Assessing Butterflies in Europe - Butterfly Indicators 1990-2018

Technical report

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A female* Euphydryas maturna *laying eggs in open woodland habitat in Southern Germany. This species is listed on the Habitats Directive and is also one of the species participating in the Woodland Butterfly Indicator.

Contents

Chapter 1 / Introduction

There is mounting evidence of widespread declines in the diversity and abundance of insects from across the globe (Sánchez-Bayo and Wyckhuys 2019, Seibold et al. 2019, van Klink et al. 2020, Wagner 2020). This gives a stark warning for the perilous state of biodiversity (Díaz et al. 2019), and demonstrates that addressing the gap in knowledge of the status of insects is vital (Cardoso et al. 2020, Samways et al. 2020). Insects are estimated to comprise more than half of all described species and are a dominant component of biodiversity in most ecosystems (Bar-On et al. 2018). Insects also provide a crucial role in the functioning of ecosystems. They are not only related to the supply of many ecosystem services such as pollination, biological control, soil fertility regulation and diverse cultural ecosystem services but also to disservices such as damage to crops and spread of diseases to livestock and humans (Gutierrez-Arellano and Mulligan 2018, Noriega et al. 2018). There is a pressing need to assess the status of insects to set and evaluate conservation targets.

At the Convention on Biological Diversity (CBD) meeting in Nagoya (Japan), the Strategic Plan for Biodiversity 2011–2020 was adopted. It proposed five goals and 20 "Aichi" biodiversity targets. In line with this plan, a new EU biodiversity strategy was adopted by the European Commission in May 2011. This strategy provided a framework for the EU to meet its biodiversity targets and global commitments as a party to the CBD. The Headline Target in the existing EU Biodiversity Strategy 2020 is to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restore them, in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss. Under Target 3A the EU is committed to increasing the contribution of agriculture to biodiversity recovery. Further, the EU Biodiversity Strategy 2030 includes the development of a coherent framework for monitoring, assessing and reporting on progress in implementing actions. Such a framework is needed to link existing biodiversity data and knowledge systems with the strategy, to help assess achievement of the goals and to streamline EU and global monitoring, reporting and review obligations.

Some of the EU biodiversity indicators provide specific measurements and trends on genetic, species and ecosystem/landscape diversity, but many have a more indirect link to biodiversity. Very few have been explicitly established to assess biodiversity. The status indicators on species only cover birds, bats and butterflies, since these are the only taxa/species groups for which reasonably harmonized European monitoring data are available (EEA, 2012). This technical report builds upon previous technical reports for the EU Grassland Butterfly Indicator (e.g. van Swaay et al., 2019) to:

1. Describe a new approach for assessing butterfly trends and developing indicators of European butterflies
2. Give an overview of the main results, and present a range of butterfly indicators
3. Discuss the next steps to improve butterfly indicators for Europe

Butterflies are ideal biological indicators: they are well-documented, measurable, sensitive to environmental change, occur in a wide range of habitat types, represent many other insects, and are popular with the public because of their beauty. Field monitoring is essential to assess changes in their abundance. Indicators based on butterfly monitoring data are valuable to understand the state of the environment and help evaluate policy and implementation. Trained volunteers are a cost-effective way of gathering robust data on butterflies, more so when supported by informative materials and efficient online recording.

Chapter 2 / Butterfly Monitoring in Europe

Butterfly monitoring enjoys a growing popularity in Europe, encouraged in particular by Butterfly Conservation Europe (BCE) and its partners. While Butterfly Monitoring Schemes are present in a growing number of countries and new ones are being initiated in many places, long time-series are currently only available for a limited number of countries. For the indicators in this report we used data from 22 countries (Figure 1): Andorra, Austria, Belgium, Czech Republic, Estonia, Finland, France, Germany, Hungary, Ireland, Jersey, Latvia, Lithuania, Luxembourg, Norway, Romania, Slovenia, Spain, Sweden, Switzerland, The Netherlands and the United Kingdom.

In this report, we update the European Grassland Butterfly Indicator, present new butterfly indicators for widespread species, woodland butterflies, as well as butterflies in urban environments, in Natura 2000 areas and as climate change indicators. The indicators use field data up to and including the 2018 field season. The method for calculating indicators has been greatly improved and enhanced. During 2018 almost 5000 standardised butterfly transects were used (Figure 2). Since 1990 over 9200 separate transects have contributed to the indicators. There are still a few schemes in Europe outside the EU (e.g. Russia, Armenia, Ukraine) which we have not included yet, as well as a few outside Europe, but this is planned for the near future.

Europe's semi-natural grasslands contain a wealth of butterfly species and numbers.

Figure 1: Countries with Butterfly Monitoring Schemes, where EU27 member states are represented in bright green.

Schemes contributing to the European Indicators up to 2018 (schemes in the EU27 are marked with ^{EU27})	***Other active schemes (data not yet included within indicators)***
Andorra: since 2004 *Austria^{EU27}: since 2013* *Belgium (Flanders)^{EU27}: since 1991* *Czech Republic^{EU27}: since 2010* *Estonia^{EU27}: since 2004* *Finland^{EU27}: since 1999* *France^{EU27}: since 2005* *Germany^{EU27}: since 2005* *Hungary^{EU27}: since 2016* *Ireland^{EU27}: since 2007* *Jersey: since 2004* *Latvia^{EU27}: since 2015* *Lithuania^{EU27}: since 2009* *Luxembourg^{EU27}: since 2010* *Netherlands^{EU27}: since 1990* *Norway: since 2009* *Romania^{EU27}: since 2013* *Spain (Catalonia)^{EU27}: since 1994,* *Spain (Basque Country)^{EU27}: since 2010* *Spain (other regions)^{EU27}: since 2014* *Slovenia^{EU27}: since 2007* *Sweden^{EU27}: since 2009* *Switzerland: since 2003* *United Kingdom: since 1976*	*Armenia: since 2003* *Belgium (Wallonie)^{EU27}: since 2010* *Cyprus Island^{EU27}: since 2019* *Israel: since 2009* *Italy^{EU27}: since 2016* *Portugal^{EU27}: since 2019* *Russia (Bryansk region): since 2013* *Ukraine (Transcarpathia): since 1974* *Malta^{EU27}: since 2020* *Bulgaria^{EU27}: since 2020* *Poland^{EU27}: since 2020* *Croatia^{EU27}: since 2020*

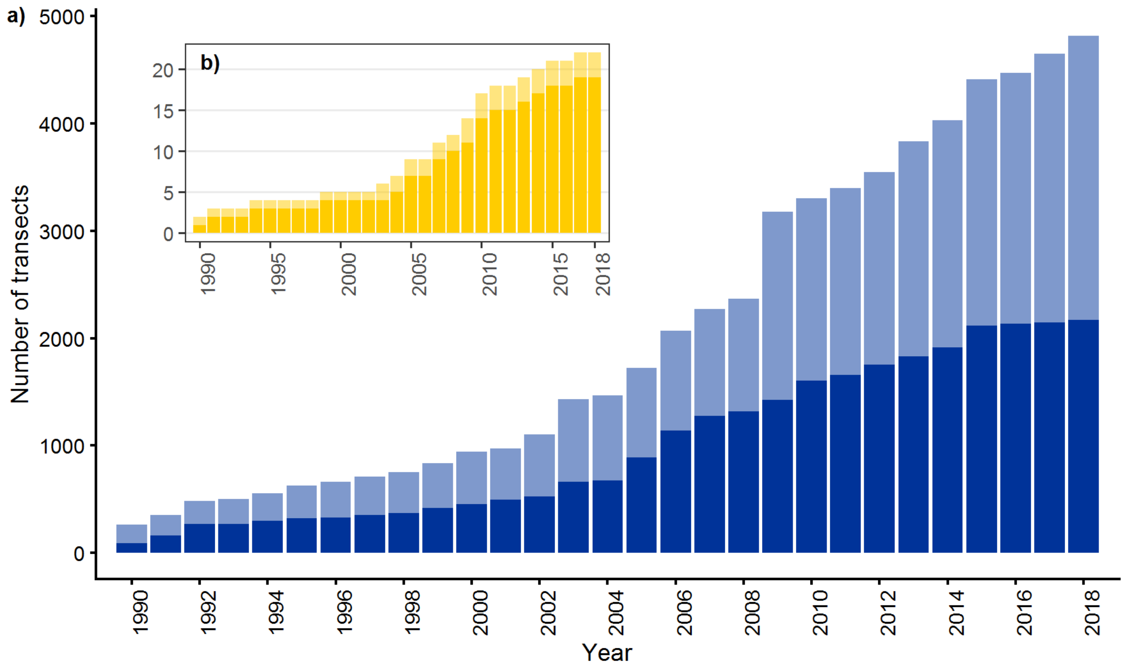


Figure 2. a) Number of BMS transects contributing to the European Butterfly Indicators between 1990 and 2018, where schemes within EU27 are represented in dark blue and non-EU schemes (UK, Switzerland and Norway) in light blue. b) Number of Schemes contributing per year.

Chapter 3 / From butterfly counts to indicators

Introduction

Butterflies can be found all over Europe and are one of the best-known groups of insects. Although popular, until recently little was known about their density and trends. In this chapter we will illustrate how counts are made and how they can be used to detect trends and to build indicators.

Fieldwork


Recording butterflies on a transect.

The butterfly indicators are based on the fieldwork of thousands of trained professional and volunteer recorders, counting butterflies on almost 10,000 transects scattered widely across Europe, with 4,816 visited in 2018. These counts are made under standardised conditions, providing high-quality data that are suitable to assess species status and trends. National co-ordinators collect the data and perform the first quality control. More details can be found in Annexe I.

