The decline of butterflies in Europe: Problems, significance, and possible solutions

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We review changes in the status of butterflies in Europe, focusing on long-running population data available for the United Kingdom, the Netherlands, and Belgium, based on standardized monitoring transects. In the United Kingdom, 8% of resident species have become extinct, and since 1976 overall numbers declined by around 50%. In the Netherlands, 20% of species have become extinct, and since 1990 overall numbers in the country declined by 50%. Distribution trends showed that butterfly distributions began decreasing long ago, and between 1890 and 1940, distributions declined by 80%. In Flanders (Belgium), 20 butterflies have become extinct (29%), and between 1992 and 2007 overall numbers declined by around 30%. A European Grassland Butterfly Indicator from 16 European countries shows there has been a 39% decline of grassland butterflies since 1990. The 2010 Red List of European butterflies listed 38 of the 482 European species (8%) as threatened and 44 species (10%) as near threatened (note that 47 species were not assessed). A country level analysis indicates that the average Red List rating is highest in central and mid-Western Europe and lowest in the far north of Europe and around the Mediterranean. The causes of the decline of butterflies are thought to be similar in most countries, mainly habitat loss and degradation and chemical pollution. Climate change is allowing many species to spread northward while bringing new threats to susceptible species. We describe examples of possible conservation solutions and a summary of policy changes needed to conserve butterflies and other insects.

insect decline | butterflies | conservation | Europe | monitoring

Biodiversity loss is one of the most pressing issues facing the planet. Insects are a vital component of biodiversity because they comprise over half of the world's terrestrial species, excluding eubacteria, archaea, and viruses (1). They also play important roles in the functioning of ecosystems: for example, as pollinators or food for other animals (2). In recent years, evidence has grown about the decline of terrestrial insects across the world and the possibility of ecosystem collapse (3–6). However, the data available on this important group are rather sparse and geographically limited such that this conclusion has been questioned (7, 8).

One of the most well-studied groups of insects is butterflies. They are popular with the public, relatively easy to identify, and have been used as model insects for many years (e.g., refs. 9 and 10). They are also a valuable environmental indicator group as they react quickly to change, and their presence and abundance do not simply follow vegetation-based indicators (11). The most robust and objective data on the group come from Europe, where standardized monitoring programs have been operating in some countries for several decades.

This paper summarizes butterfly trends in some of the best-studied countries of Western Europe, as well as the status of butterflies as assessed by Red Lists, and looks at the drivers of change. We compare these with more recent data from other countries and also give examples of conservation programs that have helped reverse the decline of threatened species at a landscape scale.

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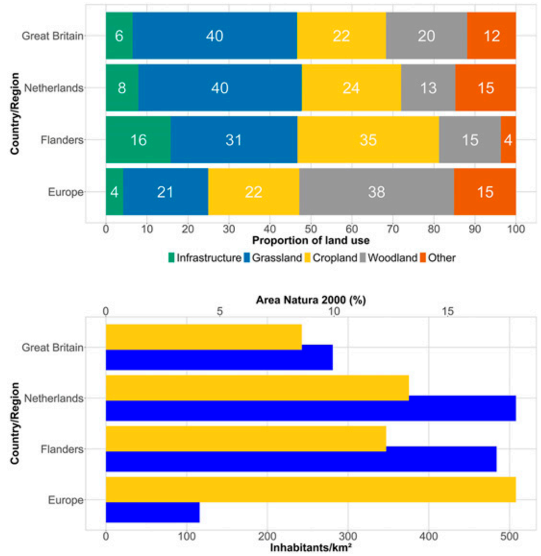

Fig. 1. **(*Top*) Coverage of different land use categories with the percentage per land use category given in white numbers (source: refs. 88 and 89). Note that "grassland" includes agriculturally improved, seminatural, and natural grasslands; the "other" category includes wetlands, shrubland, bare land, water bodies, and other seminatural areas. (*Bottom*) The percentage of areas protected under the EU Natura 2000 legislation (yellow, upper axis; source: European Environment Agency: https://www.eea.europa.eu/data-and-maps/data/natura-11) and the population density (blue, lower axis; source: https://www.worldometers.info/) in the three regions/countries. Note that data for "Europe" include the three countries.**

Background and Methods

The three focal regions in Western Europe (the United Kingdom, the Netherlands and the Flanders region of Belgium) are characterized by a high proportion of agricultural grasslands (i.e., fertilized and intensively managed grasslands for fodder production) and cropland and by a relatively low amount of woodland compared with Europe as a whole (Fig. 1*A*). Additionally, they are among the regions with the highest population density in Europe and have a lower percentage of land protected as Natura 2000 areas under the European Union (EU) Habitats Directive (Fig. 1*B*). The numbers of species in the different International Union for Conservation of Nature (IUCN) Red List categories (regionally extinct, critically endangered, endangered, vulnerable, near threatened, and least concern) in the respective regions are given in Fig. 2. These three regions have a considerably higher proportion of extinct and threatened species than Europe as a whole (the procedure of IUCN Red List assessments is in ref. 12).

