Regular breeding migrant. VU downgraded to LC because 10-year decline not supported by long-term trend or AOO trend
Painted Lady	*Vanessa cardui*	77 580		32		520	118		LC		Regular breeding migrant

Table 3. (*continued*).

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Small Tortoiseshell	*Aglais urticae*	114 780		−3		−15	−34	VU	LC		VU downgraded to LC because 10-year trend not supported by long-term trend or AOO trend. 10-year trend not statistically significant despite large sample size
Large Tortoiseshell	*Nymphalis polychloros*	–		–		–	–		**RE**		Last record in 1980s. Only vagrants since
Peacock	*Inachis io*	100 952		17		90**	−40	VU	LC		VU downgraded to LC because 10-year trend not supported bylong-term trend or AOO trend
Comma	*Polygonia c-album*	63 532		37		305***	64		LC		
Small Pearl-bordered Fritillary	*Boloria selene*	9232		−34	NT	−70***	−10		**NT**	A2 c	Decline in AOO close to VU
Pearl-bordered Fritillary	*Boloria euphrosyne*	2668		−61	VU	−66**	−51	EN	**EN**	A2 b	10-year population trend is between 50 and 79% decline
High Brown Fritillary	*Argynnis adippe*	552	VU	−79	EN	−13	−85*	CR	**CR**	A2 b	10-year trend is statistically significant despite small sample size
Dark Green Fritillary	*Argynnis aglaja*	11 424		−30		63	−10		LC		AOO trend close to NT
Silver-washed Fritillary	*Argynnis paphia*	9048		−29		33	−14		LC		AOO trend close to NT
Marsh Fritillary	*Euphydryas aurinia*	2876		−46	VU	−73**	73		**VU**	A2 c	AOO trend suggests population decline of 30–49%
Glanville Fritillary	*Melitaea cinxia*	132	EN	−17		–	–		**EN**	B2 b(v) c(iv)	AOO highly restricted (<500 km^2), continuing decline and extreme fluctuations
Heath Fritillary	*Melitaea athalia*	168	EN	−25		−73**	−46	VU	**EN**	B2 ab(ii,v)c (iv)	AOO highly restricted (<500 km^2), severely fragmented, continuing decline and extreme fluctuations

Table 3. (*continued*).

Species		AOO km^2	Category under B2	AOO 25-year trend (%)	Category under A2c	Long-term population trend (%)	10-year population trend (%)	Category under A2b	Overall assessment	Criteria for qualifying	Notes
Speckled Wood	*Pararge aegeria*	74 332		31		160***	66*		LC		
Wall	*Lasiommata megera*	37 600		−38	NT	−65**	−2		**NT**	A2 c	AOO trend close to VU
Mountain Ringlet	*Erebia epiphron*	524	NT	−12		–	–		**NT**	B2 b(ii)	AOO restricted (< 2000 km^2) and some evidence of continuing decline in AOO but not severely fragmented or with extreme fluctuations
Scotch Argus	*Erebia aethiops*	5660		−10		165**	−1		LC		
Marbled White	*Melanargia galathea*	22 260		11		129**	−15		LC		
Grayling	*Hipparchia semele*	8340		−45	VU	−51**	−41**	VU	**VU**	A2 bc	AOO trend and 10-year population trend suggest a population decline of 30–49%
Gatekeeper	*Pyronia tithonus*	80 148		12		−12	−5		LC		
Meadow Brown	*Maniola jurtina*	112 312		−4		28	−5		LC		
Ringlet	*Aphantopus hyperantus*	62 952		16		373***	33		LC		
Small Heath	*Coenonympha pamphilus*	48 660		−29		−52**	−29		**NT**	A2 b	10-year population decline is very near VU. Supported by highly significant long-term trend
Large Heath	*Coenonympha tullia*	3828		−43	VU	−26	58		**VU**	A2 c	AOO trend suggests a population decline of 30–49%

IUCN codes as follows: RE, Regionally Extinct; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern.
Statistical significance of population trends shown as $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.
Bold text highlights the overall assessment for those species qualifying as threatened or NT.

Table 4. Red List of British butterflies, listed by threat category and then taxonomic order.

Species		Overall assessment
Black-veined White	*Aporia crataegi*	RE
Large Copper	*Lycaena dispar*	RE
Mazarine Blue	*Polyommatus semi-argus*	RE
Large Tortoiseshell	*Nymphalis polychloros*	RE
Large Blue	*Glaucopsyche arion*	CR
High Brown Fritillary	*Argynnis adippe*	CR
Chequered Skipper	*Carterocephalus palaemon*	EN
Wood White	*Leptidea sinapis*	EN
White-letter Hairstreak	*Satyrium w-album*	EN
Black Hairstreak	*Satyrium pruni*	EN
Duke of Burgundy	*Hamearis lucina*	EN
Pearl-bordered Fritillary	*Boloria euphrosyne*	EN
Glanville Fritillary	*Melitaea cinxia*	EN
Heath Fritillary	*Melitaea athalia*	EN
Dingy Skipper	*Erynnis tages*	VU
Grizzled Skipper	*Pyrgus malvae*	VU
Brown Hairstreak	*Thecla betulae*	VU
Silver-studded Blue	*Plebeius argus*	VU
Northern Brown Argus	*Plebeius artaxerxes*	VU
White Admiral	*Limenitis camilla*	VU
Marsh Fritillary	*Euphydryas aurinia*	VU
Grayling	*Hipparchia semele*	VU
Large Heath	*Coenonympha tullia*	VU
Lulworth Skipper	*Thymelicus acteon*	NT
Silver-spotted Skipper	*Hesperia comma*	NT
Swallowtail	*Papilio machaon*	NT
Small Blue	*Cupido minimus*	NT
Chalkhill Blue	*Polyommatus coridon*	NT
Adonis Blue	*Polyommatus bellargus*	NT
Purple Emperor	*Apatura iris*	NT
Small Pearl-bordered Fritillary	*Boloria selene*	NT
Wall	*Lasiommata megera*	NT
Mountain Ringlet	*Erebia epiphron*	NT
Small Heath	*Coenonympha pamphilus*	NT