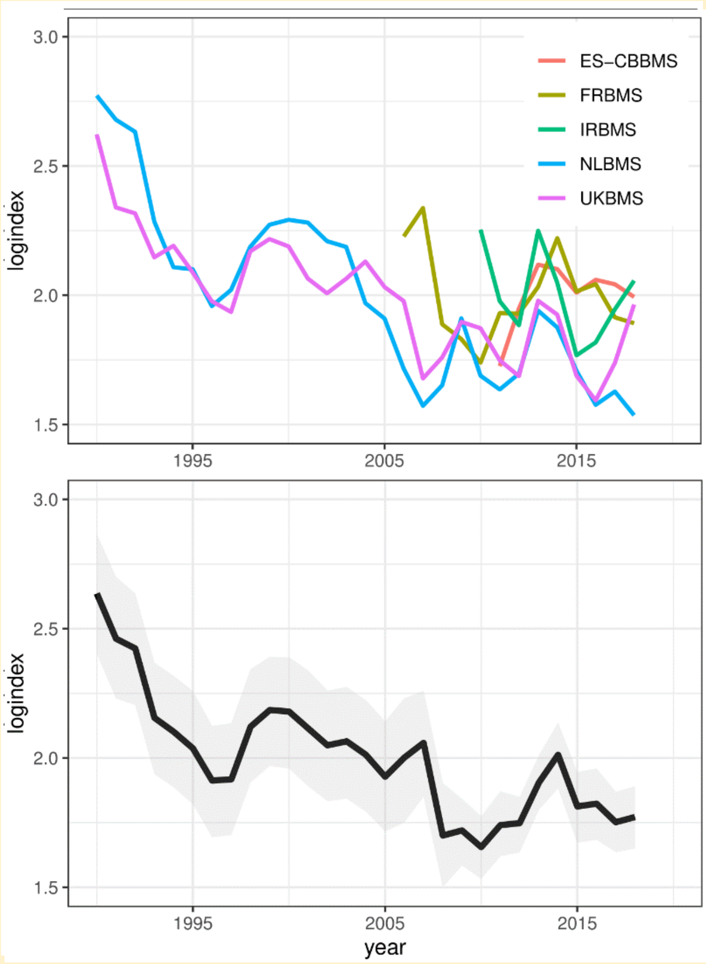
All schemes apply the method initially developed for the UK Butterfly Monitoring Scheme (Pollard & Yates, 1993). The counts are conducted along fixed transects of 0.5 to 3 kilometres in length, divided into smaller sections for recording. The fieldworkers record all butterflies that are observed 2.5 metres to their right, 2.5 metres to their left, 5 metres ahead of them and 5 metres above them (Van Swaay *et al*., 2008). Butterfly counts are conducted between March-April to September-October, depending on the region. In some places (e.g. Andalucia, Canary Islands) there are places where monitoring takes place all year round, sometimes stopping in July-August during the hot and dry summer. Visits are only conducted when weather conditions meet specific criteria. The recommended number of visits varies from every week, e.g. in the UK and the Netherlands, to 3-5 visits annually in France (see Annexe I).

Transect selection

To be able to draw proper inferences on the temporal population trends at the national or regional level, transects should ideally best be selected in a grid, random or stratified random manner (Sutherland, 2006). Several recent schemes, e.g. in Switzerland, France and in parts of Austria, have been designed in this manner (Henry *et al*., 2008). If a scheme aims to monitor rare species, scheme co-ordinators preferentially locate transects in areas where rare species occur, leading to an over-representation of special and protected areas. In most schemes transects were selected by free choice of observers, which in some cases has led to the overrepresentation of protected sites in natural areas and the under-sampling of the wider countryside and urban areas (Pollard & Yates, 1993). However, this is not the case in all countries (e.g. Germany, Kühn *et al.*, 2008).

Calculating population trends

For each species and year, flight periods were estimated (Dennis et al., 2016) based on climate zones as defined in Metzger et al. (2013), but with further geographic stratification to represent major geographic units (e.g. Britain and Ireland was treated as a separate unit to continental Europe). Site-level indices were produced by estimating the missing counts, and species' densities were produced for each combination of butterfly monitoring scheme (BMS) and biogeographical region (BGR), using a Poisson generalised linear model (GLM) with site and year effects, as well as the proportion of the flight period surveyed as a weighting factor, and using the total area sampled to derive the total number of adult butterflies monitored over the season per hectare. Several filters (see details in Annexe II) were applied to exclude potentially unreliable estimates produced from counts for only a minimal number of years and sites. Species collated indices per BMS/BGR combination were produced by transforming the densities to the log10 scale with a mean value of 2 (Box 1). Species' densities per BGR were estimated by combining the BMS/BGR densities, accounting for variation in start year and weighting by species' range. Species' collated indices for EU27 and pan-Europe were produced by fitting a Poisson GLM to the BGR-level indices, with effects for year and BGR, as well as weightings based on the product of species' range and population density at BGR level. Further details of the methods used to calculate population trends are given in Annexe II.



Box 1: Indices for Lasiommata megera in the Atlantic region.
The upper graph shows the relative abundance indices for five Butterfly Monitoring Schemes. Note that the starting year for each scheme is different.
The lower graph shows the species index and 95% confidence interval for the whole Atlantic region, resulting from all the Butterfly Monitoring Schemes in this region.

Producing butterfly indicators

Indicators were produced by combining the collated indices for EU27 or pan-Europe for the relevant species selection by taking a geometric mean of the indices and following the approach of the BRCindicators R package to account for species indices that start late (August et al. 2017). This indicator is a unified measure of biodiversity following the bird indicators as described by Gregory et al. (2005), by averaging species relative rather than absolute abundance indices in order to give each species an equal weight in the resulting indicators. When positive and negative changes of indices are in balance, then their mean would be expected to remain stable. If more species decline than increase, the mean should go down and vice versa. Thus, the index mean is considered a measure of biodiversity change. More details on the indicator method used can be found in Annexe II.

All indicators are produced for pan-Europe (all participating countries in Europe, including the UK, which was formerly included in data and indicators covering the EU28 Member States) as well as for the European Union (EU27). There are three types of indicators:

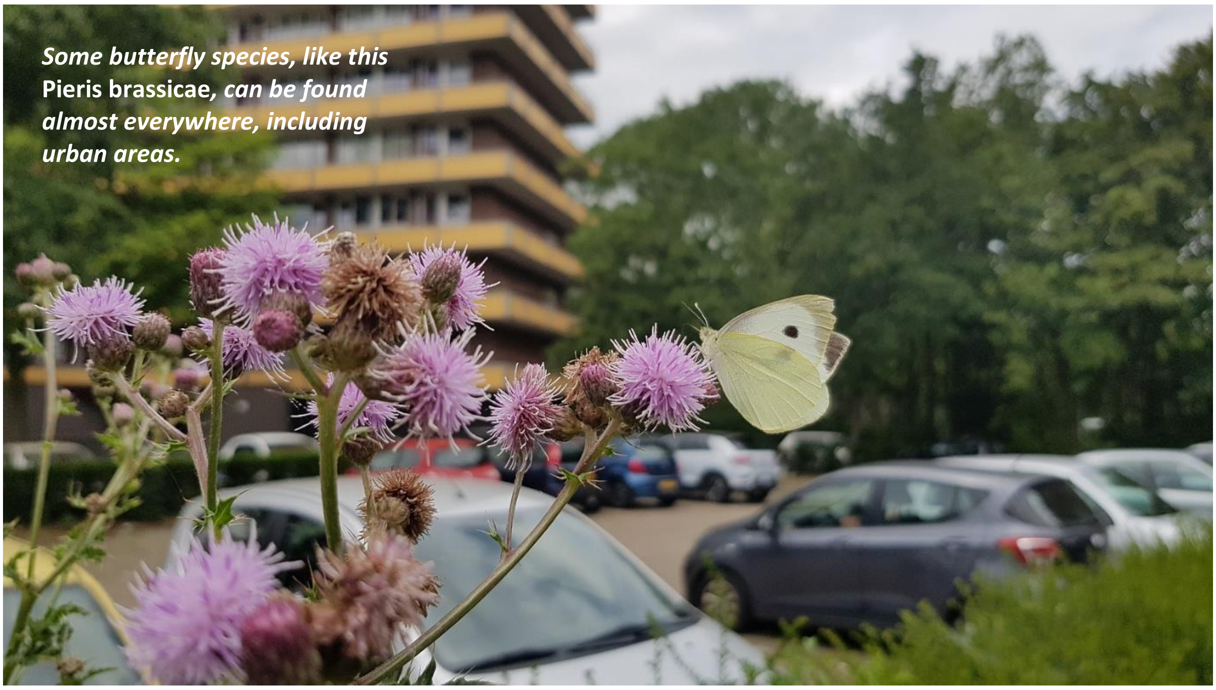
- ***Butterfly indicators based on abundances of defined species sets***
    - *Grassland Butterfly Indicator*: this is a continuation of the indicator which was produced for the first time by Van Swaay & Van Strien (2005). This means that the same set of 17 widespread and specialist species is used, and that weighting is done at the BMS-level. This makes it possible to compare this indicator with all previous versions. For each of the previous Grassland Butterfly Indicators the weights per species per BMS have changed when new countries join the eBMS.
    - *Woodland Butterfly Indicator*: this indicator is based on the 67 species which occur more in woodlands than in any other habitat types, taken from Van Swaay et al. (2006). It is the first time this indicator has been calculated, providing an insight into the changes in European woodlands since 1990.
    - *Wetland Butterfly Indicator*: using the same method as for the woodland butterflies gives 13 species that occur more in wetland habitat types than in any other habitat. However, all of these species are rare, and there are also very few transects on wetlands (for the practical reason that it is usually impossible to walk a transect on many wetlands). So for now, it is not possible to produce a butterfly indicator for wetlands.
- ***Butterfly indicators based on abundances of all widespread species occurring in defined areas***
    - *Widespread Butterfly Indicator*: this indicator includes all species for which reliable trends can be calculated. Robust trends require several sites to be monitored regularly (within and between years) across biogeographical regions in which they occur – at least ten transects within each biogeographical region within a Butterfly Monitoring Scheme is a minimum requirement. Several filters were applied to the species indices which resulted in the exclusion of rarer species – full details of the filters applied are given in Annexe II. Almost all species meeting the data requirements are therefore relatively widespread.
    - *Urban Butterfly Indicator*: this indicator is based on all species for which trends can be calculated on transects classified as urban. We classified as urban every BMS transect located within 500 m of an urban area. These urban areas were defined based on the density and continuousness of the impervious surface. Using the high-resolution map of the impervious surface across Europe, we considered each pixel (20 x 20 m) having more than 50% of its area covered in impervious surfaces as an

urban pixel (following the EEA definition). Urban areas were delimited by counting the number of urban pixels within 100 x 100 m area tiles; each tile with more than 50% of its pixels classified urban is then considered as urban. To ensure spatial continuity and include urban green space, each tile located within 200 m of an urban tile is also included in the urban area. We used the resulting map to classify transects as urban or non-urban; transects located inside or within 500 m of an urban area being urban and all others as non-urban.

  - *Natura 2000 Butterfly Indicator*: this indicator is based on all species for which reliable trends can be calculated from transects for which the centroid lies inside or within a 1 km radius of a Natura 2000 site. For this classification, we used the map Natura 2000 End 2019 released by the EEA on the 21st of April 2020 and overlaid the BMS transects to classify them Natura 2000 or non-Natura 2000.