Trends in butterflies can be detected in two ways: changes in distribution range (occurrence) or changes in abundance. Distribution data are mostly collected as casual records by citizen scientists and can be used to produce distribution atlases and calculate changes in distribution (13). Systematic butterfly monitoring to assess changes in abundance started in 1976 with the founding of what is now the UK Butterfly Monitoring Scheme (UKBMS). The method is based on weekly counts of butterflies along a fixed transect (14). The results give an estimate of the abundance of butterflies recorded each year at each monitored site, referred to as the annual Index of Abundance (15, 16). These indices can be combined to form an overall index showing trends for all butterflies or certain groups of butterflies. The same methodology has been adopted in many European countries since, allowing us to compare trends between countries and combine them into a continental trend.

Results

Trends in the United Kingdom. The UKBMS started in 1976 and now monitors over 2,000 sites. The Index of Abundance averaged for all butterflies decreased by around 50% since 1976 (the start of butterfly monitoring) (Fig. 3*A*), a year when there was an extreme drought. To better visualize changes, we grouped species into habitat specialists (i.e., species that are more or less confined to discrete patches of seminatural habitat) and wider countryside species (i.e., species that either range across the countryside or breed in a wide variety of habitats). Since 1976, habitat specialists showed a slow but steady decline in abundance of 68% (https://www.gov.uk/government/statistics/butterflies-in-the-wider-countryside-uk). In contrast, wider countryside species recovered back to their predrought level within around 8 y after the drought. However, since the mid-1990s, they too have started to decline so that they have dropped by 30% since 1976. Overall, 20 species are declining, 21 are stable, and 9 are increasing in abundance.

By analyzing distribution data, butterfly occurrence for the 1970 to 1976 period was found to be broadly stable, confirming that the drop in abundance after 1976 was likely to have been caused by the drought effect (17). However, not all butterflies are declining. Around 30% are expanding their range, many of them also increasing in abundance. These expanding species usually either occur in a wide range of habitats or breed in habitats that still occur widely in the landscape and have thus been able to move through the landscape more easily than those whose habitats have become highly fragmented.

Trends in the Netherlands. The Dutch Butterfly Monitoring Scheme started in 1990 and samples over 1,000 locations. It shows that the Index of Abundance (18) has declined by almost 50%, with 25 species declining, 9 remaining stable, and 16 increasing (19). Not only habitat specialists have decreased in numbers; also, common and widespread species of gardens, parks, and the countryside have declined by on average 30% between 1992 and 2007 (20). Climate change has had a dual effect, forcing some northern "cool" species to abandon parts of their former range or to go extinct locally but allowing southern and relatively mobile species to successfully colonize the country during the last decade: *Cupido argiades*, *Carcharodus alceae*, *Brenthis daphne*, and *Pieris mannii*.

By analyzing distribution data, van Strien et al. (21) showed that butterflies started declining in the Netherlands long before detailed monitoring began. Between 1890 and 1940, butterflies declined in distribution by at least 80% on average. Intensifying agricultural practices in the 1960s and 1970s (more arable cropland and increased use of chemicals) triggered further declines, and butterflies have since become largely restricted to nature reserves and rail and road verges.

Trends in Flanders (North Belgium). In the early 2000s, the first Red List of butterflies in Flanders (northern Belgium) revealed that 19 of 64 indigenous species (30%) had become extinct and that 18 species (28%) were threatened with extinction (22). This

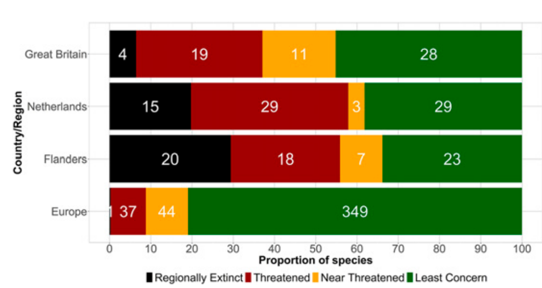

Fig. 2. **Number of species that are regionally extinct, threatened (critically endangered, endangered, or vulnerable), near threatened, and of least concern according to the respective Red Lists in the United Kingdom (90), the Netherlands (91), Flanders (92), and Europe (27). The absolute numbers of species per region and per Red List category are given in white.**

massive decline was called “Europe’s worst-case scenario” and was picked up by the journal *Nature* as “Butterflies fall in Flanders fields” (23). Rare and sedentary species and species of nutrient-poor biotopes showed a significantly stronger decline than more common, mobile species and species of eutrophic biotopes. This indicates that ecological profiles and life history traits can affect butterfly losses, which have been analyzed subsequently for other parts of Europe (e.g., Finland) (24).

The Flemish butterfly scheme started in 1991 but samples less than 100 sites. Between 1991 and 2019, the abundance of widespread grassland species has declined by 12%, while woodland species showed an increase of 19% in abundance (25).

The European Butterfly Grassland Indicator. Pan-European trends derived from butterfly transects from 16 (mainly Western) European countries have been collated for 17 characteristic and widespread grassland species to produce a European Grassland Butterfly Indicator. The results show that the combined Index of Abundance of these butterflies has declined by 39% since 1990, indicating a serious deterioration of grassland habitats (Fig. 3*B*) (26). Additional indicators (e.g., all species, woodland, climate change) will be published shortly as part of the newly formed European Butterfly Monitoring Scheme (https://www.butterfly-monitoring.net/) and will give us a more accurate picture on the overall state of European butterflies.