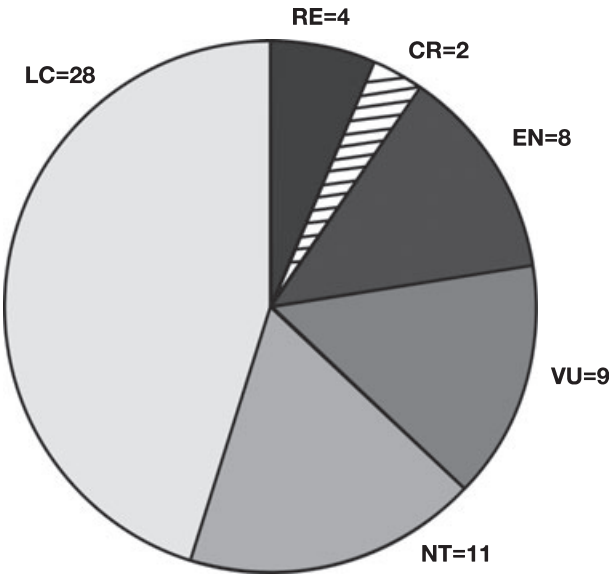

Fig. 1. Summary of Red List assessment for British butterflies (RE, Regionally Extinct; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern).

Table 5. Comparison with previous Red List assessments of butterflies in Britain.

IUCN category	Shirt (1987)	Warren *et al.* (1997)	Current assessment
Regionally Extinct	3	5	4
Critically Endangered	–	0	2
Endangered	2	0	8
Vulnerable	3	7	9
Near Threatened	–	7	11
Least Concern	–	–	28
Rare	3	–	–
Out of Danger	2	–	–
Total Threatened or NT (excluding LC and Out of Danger)	11	19	34

IUCN, International Union for Conservation of Nature; LC, Least Concern; NT, Near Threatened.

We consider that the current IUCN criteria provide a more valid assessment of extinction risk than earlier versions (Mace *et al.*, 2008) and are highly applicable to species with comprehensive quantitative data, such as British butterflies. Nevertheless, even for British butterflies, one of the most intensively studied invertebrate faunas in the world, the application of IUCN criteria was not straightforward. There were no species for which Red List criteria C or D, which rely on knowledge of the absolute population size (i.e. the total number of individuals) of a species, could be applied. The final criterion, E, requires a quantitative analysis of the probability of extinction. Such analysis, typically referred to as population viability analysis (PVA), requires detailed information about species and, as a result, has not been used widely for butterflies or other invertebrates (Schtickzelle & Baguette, 2009). Only two butterflies in Britain have been the subject of PVA analysis incorporating a substantial proportion of the species' range (i.e. approaching national scale); the Silver-spotted Skipper *Hesperia comma* (Hanski & Thomas, 1994; Wilson *et al.*, 2009) and Marsh Fritillary *Euphydryas aurinia* (Bulman *et al.*, 2007; Thomas *et al.*, 2008), although a few others have been studied in restricted local areas. As a result, criterion E was not suitable for this assessment of the British butterfly fauna, and the new Red List was constructed using criteria A and B only. Even for criterion A, the nature of the available data meant that thresholds had to be modified to allow for different timescales and geographical resolution, and expert judgement used to

interpret 10-year population trends in the context of long-term trends.

For other invertebrate groups in Britain and, particularly, in other countries, paucity of detailed data on current range size or population trend makes the Red List process more difficult (Dunn, 2005; Regan *et al*., 2005; Akçakaya *et al*., 2006; Warren *et al*., 2007). However, it does not preclude the creation of regional or global Red Lists. The two Red Data Books of European butterflies (Van Swaay & Warren, 1999; Van Swaay *et al*., 2010) were completed using limited data of varying quality and a sampled Red List Index approach is being developed for butterflies at the global scale (Lewis & Senior, 2010).

In many instances, Red Lists and Red Data Books act as drivers for biodiversity conservation both at policy level and in terms of practical management for threatened species. The European assessments have proved important and influential in advancing the cause of butterfly conservation across the continent, leading to further analyses (e.g. Konvicka *et al*., 2006; Van Swaay *et al*., 2006) and the identification of a network of priority sites for conservation (Van Swaay & Warren, 2003). In Britain, whilst the UK Biodiversity Action Plan (UK BAP) is well established as the principle mechanism to define priorities and implement conservation action, this new Red List assessment provides an important foundation and shows the ongoing deterioration of many butterfly populations. Although UK BAP priorities are drawn up using different criteria (UK Biodiversity Group, 1998; Bourn *et al*., 2005), both lists include many of the same species and highlight the serious extinction risk facing butterflies in Great Britain.

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