- ***Butterfly indicators based on abundances of all species and species characteristics***
  - *A Butterfly Indicator on climate change impacts*: this indicator is produced following a very different technique, based on Devictor et al. (2012), and uses changes in the butterfly community preferences for temperature.

An overview of the species included in each indicator is provided in Annexe III.



Some butterfly species, like this Pieris brassicae, *can be found almost everywhere, including urban areas.*

Chapter 4 / Trends and Indicators

Introduction

There is considerable variation in European landscapes and climate. Also, Europe's butterfly fauna is highly diverse with 435 species, 142 (33%) of them endemics (only occurring in Europe). A species might be doing well in one region while showing a strong decline in others. For this reason, we will also present species trends per biogeographical region (BGR), where possible (Figure 3).

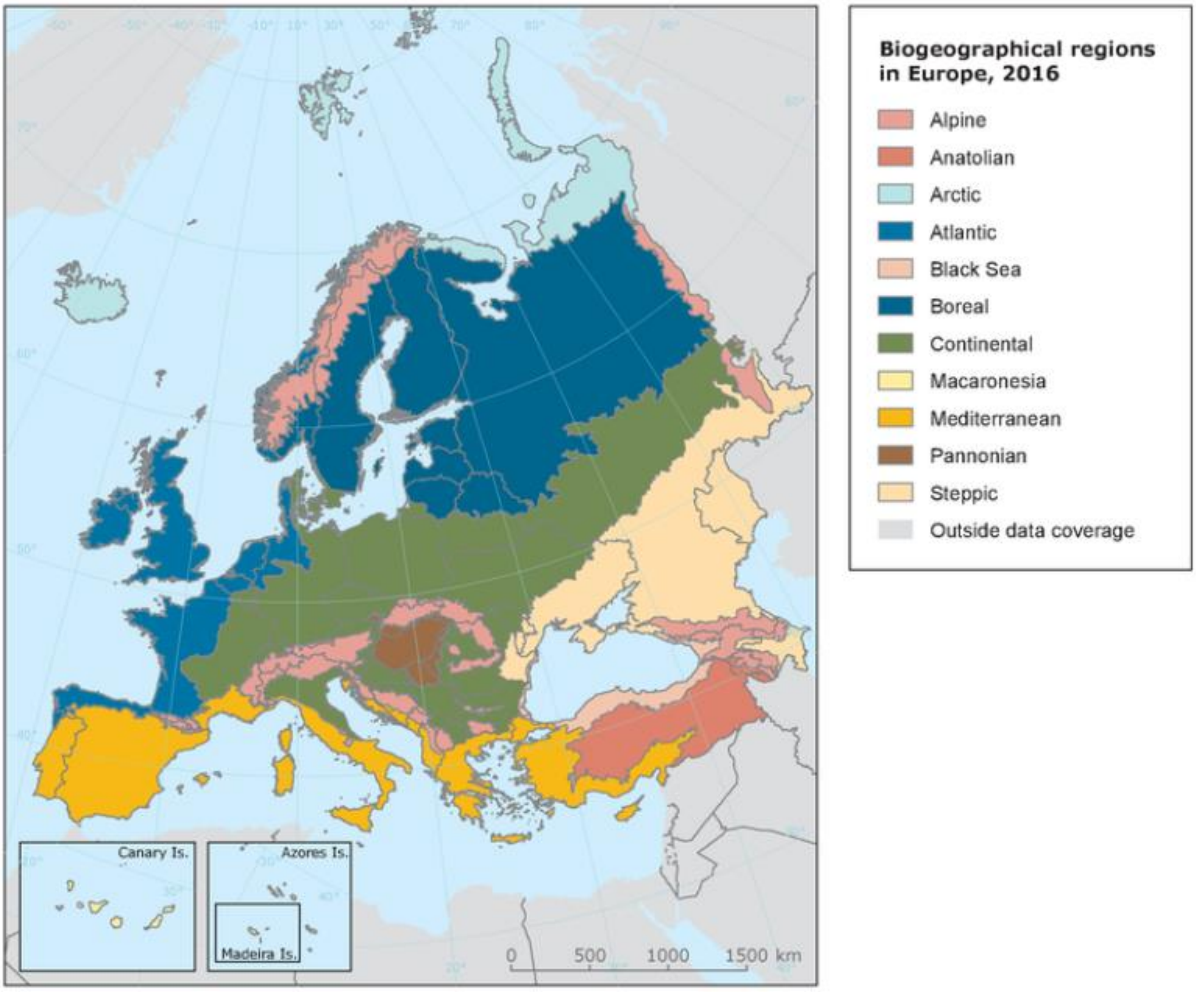


Figure 3: Biogeographical regions in Europe (source: https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2).

When interpreting the species trends and the indicators, it is essential to note that:

- Trends and indices could be calculated for 167 (35%) of the 483 butterfly species occurring in Europe.
- Such indices and trends are available for each of the biogeographical regions, as well as for the EU27 and Europe.
- These have been used to produce indicators covering the biogeographical regions, the EU27 and Europe.

- Results are only available for common and widespread species, as the number of transects for most rare species is too low to calculate reliable indices and trends. As a result, trends cannot be calculated for 62% (Boreal zone) to 72% (Continental zone) of the species occurring in that part of the biogeographical zone covered by a Butterfly Monitoring Scheme. In addition, for species where trends can be estimated, the trend can be uncertain as a result of large fluctuations, a low number of transects, or contrasting trends between sites and regions, e.g. 10% (Continental zone) to 12% (Boreal zone) of species have an uncertain trend estimate.
- The coverage of the species' populations and thus the representativeness of the data may be lower at the beginning of the time series (see also Figure 1). As more countries join in later, the indices improve in accuracy for later years.
- Large year-to-year fluctuations or a low number of transects can cause large standard errors in yearly estimates of population abundance, leading to uncertain trends.
- In most of the EU countries, Butterfly Monitoring Scheme data was available by 2020. However for a number of countries, data was only available for 2018 or 2019, as it is the result of the ABLE project. These new schemes increase the coverage and representativeness of trend assessments, especially in Eastern and Southern Europe. Most of the data used in the indicators have been collected before the start of the ABLE project in December 2018. In the next version of the indicators, more countries will be included.
- The trends shown only represent the countries for which we had data up to 2018 (Figure 4), which means they are based on a wide range of countries, including larger ones such as France, Spain, Sweden, Finland and Germany. The data gathered in future as a result of the ABLE project will make the results more representative for the EU and pan-Europe.
- For the grassland butterfly indicator new countries have joined in, new data have become available in existing schemes, the method for trend calculation has been improved, and extra years have been added. These developments can lead to changes in trends as compared to previous versions of the indicator. In some cases this can even lead to a change in the direction of the trend.
- Apart from the EU countries, the pan-European trend is determined by the United Kingdom, Switzerland, Andorra, Jersey, Isle of Man and Norway. For many species, these non-EU countries in the analysis represent only a minor part (sometimes less than 10%) of each species distribution as compared to the EU countries.
- This means that the pan-European trends in this report are dominated by the trend in the EU. Note that most of Russia, Ukraine, the Balkans and the Mediterranean are still not covered.

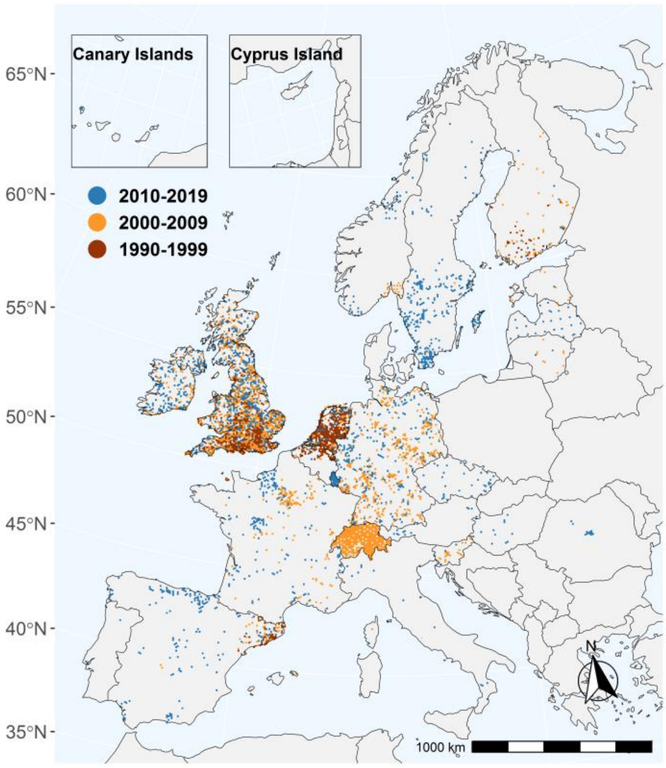
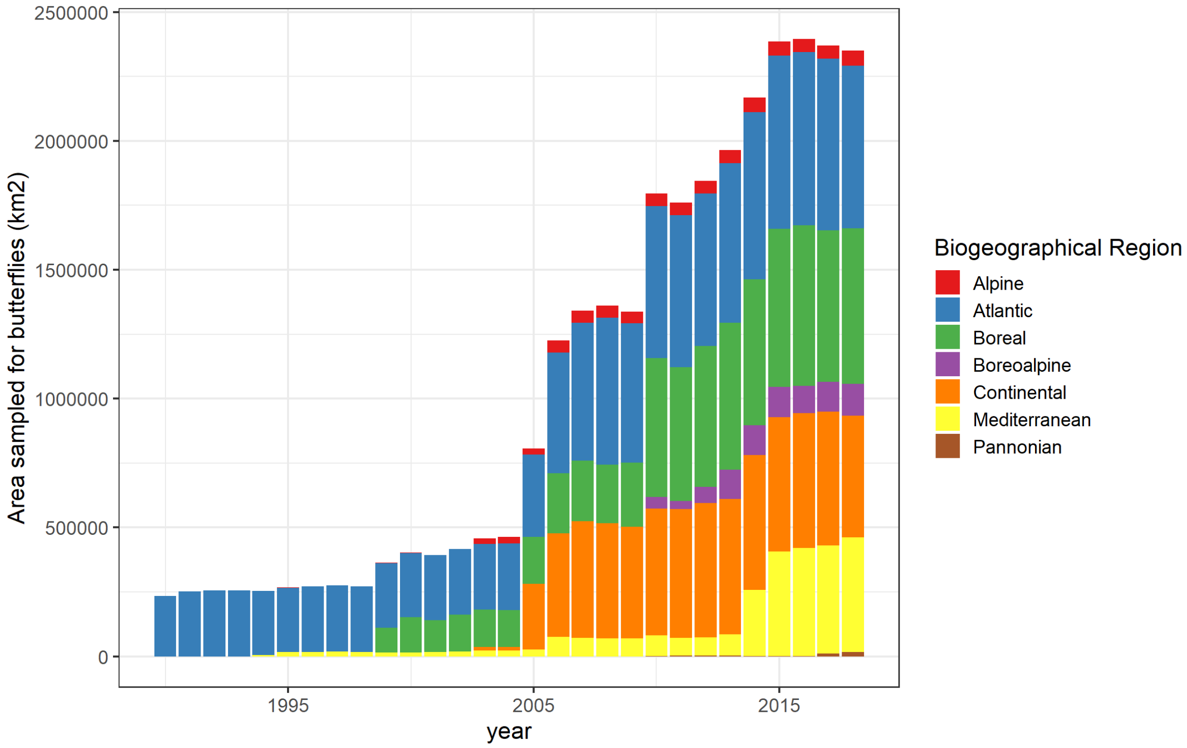


Figure 4: Location of butterfly transects in Europe in 2020. Symbol colour indicates the decade a transect was first counted.