The Red List of European Butterflies. An overview of the status of all 482 European butterflies was produced in 2010 using distribution monitoring data, published studies, and expert opinion (27, 28). The results showed that one species was regionally extinct in Europe and that 37 of the 435 assessed species (9%) were classified as threatened (3 critically endangered, 12 endangered, and 22 vulnerable). A further 44 species (10%) are declining rapidly and were classed as near threatened (Fig. 2). Since the assessment, *Pieris wollastoni*, an endemic of Madeira, is assumed to have become globally extinct (the first documented butterfly extinction in Europe). However, the lack of accurate data in large parts of eastern Europe means that this Red List assessment most likely underestimates the overall threats to European butterflies (28).

The Red List provides an overview of which biotopes are most important to butterflies. The most species rich are dry grasslands and steppes (274 species), alpine and subalpine grasslands (261 species), mesophile grasslands (223 species), and dry siliceous grasslands (220 species) (29). Most of these grasslands are seminatural: that is, they have been created or extended by forest clearance, traditional agriculture, and either livestock grazing or by making hay for livestock. Other important habitats for butterflies are sclerophyllus scrub and heath (202 and 189 species, respectively) and different types of woodland (156 to 187 species). Within woodland, several species rely on open microhabitats or on forest edges next to pastures. Once again, these habitats have

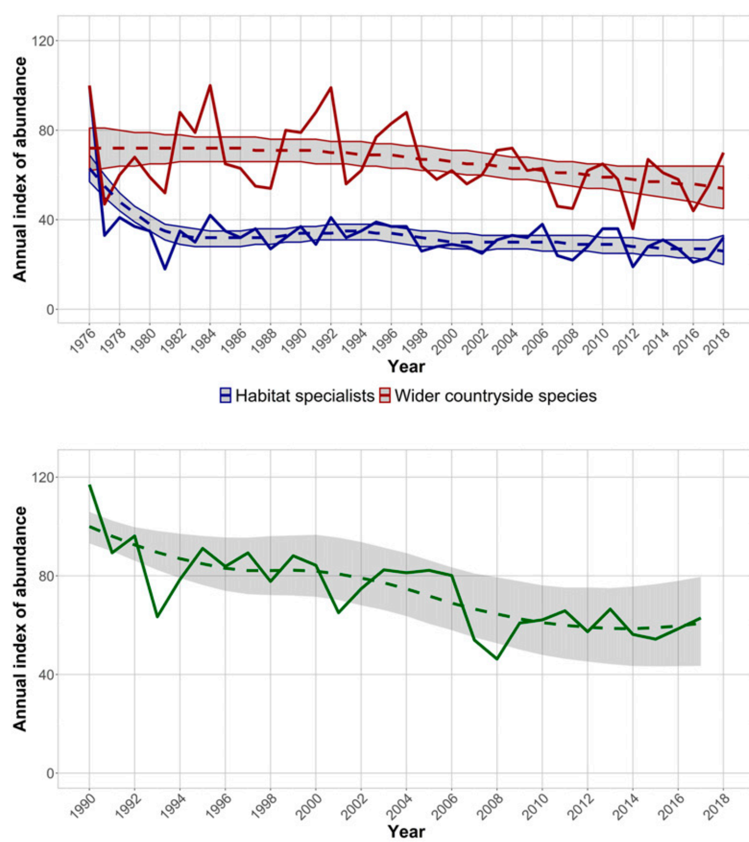

Fig. 3. **(*Top*) Observed (solid line) and smoothed (dashed line) trends of the UK butterfly index for habitat specialists (blue) and wider countryside species (red) together with the 95% CI of the smoothed trend. The first year of monitoring is set to 100 (source: ref. 93). (*Bottom*) The Grassland Butterfly Indicator for EU countries. The smoothed line starts at 100, and the shaded areas represent the 95% confidence limits surrounding the smoothed trend (source: ref. 26). The smoothed line is based on the loess method after 18.**

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been heavily influenced by human activity: for example, felling or coppicing (cutting trees on a rotation and allowing them to regrow). The net result is that the majority of European butterflies live in cultural landscapes that have been heavily modified or maintained by human activity for at least two millennia. This is a critical aspect when we come to consider practical conservation measures.

Another insight into the pattern of decline of butterflies in Europe is gained from analyzing the Red Lists of individual countries. The numbers of threatened species are highest in the Netherlands, Belgium, the Czech Republic, and Denmark (Fig. 4) and more or less decreases concentrically toward southern and eastern Europe in the Mediterranean region, such as Spain, France, and Italy (30). This suggests that the latter countries have not experienced such a severe decline of butterflies, but this may be masked to some extent by a lack of accurate trend data; most had no comprehensive monitoring data until recently.

Causes of Decline

The factors causing the decline of butterflies fall into three main categories: habitat loss/degradation, chemical pollution, and climate change (the latter having both positive and negative effects, depending on the species and region).