- The trends and indicators are increasingly representative of biogeographic zones across Europe but early parts of the time series are dominated by monitoring within the Atlantic Zone. It remains a priority to retain existing butterfly monitoring across Europe and to further improve coverage of biogeographic regions that are poorly represented (Figure 5).
- The EU Pollinator Monitoring Scheme (EUPMS) in development, and including butterfly transects, is likely to adopt a random or stratified-random selection of monitoring sites across the whole of the EU to provide representative coverage. Future indicators combining complementary data from the EUPMS and eBMS will provide a more robust assessment of butterfly populations.

Figure 5: Annual area of European biogeographic regions sampled by butterfly monitoring scheme transects, 1990-2018.



Trends of Red List butterflies

Almost all species for which trends on a pan-European or EU scale can be calculated, are marked as Least concern (LC) on the latest European Red List of Butterflies (Van Swaay et al., 2010; Figure 656). The main reasons for that are:

- The countries with long running Butterfly Monitoring Schemes covering all or nearly all species in that country (mainly the Netherlands and United Kingdom), host almost no species classified as threatened in the 2010 Red List assessment (Van Swaay et al., 2010). But it must be borne in mind that this is partly because of the methodology employed in the Red Listing – where declines are estimated over the decade 2000 to 2010, whereas these butterflies started that decade at a low level because of previous serious declines. So the current Red List underplays their poor conservation status. Article 17 Reports of Habitats Directive listed butterflies, many of which are also Red Listed, show that most are in unfavourable conservation status (Inadequate or Bad) and some show a continuing declining trend from unfavourable over most EU biogeographical regions.

- We applied strict data filtering to be sure that trends were representative for the BGR, and to take a consistent approach across schemes. As a consequence rare species (with few sites) were rejected.
- Only line transect counts (i.e. Pollard walks) were used, whereas some national Butterfly Monitoring Schemes include monitoring data using different methods for rare species (e.g. for *Lycaena dispar* in the Netherlands and *Phengaris arion* in the UK).
- The countries that recently joined the eBMS and do host threatened butterflies still have few transects and short time-series.
- As a result a trend could be calculated for 167 (35%) of the 483 butterfly species occurring in Europe.
- Most of the Red Listed species, listed as one of the "Threatened" categories, are endemics and occur either on Macaronesian or Mediterranean islands, in the mountains and in Eastern Europe, where butterfly monitoring is still underdeveloped.

As a consequence, for most species listed as Critically Endangered, Endangered or Vulnerable on the last European Red List of Butterflies (Van Swaay et al., 2010) it is not possible to calculate trends at a pan-European, EU27 or biogeographical level. These are the exceptions:

- *Lycaena helle*: there is a trend for this species in the Continental zone (strong increase), however this is based only on the short 2016-2018 trend in Luxembourg. There is no trend from the other BGRs.
- *Phengaris teleius*: there is only a trend for this species in the Atlantic zone (uncertain), based on the Dutch population (one population only) for 2010-2018. There is no trend from the other BGRs, the main distribution of this species is in the Continental zone.
- *Phengaris arion*: there is only a trend from the Alpine zone (uncertain), based on the trend in Switzerland (2003-2018). Although it occurs in most other BGRs, there is no trend from those regions.
- *Coenonympha hero*: there is only a trend for this species in the Boreal zone (uncertain), based on the Swedish population for 2015-2018. There is no trend from the other biogeographical regions. The main distribution of this species nowadays is in the Continental and Boreal zone, in the past also in the Atlantic.
- *Coenonympha tullia*: there is only a trend for this species in the Atlantic zone (uncertain), based on the UK population for 2002-2018 and the Irish population for 2015-2018. There is no trend from the other BGRs. The species is also found in the Boreal and Continental zones.
- *Euphydryas maturna*: there is only a trend for the species in the Boreal zone (uncertain), based on the Finnish population for 1999-2018. There is no trend from the other BGRs (mainly Continental).

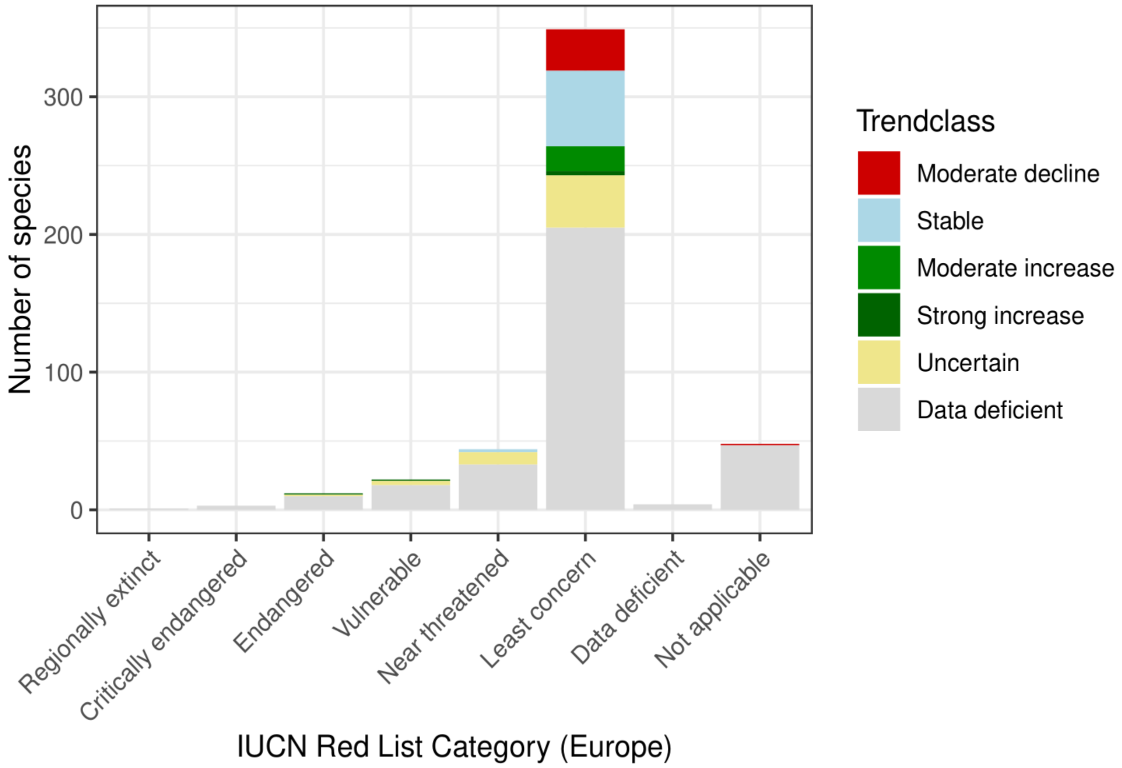


Figure 65: Number of species with trends per IUCN Red List category (Van Swaay et al., 2010). The trend class 'Uncertain' indicates there is enough data, but it is not possible to calculate a significant trend (e.g. because of opposing trends in parts of the range, or large fluctuations). The trend class 'Data deficient' means not enough counts are available to calculate a trend.

Habitat Directive butterflies

For seven of the 32 butterflies listed on one of the annexes of the Habitats Directive a trend could be calculated for the EU27 (full trend data to be published separately):

- *Coenonympha hero*: there is only a trend for this species in the Boreal zone (uncertain), based on the Swedish population for 2015-2018. There is no trend from the other BGRs where it occurs (mainly the Continental region).
- *Euphydryas aurinia*: there is a trend in the Atlantic and Mediterranean region based on a few BMS only. Over the whole EU27 the trend is uncertain. The species occurs in most of the European BGRs, with the exception of the Arctic region.
- *Euphydryas maturna*: there is only a trend from the species in the Boreal zone (uncertain), based on the Finnish population for 1999-2018. There is no trend from the other BGRs.
- *Lycaena dispar*: there is a trend for the Continental region (moderate decline), however only based on the German BMS (2008-2018). The species also occurs in the Pannonian zone (where monitoring started after 2018) and the Atlantic zone (the Netherlands, where a non-transect method was used, and the species is showing large fluctuations).
- *Lycaena helle*: there is a trend for this species in the Continental zone (strong increase), however this is based only on the short 2016-2018 trend in Luxembourg. There is no trend from the other BGRs, the species also occurs in the Boreal zone.
- *Phengaris nausithous*: there is only a trend for this species in the Continental zone (uncertain), based on the German BMS. The species also occurs in the Atlantic zone (one population with four transects in the Netherlands which was not enough to pass the filters).
- *Phengaris teleius*: there is only a trend for this species in the Atlantic zone (uncertain), based on the Dutch population (one location only) for 2010-2018. There is no trend from the other BGRs.

The spectacular upperside of* **Phengaris teleius** *is not often displayed. This species is listed on the Habitats Directive.

Widespread Butterfly Indicator

For the species for which we can calculate trends per biogeographical region (BGR), there is a balance between increasing and declining species, with the exception of the Atlantic region, where more species are declining than increasing (Figure 76). However, for most of the species there are not enough data to calculate trends, as these species are too rare or there are insufficient transects to be able to calculate reliable trends. For those widespread species for which we do have data, the results show that more species are declining than increasing in the Atlantic and Mediterranean regions, while there is a comparatively balanced pattern in the Boreal and Continental regions.