Habitat Degradation. Without doubt, the most serious cause of butterfly decline has been habitat loss and degradation. Since the 1950s in the United Kingdom, there has been a 97% loss of flower-rich meadows, 80% loss of calcareous grassland, 50% loss of ancient native woodland, and 40% loss of lowland heath land (31). Similar losses have been experienced in other Western European countries and to a lesser extent, in the rest of Europe. A major driving force behind these losses has been the expansion of intensive agriculture, which has led to plowing of grasslands for arable crops, and the reseeding and/or fertilization of pastures and other habitats. Accompanying this gross loss have been major changes in habitat management. Traditional regimes such as extensive grazing or hay cutting disappeared from most of Western Europe in the first half of the 20th century and were replaced by large-scale and intensive farming practices. This led to a substantial loss of herbs and nectar sources that many butterflies rely on (32). In the short term, a few species may benefit from abandonment, but as the vegetation succeeds to woodland, only a small number of tree and shrub-feeding species benefit (29, 33, 34).

Within woodland, several butterflies breed in the canopy (feeding on deciduous trees), but others occur in open spaces in woodland: for example, in rides, glades, and clearings. These open space species are also declining because of a lack of traditional management or the replanting with nonnative coniferous trees that cast a dense shade. In Western Europe, many woodlands were coppiced until the 20th century, creating a range of seral stages in which many butterflies could breed. Now, only a small percentage is actively coppiced, leading to the decline of several species, such as *Boloria euphrosyne* and *Boloria selene*.

One consequence of widespread habitat loss and degradation is that remaining habitats tend to be relatively small and isolated. Populations breeding in such areas are more likely to become extinct, either through normal stochastic processes or by inbreeding depression (35). Habitat fragmentation is now a serious concern for many butterflies, especially sedentary habitat specialists. In fragmented landscapes, they frequently occur as metapopulations spanning a number of small patches of habitat (35). Across much of Western Europe, habitat fragmentation has been severe (36) and is a pressing issue.

Chemical Pollution. Chemical pollution covers a wide variety of substances that adversely influence butterflies and their habitats. The most obvious are insecticides, which are routinely sprayed on arable crops to reduce damage by insects and other organisms. Despite the potential risks from insecticides, surprisingly little research has been done on butterflies (37). The biggest recent concern comes from neonicotinoids, a group of chemicals that were introduced in the early 1990s and that have been implicated in the decline of bees (38) and insectivorous birds (39). The other problem with neonicotinoids is that they are persistent and leach into the soils and water courses (40) as well as into field margins where certain butterflies breed or forage. Researchers have found that bumblebees can pick up harmful doses just from feeding on wildflowers in field margins (41).

Little research has been done on the impact of neonicotinoids on butterflies. They are known to kill Monarch butterflies in the laboratory (42), and lethal quantities have been found in host plants in the field (43). Harmful effects have also been shown for predators of butterflies and other insects (44). Another strand of evidence comes from a study in the United Kingdom that showed a strong correlation between the declines of "wider countryside" butterflies (many of which breed in field margins) and the use of neonicotinoid pesticides (45). However, this study did not demonstrate cause and effect, and further research is urgently needed both on direct mortality and on indirect effects that may affect butterfly behavior, longevity, and reproductive success. Neonicotinoids have now been banned from all crops in the EU, but negative effects may persist in coming years.

The other harmful pollutant for butterflies is aerial nitrogen deposition. The chief sources are from the ammonia produced by intensive livestock rearing and the emission of nitrogen oxides from vehicles. Nitrogen pollution has been implicated in the decline of several butterflies because it changes either microclimates (46) or the nature of the vegetation where they breed (47, 48). Many habitats of specialist butterflies are naturally low in nutrients, which allows for high plant diversity, including butterfly food plants and structural diversity. Nitrogen enrichment encourages the spread of nitrogen-tolerant species at the expense of those that require nutrient-poor conditions (49). Nitrogen deposition is thought to be responsible for the decline of *Lasiommata megera* in the Netherlands because it encourages vegetation growth and reduces the amount of bare ground where the butterflies breed (50). This butterfly is one of the most rapidly declining species in the European Grassland Butterfly Indicator.

Further evidence that nitrogen deposition can cool otherwise warm microclimates comes from a study showing that butterfly species that overwinter as eggs or caterpillars are declining faster than those that overwinter as adults or chrysalids (46). This is probably because caterpillars are falling victim to the increasingly rapid growth of vegetation in the early spring, which cools the within-vegetation temperature and so, reduces their growth rates and chances of survival. Grazing, however, could reduce grass cover and benefit butterflies of warm microclimates (51).

Climate Change. Climate change can have both positive and negative effects on butterflies. The range of several thermophilus species has spread dramatically northward in Europe as a direct consequence of climate change, sometimes by several hundred kilometers (52, 53). On the other hand, cold-adapted species have retreated to cooler conditions higher up in hills and mountains (54) or have gone locally extinct. Certain species that already live on mountain tops are especially threatened, including some endemic species in the Sierra Nevada in south Spain (55).

In Europe, the growing season has increased by more than 10 d since 1992 (https://www.eea.europa.eu/data-and-maps/indicators/growing-season-for-agricultural-crops-2/assessment), leading to more rapid growth of natural vegetation and problems for species associated with intermediate successional vegetation by affecting either their microclimate or the nutritional quality of food plants (56). Voltinism is also an important, but complex, factor. Multivoltine species are declining less rapidly than univoltine ones in the United Kingdom (57), whereas the opposite is true in a Mediterranean region of Spain (58). Another problem caused by climatic warming is that species with complex life cycles such as butterflies may suffer from developmental traps if environmental cues to enter diapause are disrupted (e.g., *L. megera* in Belgium) (59).

Climate change is predicted to increase the frequency of extreme weather events such as droughts and floods. As mentioned earlier, the 1976 drought was followed by a rapid drop in butterfly abundance in the United Kingdom, from which some species have never recovered. Similarly prolonged rainfall and storms can reduce breeding success and reduce overall population size. In fragmented landscapes, this could increase local extinction rates and affect the viability of metapopulations (e.g., ref. 60).

Conservation Solutions

Landscape-Scale Conservation. In Western Europe, many important habitats survive only as small and isolated fragments. For example, seminatural grasslands now comprise less than 0.6% of the land area of England and Wales (the United Kingdom), and most fragments are less than 10 ha in extent (61). Most threatened species, many of which are habitat specialists, now exist on small patches of habitat surrounded by intensively used land. To tackle the problem, Butterfly Conservation has developed a comprehensive landscape-scale conservation program in the United Kingdom, targeted at 200 priority landscapes for threatened butterflies and moths. These have shown that declines can be reversed by improving land management on networks of sites (Fig. 5) (62).

Landscape areas are chosen to encompass networks of sites supporting metapopulations of threatened species. About half of them are considered of high priority because they support 1) more threatened species; 2) significant proportions of threatened species' distributions; 3) networks of both occupied and unoccupied sites (i.e., a metapopulation structure), the latter of which could be (re-)colonized following landscape-scale conservation; and 4) more habitat types in which management intervention can be undertaken.

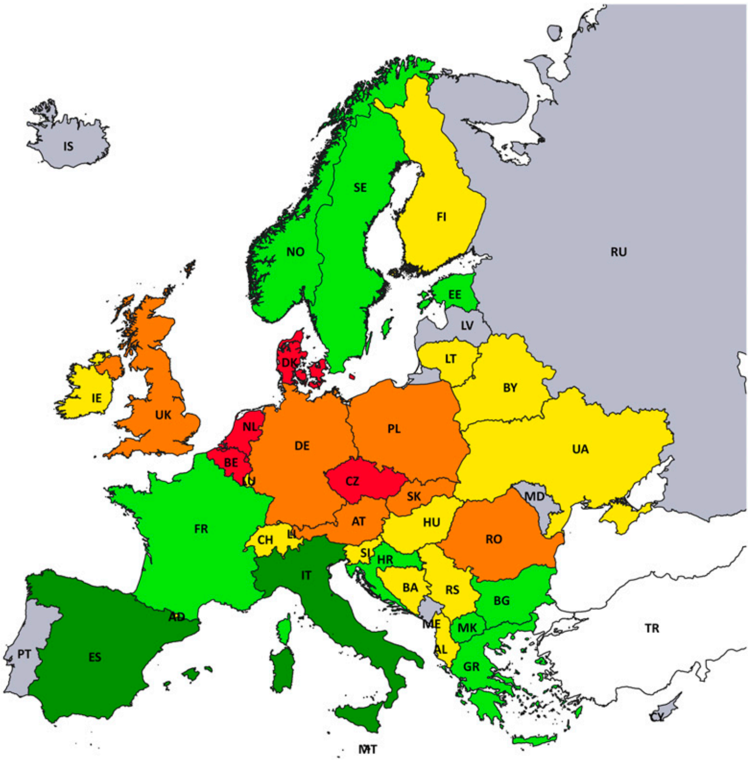

Fig. 4. Mean Red List value (cRLV) per European country (this value is calculated by giving each Red List category a numerical value and subsequently averaging out this value for each country). Red indicates cRLV ≥ 30. Orange indicates cRLV = 20 to 30. Yellow indicates cRLV = 10 to 20. Light green indicates cRLV = 5 to 10. Dark green indicates cRLV ≤ 5. Gray indicates no Red List available (full details are given in ref. 30). Country codes: AD, Andorra; AL, Albania; AT, Austria; BA, Bosnia and Herzegovina; BE, Belgium; BG, Bulgaria; BY, Belarus; CH, Switzerland; CY, Cyprus; CZ, Czech Republic; DE, Germany; DK, Denmark; EE, Estonia; ES, Spain; FR, France; FI, Finland; GR, Greece; HR, Croatia; HU, Hungary; IE, Ireland; IS, Iceland; IT, Italy; LI, Liechtenstein; LT, Lithuania; LU, Luxembourg; LV, Latvia; MD, Moldova; ME, Montenegro; MK, North Macedonia; MT, Malta; NL, the Netherlands; NO, Norway; PL, Poland; PT, Portugal; RO, Romania; RS, Serbia; RU, Russia; SE, Sweden; SI, Slovenia; SK, Slovakia; TR, Turkey; UA, Ukraine; UK, the United Kingdom. Source data are from ref. 94. Reprinted by permission from ref. 30, Springer Nature: *Journal of Insect Conservation*, copyright (2019).