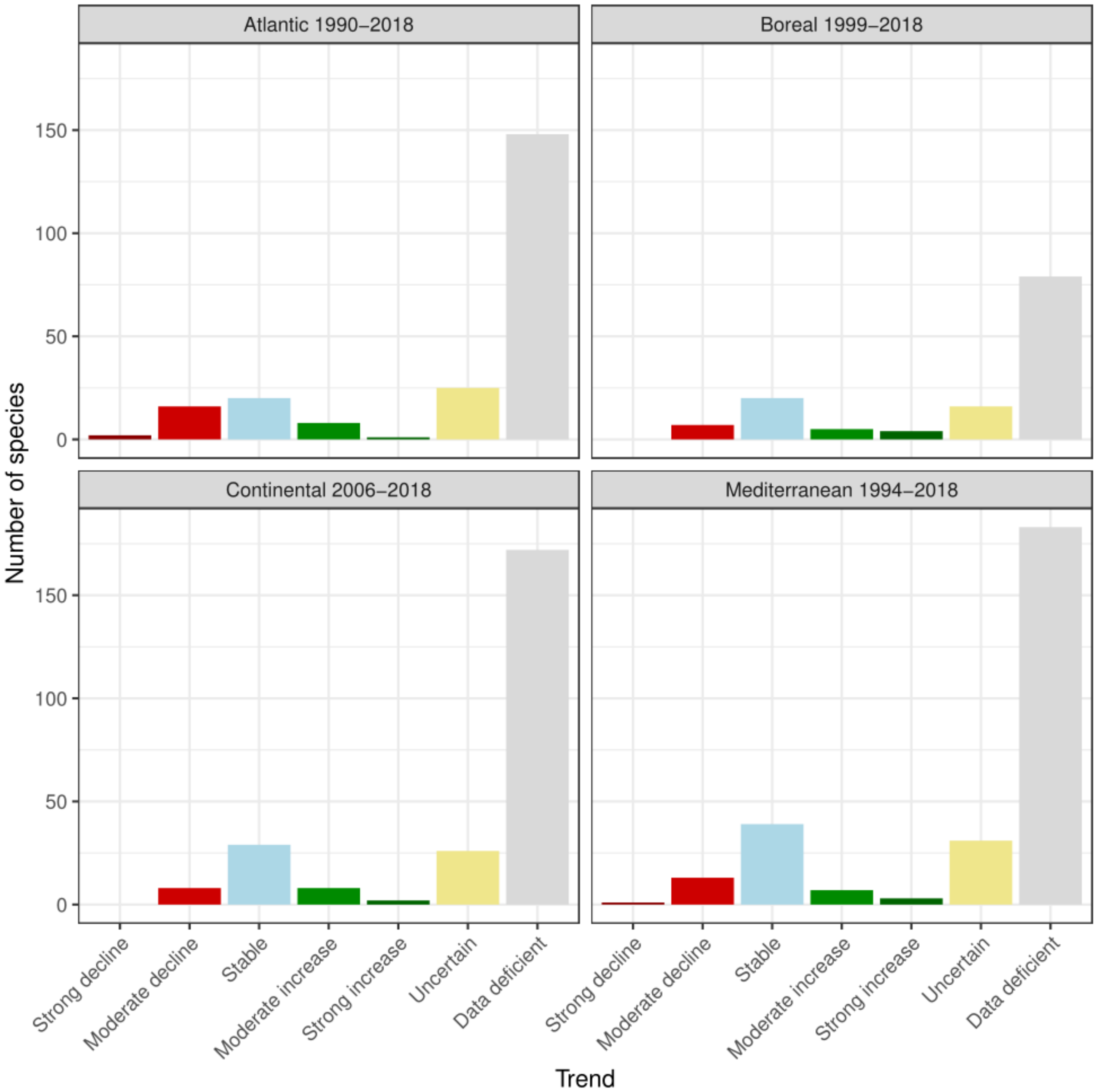


Figure 76: Number of butterfly species per trend class per biogeographical region in Europe. The trend class 'uncertain' indicates there is enough data, but it is not possible to calculate a significant trend (e.g. because of opposing trends in parts of the range, or large fluctuations). The trend class `Data deficient' means not enough counts are available to calculate a trend.

Both in the EU27 and in Europe, widespread butterflies for which we have enough data to calculate trends (35% of the species) showed an overall decline in abundance from 1990 up to the period 2011-2016 (**Error! Reference source not found.**). After that the declining trend for these butterflies s lowed and seems to reverse. This is due primarily to the higher indicator values in the two years 2017 and 2018. The result brings the levels back close to those of 1990.The trend over the whole period 1990-2018 is therefore shown as stable, but fell significantly during the period, before recovering somewhat. The number of species participating in this indicator for Europe rose from 50 in 1990 to 167 in 2018 (Figure 192: Number of species contributing per year to the widespread butterfly indicator for EU27 and Europe.) as a consequence of the rising number of countries and transects participating in the eBMS. However these graphs represents only the common and widespread species. If in future more of the rare and threatened species can be included, which are often declining (as shown by the Red List assessment or the article 17 reporting), then this indicator could become more negative as well. Evidence from analysis of atlas data suggests that butterflies declined markedly in their range extent before 1990, so the trends in abundance analysed in this report likely started from a low level in 1990.

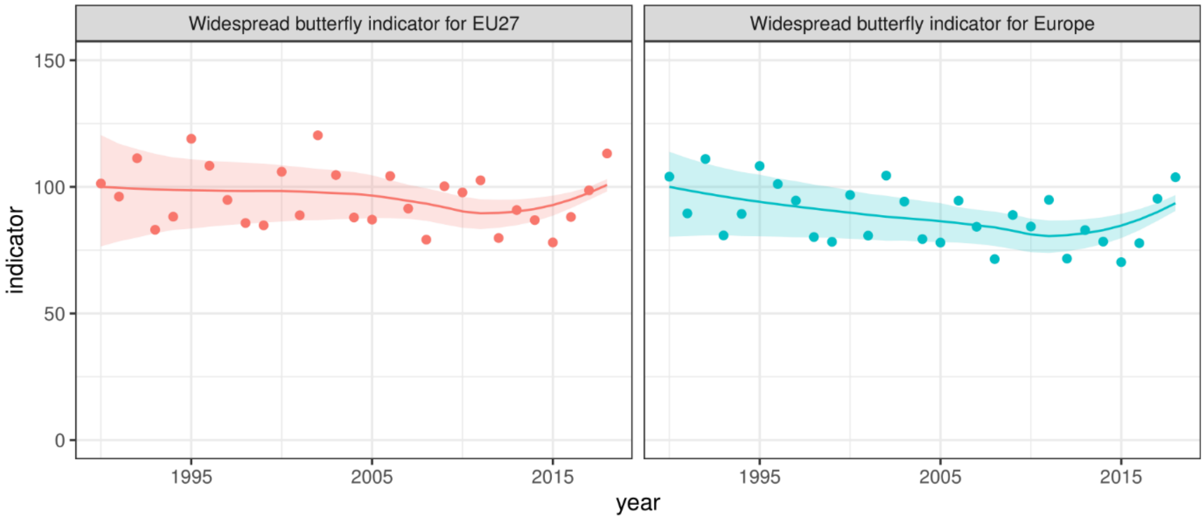


Figure 87: Widespread butterfly indicators for EU27 and Europe. Beware that rare and threatened (and often declining) species could not be included because of insufficient data, meaning the indicator for all butterflies might be more negative. Shaded areas represent 95% confidence intervals.

The indicators for widespread butterflies per biogeographical region (BGR) in the EU27 show that in the Atlantic region butterflies have declined substantially, but the trend is stable in the other three BGRs for which enough data were available.

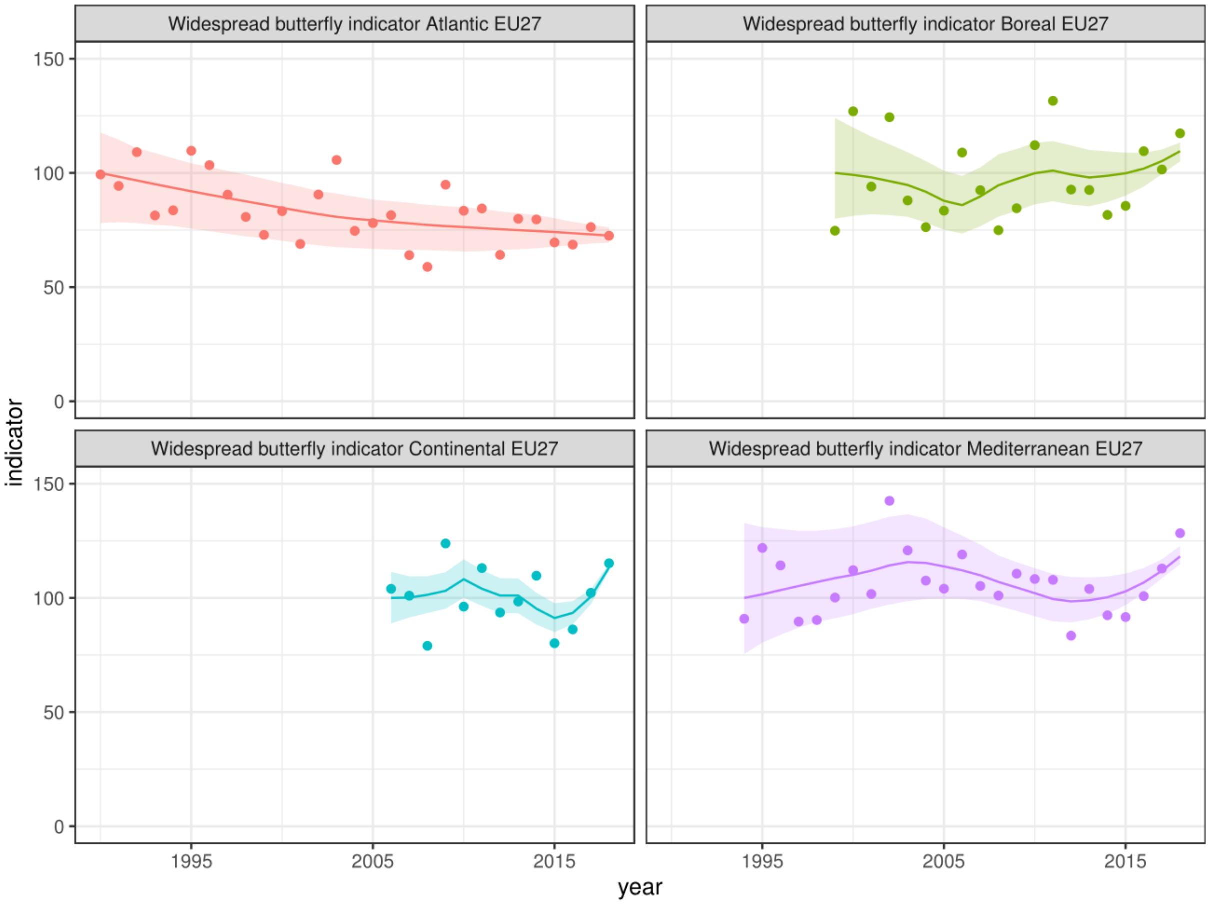


Figure 98: Widespread butterfly indicators per biogeographical region for EU27. Shaded areas represent 95% confidence intervals.