around the landscape and increasing the rate of colonization and gene flow (63). In grasslands, a key mechanism for habitat enhancements is government-funded agrienvironment schemes. These pay farmers to manage the land in a sensitive way to enhance biodiversity and landscape quality. On land that is not eligible for such payments, funds can sometimes be raised from

Landscape-scale conservation involves three main elements: 1) increasing the area of suitable breeding habitat; 2) maximizing habitat quality by targeted management, both to enhance existing populations of threatened species and to make unoccupied sites suitable for (re-)colonization; and 3) improving connectivity both within and between sites—thus helping butterflies to move

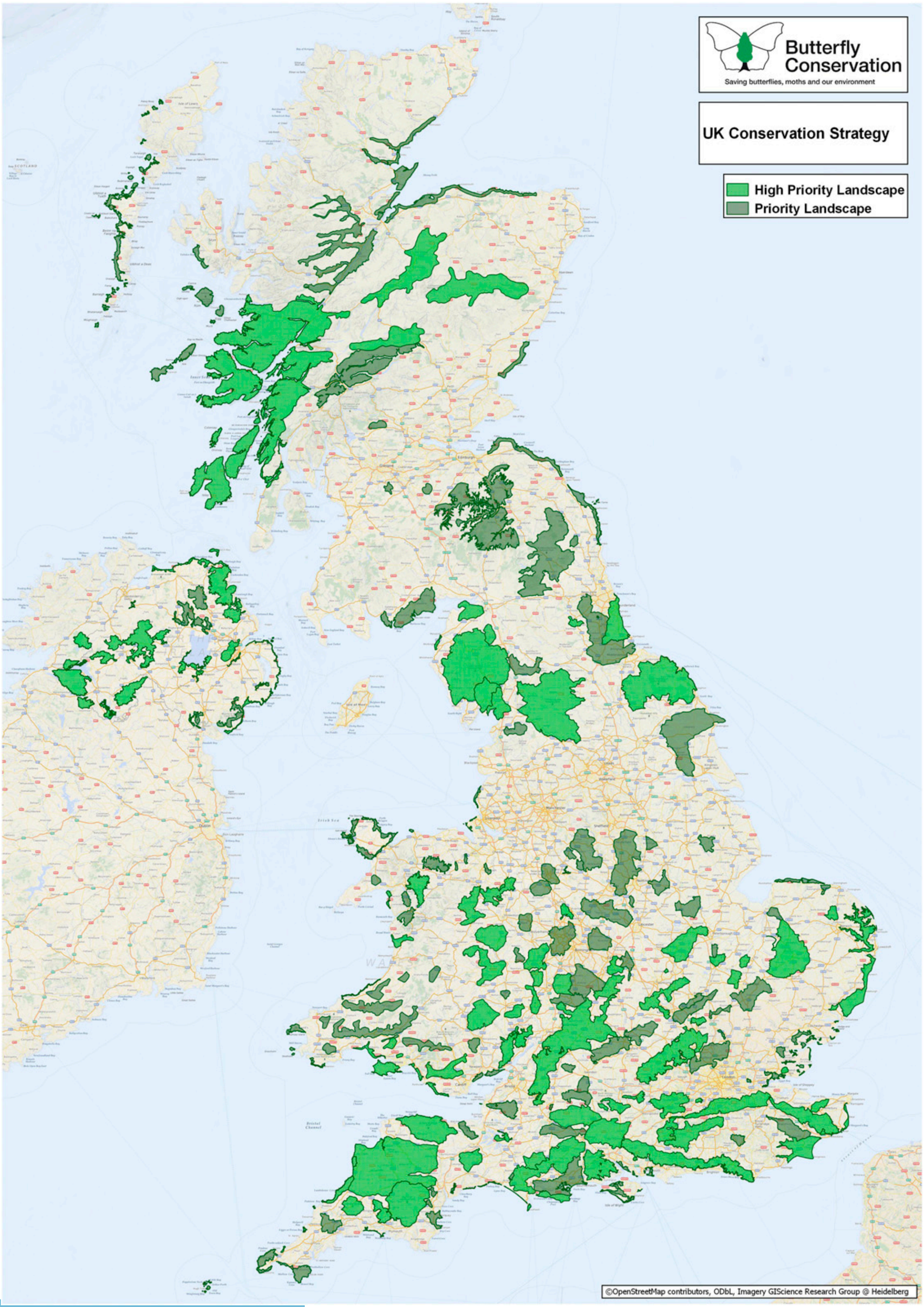

Fig. 5. Landscape conservation areas in the United Kingdom as defined by Butterfly Conservation (62).

other sources, and volunteer groups can be organized to do some, sometimes all, of the practical work for free. To date, this approach has been applied to around 75 priority landscapes in the United Kingdom, reversing the decline of several species (63).