Grassland Butterfly Indicator

In Europe, 8 (47%) out of the 17 species used for the Grassland Butterfly Indicator show a moderate decline, 5 (29%) are stable and for the remaining species the trend is uncertain. None of these characteristic species of grasslands show an increase at European scale.

In the EU27 the situation is a bit less negative, with 5 (29%) of the species showing a moderate decline, 6 (35%) stable and one (6%) species showing a moderate increase (the Orange Tip, *Anthocharis cardamines*). The trends for the remaining species are uncertain (Table 1).

Table 1: Trends for the 17 butterflies used in the Grassland Butterfly Indicator in Europe and the EU27.

Species	TrendClass Europe	period	TrendClass EU27	period
Lasiommata megera	Moderate decline	1990-2018	Moderate decline	1991-2018
Lysandra coridon	Moderate decline	1994-2018	Moderate decline	2006-2018
Ochlodes sylvanus	Moderate decline	1990-2018	Moderate decline	1991-2018
Coenonympha pamphilus	Moderate decline	1990-2018	Stable	1991-2018
Lycaena phlaeas	Moderate decline	1990-2018	Stable	1991-2018
Maniola jurtina	Moderate decline	1990-2018	Stable	1991-2018
Polyommatus icarus	Moderate decline	1990-2018	Stable	1991-2018
Euphydryas aurinia	Moderate decline	1994-2018	Uncertain	2006-2018
Erynnis tages	Stable	1991-2018	Moderate decline	1994-2018
Anthocharis cardamines	Stable	1990-2018	Moderate increase	1991-2018
Cyaniris semiargus	Stable	1999-2018	Stable	1999-2018
Cupido minimus	Stable	1994-2018	Uncertain	2006-2018
Thymelicus acteon	Stable	1994-2018	Uncertain	2006-2018
Lysandra bellargus	Uncertain	1994-2018	Moderate decline	2006-2018
Spialia sertorius	Uncertain	2003-2018	Stable	2006-2018
Phengaris arion	Uncertain	2006-2018	Uncertain	2006-2018
Phengaris nausithous	Uncertain	2007-2018	Uncertain	2007-2018

Because of the filtering by the minimum number of Butterfly Monitoring Schemes (BMS), the Grassland Butterfly Indicator for the EU27 (using the enhanced method, developed in ABLE) starts one year later than the European one. For both indicators the 2018 value is lower than the start value of the indicator, with the European trend showing a significant moderate decline of 22%. For the EU27 the decline is 25%, although there is greater uncertainly in the yearly estimates for this indicator due to less data included.

This decline is slightly lower than reported in earlier versions of this indicator. The main reasons are that the main decline of grassland butterflies to date is in Northwestern Europe, caused by intensification of agricultural grasslands, and nitrogen deposition in nature reserves (WallisDeVries & Van Swaay, 2017). Furthermore substantial decreases probably already happened before the start of the indicator calculation in 1990 (Van Strien et al. 2019). In the rest of Europe, trends are more relatively stable, although grassland abandonment is a threat. As new BMSs are starting up in such regions, inclusion of their recent data means the rate of decline of the overall European and EU27 indicators is reduced, compared with previous calculations.

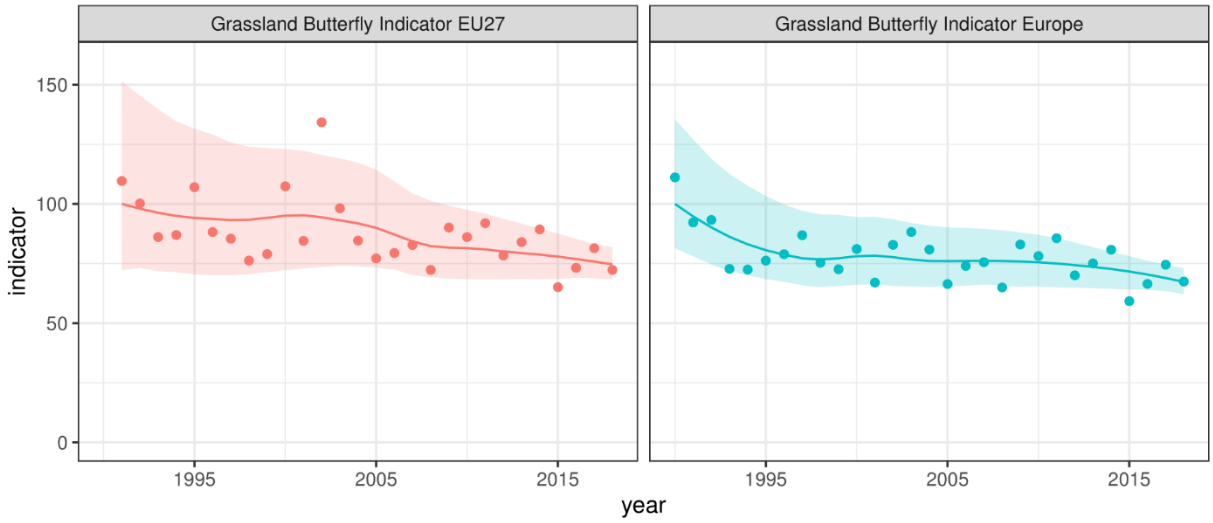


Figure 10: Grassland butterfly indicators for EU27 and Europe. Shaded areas represent 95% confidence intervals.

A male Orange Tip (Anthocharis cardamines), a butterfly species showing a moderate increase in the EU27.

Woodland Butterfly Indicator

An overview of indicator species for the Woodland Butterfly Indicator is given in Annexe III. In the EU27 it was possible to calculate reliable trends for 28 out of 67 woodland indicator species (42%) over at least 13 years, and in Europe for 31 (46%) of the species.

In the EU27, the number of declining and increasing species is in balance (Figure 9: Number of woodland species per trend class in the EU27 and Europe. Species with no data or trends for less than 13 years are included in the category 'Data deficient'.1), while in Europe as a whole there are more woodland species showing an increasing trend than a decline. Still for most species for which a trend could be calculated, the trend is stable. However, for the bulk of woodland species there is not enough data available (Data deficient in Figure 9).

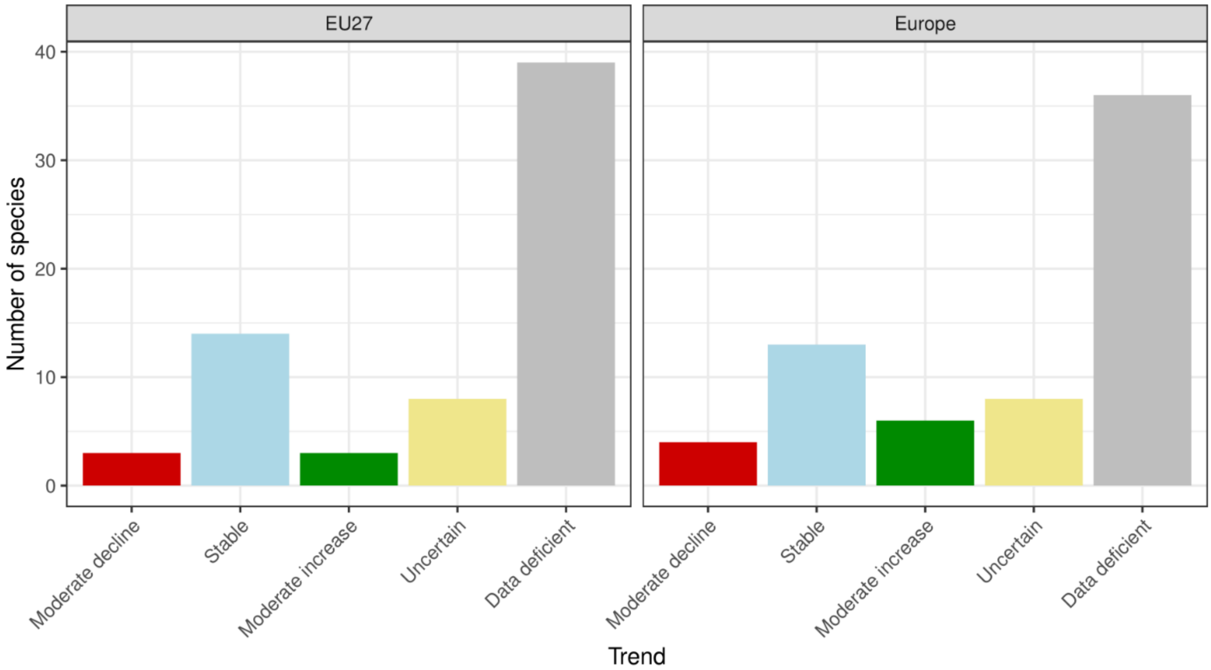


Figure 9: Number of woodland species per trend class in the EU27 and Europe. Species with no data or trends for less than 13 years are included in the category 'Data deficient'.

Over the whole investigation period, the trend for woodland butterflies both in the EU27 and in Europe is stable. However up to 2016 woodland butterflies were generally declining, and after that they seem to be increasing. The main drivers might be:

- There is more and more woodland in Europe. Since 1990, the woodland area in Europe has increased by 17 million hectares of which more than half are planted. This has been the result of afforestation (e.g. planting and seedling of trees on land that was not previously woodland) and through natural expansion of woodlands such as on abandoned land (www.eea.europa.eu/soer/2015/europe/forests). Plantations are usually far less suitable for woodland butterflies.
- A larger part of the woodland has become available for woodland butterflies due to disturbances caused by climate change and the outbreak of forest pests and diseases. Most woodland butterflies are woodland-edge species that need the sun along the edges, as well

as open clearings, paths and rides to heat up. With climate change more of such places become suitable for woodland butterflies.

- The use of clear-cuts and the gradually shortened intervals between forest planting and harvesting that are a consequence of climate change mean that a considerable part of forest succession today consists of early successional stages with abundant resources attractive to butterflies (Ram et al. 2020).