Case Studies. **Hamearis lucina in the United Kingdom.** *H. lucina* is a threatened UK butterfly mainly restricted to calcareous habitats in the south of England, either scrubby grassland or clearings in ancient woodland where its two larval food plants, *Primula veris* and *Primula vulgaris*, occur. Between 1976 and 2014, the butterfly declined in distribution by 84% and in abundance by 42% (17). By 2012, it was restricted to just 160 populations with 260 recorded extirpations between the 1980s and 2012, a 62% loss. The main causes of decline were lack of management on sites (abandonment, lack of scrub control) implicated in 57% of extirpations and excessive management (usually the restoration of heavy grazing) in a further 27% of cases (64). Concerted efforts to reverse this decline began in 2003 with a program of landscape-scale conservation (63). This was composed mainly of targeted emergency recovery management, with the rotational management of scrub and the fencing of sites to reduce grazing pressure.

This approach has now been fully applied to 9 and to some extent in 7 others of the 17 landscapes in which the species still occurs (62). In the North Downs in Kent, two extensive landscape-scale projects were implemented, and the average peak count of *H. lucina* has increased almost threefold from 28 in 1995 to 2007 to 83 in 2008 to 2017 ($t = -4.18$, $df = 11.39$, $P = 0.001$). As populations have increased, the butterfly has been able to spread naturally, and the number of occupied sites has increased from an average of 3 per year for the earlier period to 12 to 14 sites per year for 2012 onward ($t = -7.82$, $df = 11.4$, $P < 0.001$). Overall, the landscape-scale conservation approach seems to be having an impact on the butterfly's abundance at a country scale, with a short-term (10-y) abundance trend of 90% increase ($P < 0.01$) from 2007 to 2016.

Conserving wet grassland butterflies in south Belgium. Between 2009 and 2014, a "Butterfly" (L'Instrument Financier pour l'Environnement [LIFE+]) project was funded by the EU in five regions in the south of Belgium. Three target butterfly species, *Euphydryas aurinia* (European Habitats Directive Annex II), *Lycaena dispar*, and *Lycaena helle* (both European Habitats Directive Annex II and IV), were the subjects of landscape-scale restoration actions in large humid forests and wetlands (65–67). Rides and glades have been enlarged and humid grasslands have been restored or created to increase the area of suitable habitat and the abundance of respective food plants *Succisa pratensis*, *Rumex* sp., and *Persicaria bistorta*.

In total, the project helped restore over 600 ha of habitat (https://www.life-papillons.eu/index.php?id=3578&L=1). After just 3 to 4 y, butterfly abundances and species richness have increased strongly on the newly created and/or restored sites to reach similar levels as surviving reference sites. Apart from the three target species, several other threatened butterflies such as *B. euphrosyne*, *Mellicta athalia*, *Argynnis aglaja* and *Lycaena hippothoe*, but also other taxa such as bats (e.g., *Rhinolophus ferrumequinum*), birds (e.g., *Ciconia nigra*, *Cuculus canorus*), reptiles (e.g., *Coronella austriaca*), and plants (e.g., *Dactylorhiza maculata*), have colonized the restored sites or regularly forage in them.

Lessons from conserving a rare blue in the Netherlands. Some of the most intriguing butterflies in Europe are the *Phengaris* species that have evolved a social parasitic lifestyle, living in the nests of *Myrmica* ants. In the Netherlands, *Phengaris (Maculinea) teleius* used to occur on mesophilic wet fen meadows, which were quite common in the agricultural countryside until the 1970s. However, the area of meadows was reduced by 99.9%, from circa 30,000 ha in 1900 to 30 ha in 2016 (68). As a result, *P. teleius* was extirpated from the country in 1976. In 1990, a project was initiated to reestablish the species, and adults were released in a specially managed nature reserve (Moerputten). The butterfly was expected to colonize six nearby meadows, but they chiefly remained on just one, which had the highest host ant nest density.

In 2012, an EU-funded (LIFE+) project "Blues in the Marshes" was started to extend the habitat, by converting 170 ha of intensive agricultural land into fen meadows over a period of 3 y. Suitable hydrological conditions were reinstated, and the upper, heavily enriched soil layer was removed to a depth of 40 cm to create more nutrient-poor conditions. To facilitate the establishment of the target vegetation community, green hay was gathered from the fen meadows surviving nearby and spread over the soil-stripped area.

To date, 123 plant species have become established; 44 of them are on the Dutch Red List. Several rare and Red-Listed birds have also increased in the reserve, including *Coturnix* and *Perdix perdix*. Many common butterflies have spread, but the target species *P. teleius* has still not successfully colonized areas outside the Moerputten nature reserve, probably because the density of host ants is still too low (69). Thus, although conservation has expanded its habitat, the quality is not yet sufficiently high enough to support the butterfly. This is a salutary lesson that it can be hard to restore habitats for specialized butterflies, and it shows that it is vital to conserve remaining habitats.