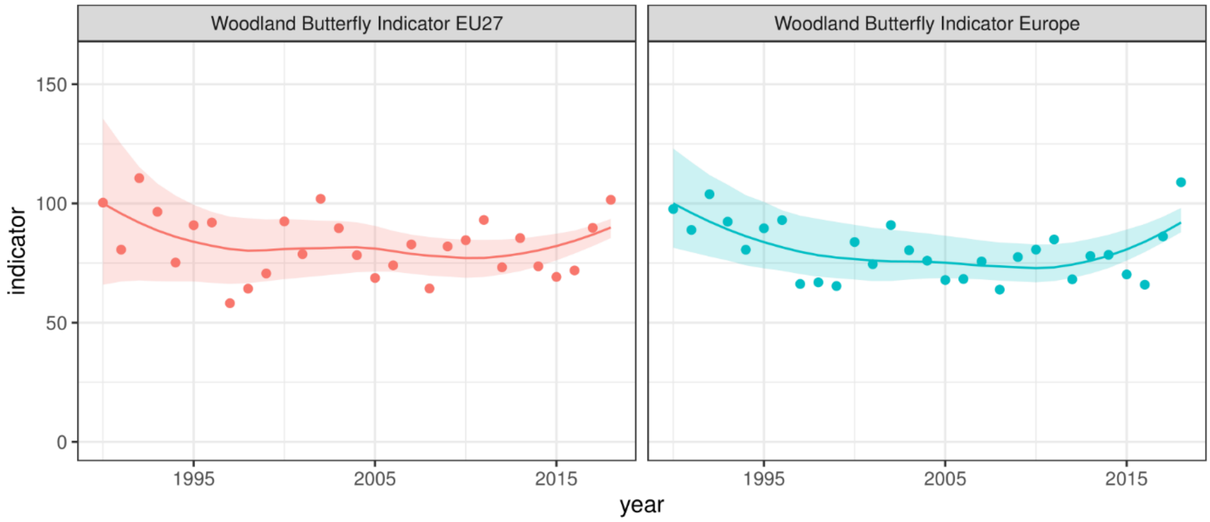


Figure 102: Woodland butterfly indicators for EU27 and Europe. Shaded areas represent 95% confidence intervals.

When we break down the Woodland Indicator by BGR, the trend in the Mediterranean region shows a moderate increase over the whole period, while the others are considered stable. The increase of woodland butterflies in the Mediterranean region is consistent with reports from Ubach *et al.* (2019), who show that butterfly assemblages in Catalonia have undergone changes toward species preferring closed habitats, in parallel with a process of vegetation encroachment in the region.

Although stable over the whole investigation period, the trend for woodland butterflies in the Atlantic region has been increasing since 2005, and in the last few years the indicator values are higher than in the 1990s. In the relatively cool and moist Atlantic zone, climate change will have made more and more forests suitable for woodland butterflies to breed. As well as tree canopy butterfly species, many woodland butterflies benefit from open areas in forests and from wide, flowery and herb rich rides and woodland edges (which can support their larvae as well as providing adult butterflies with nectar).
In the other biogeographical regions, the trends are stable.

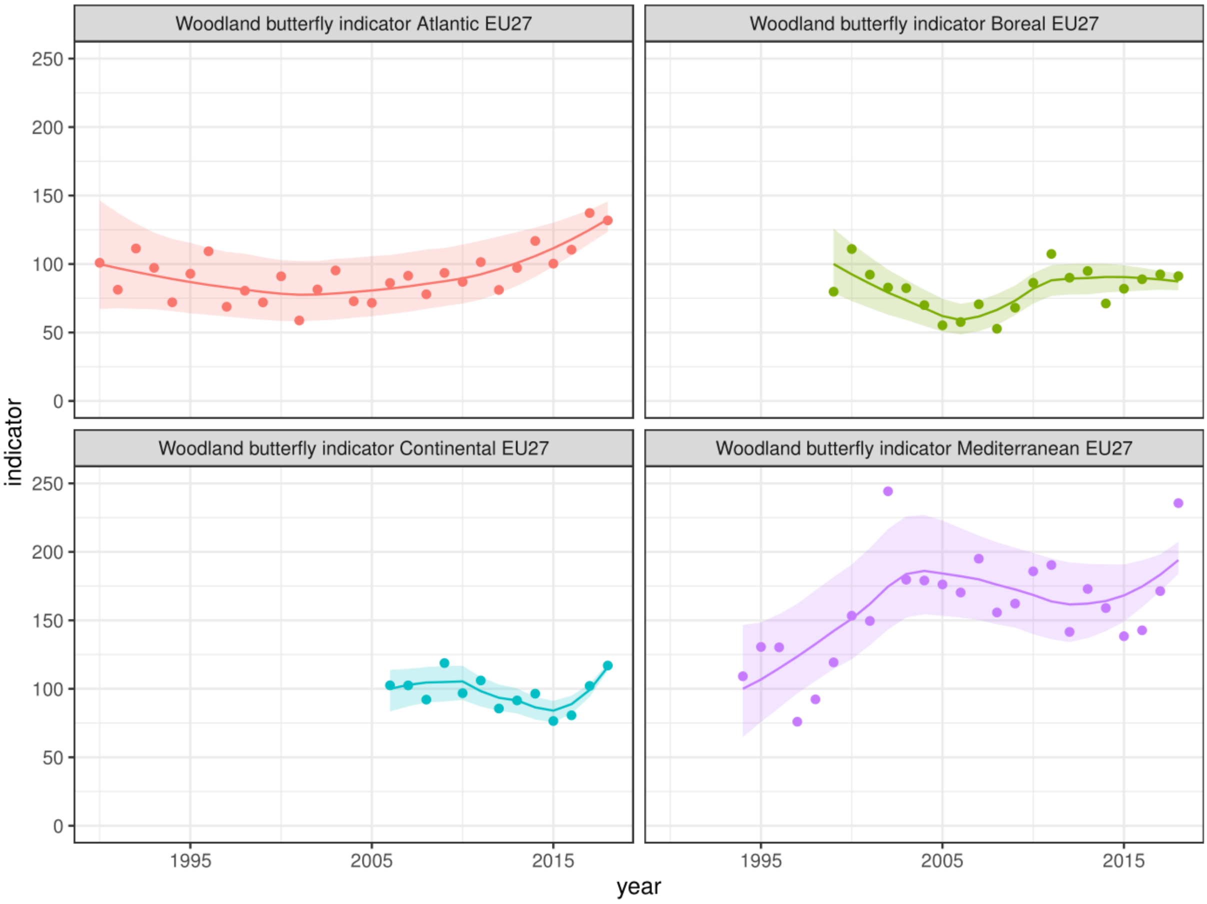


Figure 113: Woodland butterfly indicators per biogeographical region for EU27. Shaded areas represent 95% confidence intervals.

Urban Butterfly Indicator

For the urban indicator for each species the trend is calculated inside and outside urban areas using the same species-set (see Annexe II for details). In the EU27 butterfly trends in urban and non-urban areas are stable over the whole investigation period, however during the 1990s there was a remarkable decline of butterflies in non-urban areas which did not occur in urban areas.

In the whole of Europe butterflies show a moderate decline in non-urban areas whereas they are stable within urban areas.

The conclusion is that common, widespread and mobile butterflies seemed to be faring better in urban areas than outside. This may be because there is more attention to butterfly-friendly management in urban areas than outside, where intensive agriculture often dominates the landscape. This finding contrasts with previous work in the UK (Dennis et al. 2017) which showed greater declines of butterflies in urban versus non-urban areas. Further work is required to understand these differences that may relate to the time periods analysed, classification and filtering of data or differing patterns of urbanisation between the biogeographic regions of Europe.

For Europe, only 25 species contribute to the urban/non-urban butterfly indicators in 1990, which rises to 59 species by 2018 (Figure 24: Number of species contributing per year to the urban and non-urban butterfly indicators for EU27 and Europe. The number of species was fixed to be the same for urban and non-urban for direct comparison.).

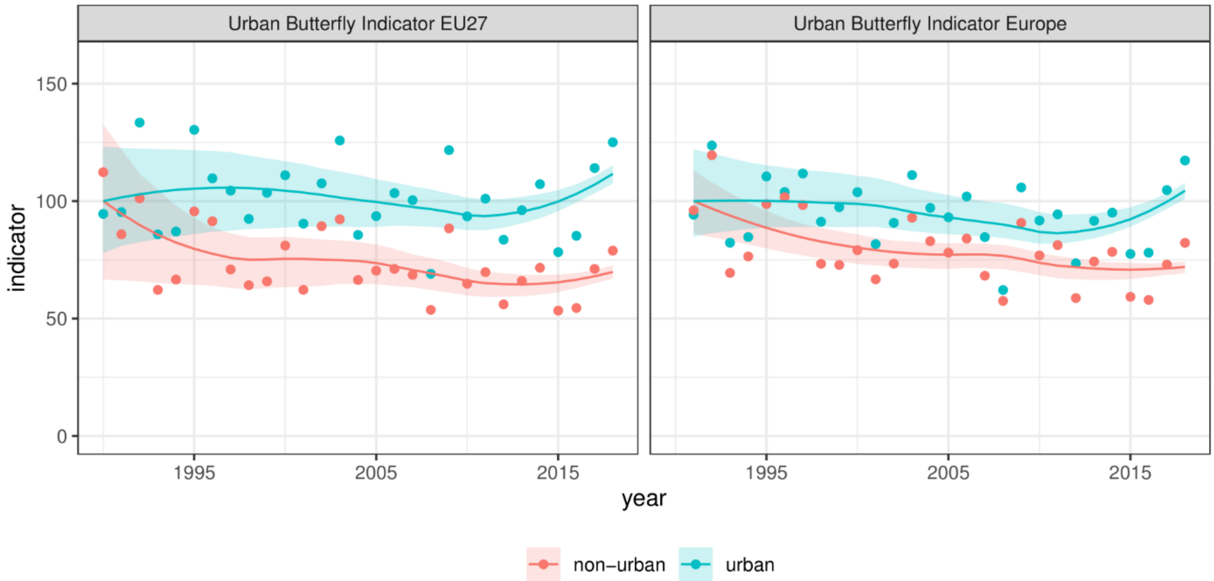


Figure 124: Indicators for the widespread butterfly species inside and outside urban areas in EU27 and Europe. Shaded areas represent 95% confidence intervals.

Almost all the data from urban areas come from the Atlantic region. Although there is not enough data to split up the data into groups with a preference for grassland and woodland, there is a remarkable tendency for a group of woodland specialist butterflies to do better in urban than in non-urban sites. Some of these species, e.g. *Pararge aegeria*, are performing much better

in urban areas, showing a strong increase over time, suggesting that parks and other woody parts of the urban environment are becoming increasingly suitable for these butterflies. As most of these butterflies are relatively mobile, they seem to be able to successfully move into cities and villages and breed and expand there. Providing nectar over several months and planting butterfly larval food plants and avoiding adverse effects of pesticides will be important to sustain and enhance urban butterfly populations.