Policy Solutions. In addition to practical solutions to conserving threatened species, far-reaching changes are needed in several policy areas to reverse the decline of butterflies (70). The following brief suggestions are the main priorities for butterflies. They will also help biodiversity in general and complement the proposals by other authors (71–73).

Agriculture and forestry.

Maintain traditional systems of management in key habitats such as seminatural grasslands, wetlands, and woodland. Financial support may be needed to ensure sustainable income and prevent the need for intensification.

Reward farmers who manage high nature value farmland that supports biodiversity (http://www.high-nature-value-farming.eu/).

Support wildlife-friendly management on all farms, including field margins and hedges, and the maintenance of seminatural features.

Ensure more efficient fertilizer use so that it stays on the cropland and does not spread into surrounding habitats or pollute the air (e.g., with ammonia). A reduction in fertilizer use may be needed in areas with sensitive soils.

Ensure that pesticides do not harm nontarget organisms.

Nature reserves and protected areas.

Ensure that existing reserves and protected areas are managed to maintain their biodiversity. Dos and don'ts for managing habitats for threatened European butterflies are available (74).

Expand the protected area network to cover core areas for all highly threatened species.

Towns and cities.

Create and manage urban green space to encourage biodiversity. Simple measures such as reducing mowing intensity or creating new habitat by sowing wildflowers could produce quick wins (see https://butterfly-conservation.org/our-work/conservation-projects/building-sites-for-butterflies).

Encourage wildlife-friendly practices in existing gardens as well as in new developments.

Develop green corridors so that wildlife can move between green spaces.

Planning policies should avoid new developments in or close to important wildlife areas, including protected areas and reserves.

Climate change.

Urgent action and new policies are needed to reduce carbon emissions and avoid further climate change.

Mitigation measures should be taken to reduce the impacts on insects: for example, maintaining extensive areas of habitat, maintaining large populations and metapopulations, and ensuring habitat heterogeneity (see ref. 75).

Raising awareness.

Raise awareness of the importance of insects and the need to conserve them among the public and key stakeholders (76).

Monitoring and review.

Maintain and expand butterfly monitoring to continue to gather robust data on trends and as a means to evaluate policies. Butterfly trends can act as a proxy for other terrestrial insects, but comprehensive monitoring programs for other insects that occupy different environments (e.g., aquatic) should also be a priority (77).

Conclusions

There is clear evidence that butterflies are declining across large parts of Europe. Declines have been severe in central and mid-Western Europe. Studies in the Netherlands show that these declines probably started at least a century ago when agricultural intensification really began to change the landscape. Most monitoring programs (which started in the last 20 to 40 y) are therefore picking up the tail end of long-term declines. Although we have concentrated on longer-running schemes in relatively species-poor regions of Western Europe, serious declines have also been reported in other European countries such as Sweden (78), Germany (79), and Spain (58). Similar butterfly declines have been observed elsewhere in the world such as in the United States (80–82) (a full list of transect schemes in the United States can be found at https://pollardbase.org/) and in Japan (83). One of the most comprehensive studies in the United States studying population trends of 81 species found a 33% decline in total butterfly abundance over 21 y, with roughly two-thirds of the species declining (84). The drivers of loss in Ohio were also thought to be similar to Europe, including climate change, habitat degradation, and changing agricultural practices. Studies on trends of butterflies in more species-rich regions such as the tropics, however, remain scarce (85–87).

The decline in butterflies reflects the declines reported in other insect groups and acts as a warning that ecosystems are deteriorating. We may still lack good information on many, indeed most, insect groups, but the evidence available indicates widespread losses among many terrestrial species, although these are being counteracted to some extent by the expansion of others due to climate change. It may be too soon to say we are in the midst of a global insect apocalypse, but we know enough to recognize that action is needed urgently to conserve insect diversity and the ecosystems they help to maintain.

The causes of butterfly decline are well known: agricultural intensification, habitats loss, and the decline in traditional land use practices. However, climate change is adding a new and complex dimension. It is allowing many butterflies to spread north in Europe, possibly giving a false impression that some species are doing well. In fact, some of them are thinning in population as they spread, and some are retreating from the southern edge of their range. Additionally, others are taking advantage of warmer conditions and increasing in abundance despite extensive habitat loss. Perhaps they will be among the survivors of the Anthropocene.

Conservationists have tried to tackle the decline of butterflies by developing large-scale programs to improve land management. These provide evidence that practical conservation can successfully reverse the decline of threatened species. Clearly, this work needs to be expanded and developed. A bigger problem is how to conserve butterflies across the wider landscape and not just in nature reserves. This will require measures at a far broader scale, tackling the major drivers of decline such as agricultural intensification, chemical pollution, and climate change.

We suggest a range of policy measures that could help slow and reverse the decline of butterflies and help insects as a whole. There is no doubt that the road ahead looks extremely difficult, but we have some substantial evidence to build on. Improved land use policies, continued monitoring, evaluation, and good science will all be essential if we are to successfully conserve insects in the future and avoid the risk of ecosystem collapse.

Data Availability. Data on the Red List statuses of butterflies in the different European countries (94) have been deposited in Global Biodiversity Information Facility (GBIF), https://doi.org/10.15468/ye7whj. All study data are included in the article.

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