Natura 2000 Butterfly Indicator

The indicator for the widespread species inside and outside Natura 2000 areas shows a stable trend in both areas. For most individual species there is also no significant difference in trend between Natura 2000 areas and non-protected areas, with the exception of:

- Four species showing an increase inside Natura 2000, and a decline outside: *Hipparchia semele, Pieris brassicae, Pyronia tithonus* and *Vanessa cardui* (a migrant species from Africa with large fluctuations in numbers from year to year).
- Two species with a stronger decline outside Natura 2000: *Aglais urticae* and *Lasiommata megera*.
- One species with a stronger decline inside Natura 2000: *Melanargia lachesis* (this species only occurs on the Iberian peninsula and a small area in France).
- Two species with a stronger increase inside Natura 2000: *Glaucopsyche alexis* and *Gonepteryx rhamni*.
- Two species with a stronger increase outside Natura 2000: *Fabriciana niobe* and *Favonius quercus*.

None of these are butterflies listed on the annexes of the Habitats Directive.
The outcomes of this indicator are in line with Pellissier et al. (2019). As this indicator is based on widespread species, this might be very different for the target species of the Natura 2000, as listed in Annexe II of the Habitats Directive.

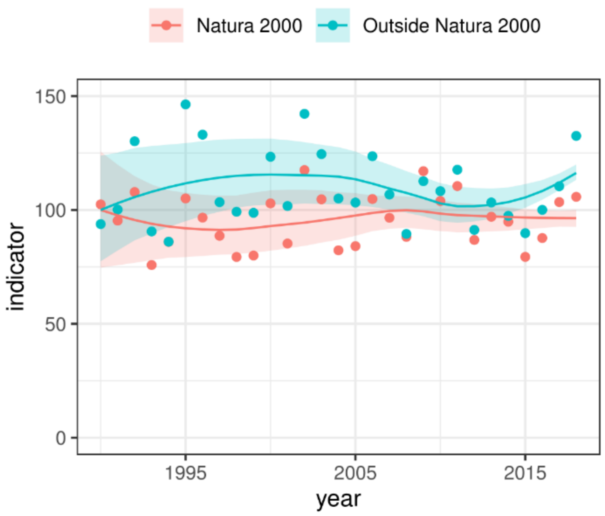


Figure 13: Indicators for the widespread butterfly species inside and outside Natura 2000 areas in the EU27. Shaded areas represent 95% confidence intervals.

Climate change indicator

The climate change indicator for butterflies, as developed by Devictor et al. (2012), is based on the assumption that climate change leads to changes in the composition of butterfly communities. This is quantified as a change in the Community Temperature Index (CTI), based on the mean annual temperature in the European range of a butterfly species (Schweiger et al., 2014). A rise in the CTI indicates that species preferring warm conditions (with a higher mean annual temperature in their European range) are becoming relatively more abundant than species preferring cool conditions.
To get a good view of the communities, only years from transects with counts in at least the months May-August are used. The number of transects rises from 241 transects in two BMSs in 1990 (United Kingdom and the Netherlands) to 2972 transects in 19 BMSs in 2018 (Figure 14).

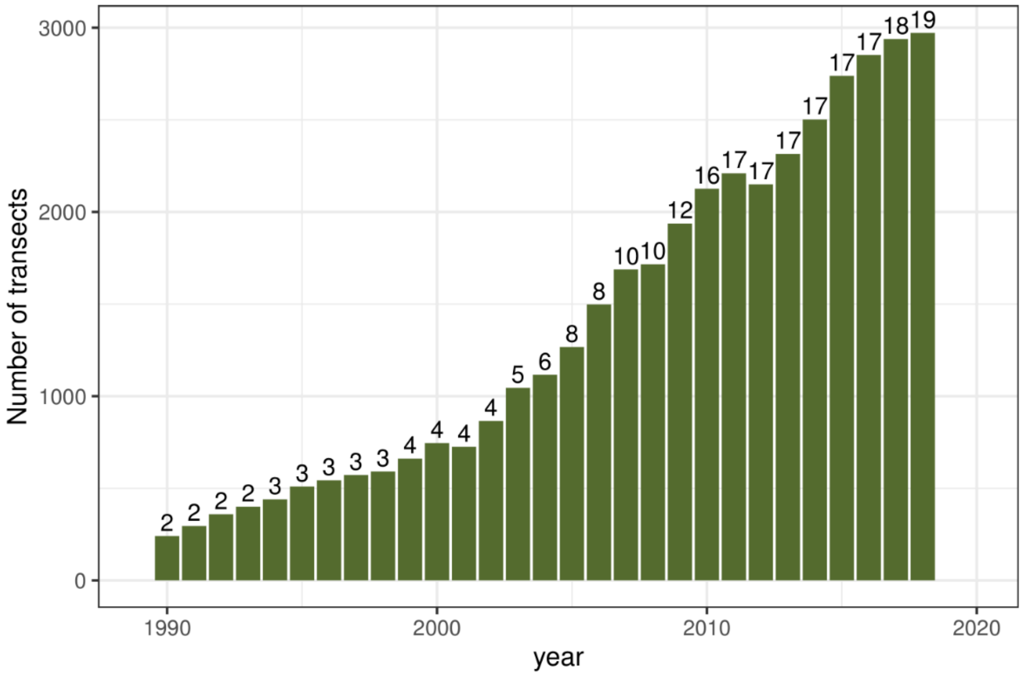


Figure 14: Number of transects that can be used for the calculation of the CTI in Europe. The number on the bars represents the number of different Butterfly Monitoring Schemes (BMS's) they originate from.

Butterfly transects in Northern Europe show a much lower CTI than in the south (Figure 15). The sites with the lowest CTI (a butterfly community with a high proportion of species preferring cool conditions) can be found in Central Finland and NW Scotland, the sites with the highest CTI in Spain.

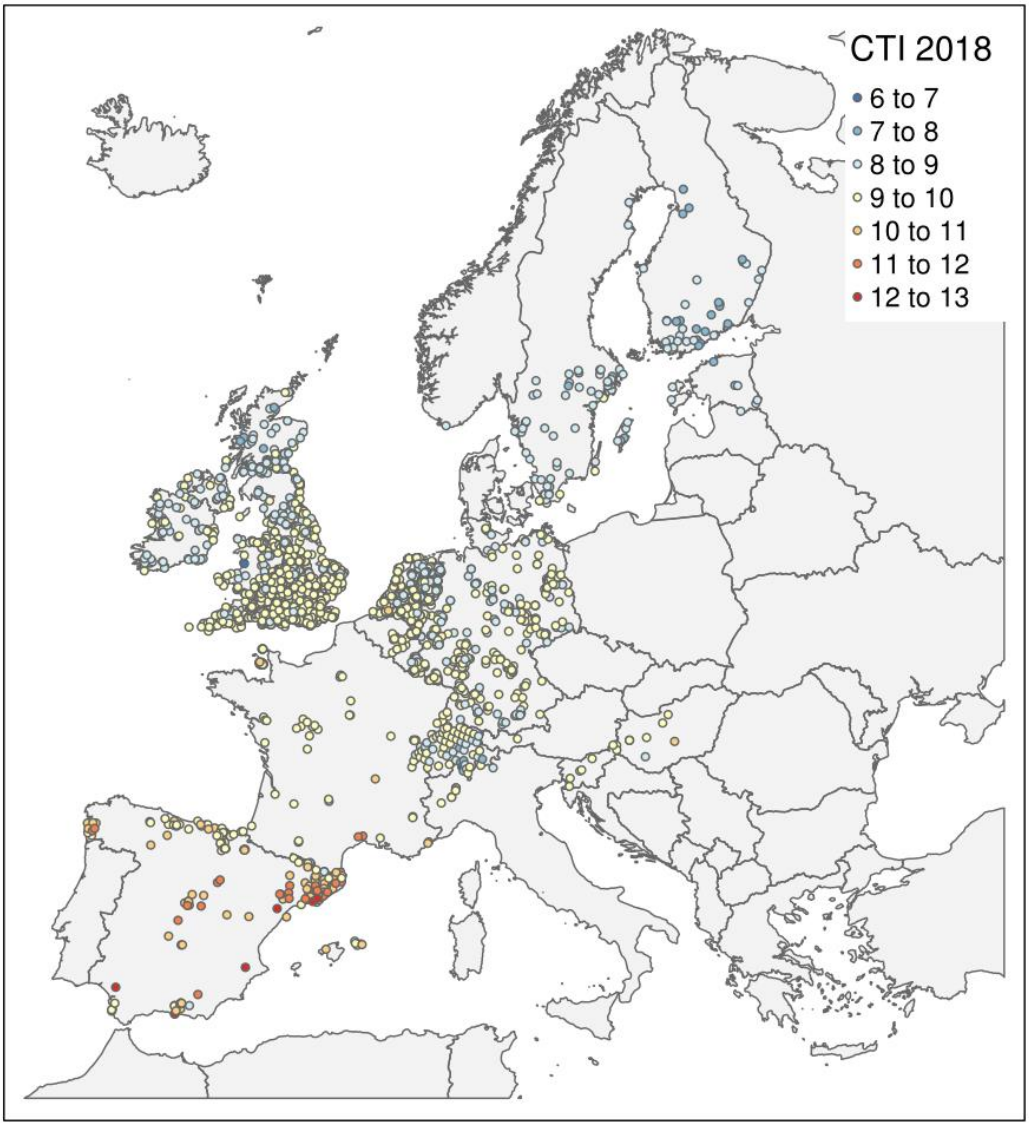


Figure 15: Community Temperature Index (CTI in °C) per transect in 2018.

In the EU27, the CTI is slowly increasing, though with large fluctuations. Cool and rainy summers can have a large effect on all butterflies, including the species preferring cooler conditions. When including the Butterfly Monitoring Schemes from outside Europe, the overall trend in the CTI becomes negative, indicating that species preferring cool conditions do relatively better than species preferring warm conditions. This is mainly caused by the large number of transects in the United Kingdom, where the CTI has a strong decline after 2008. It is still unclear what causes this. Although Devictor et al. (2012) shows that the CTI was a good indicator of climate change and the effect on butterflies over the period 1990-2008, the extra data which is now available makes this indicator less clear and hard to interpret, and hence also less suitable as a climate indicator.

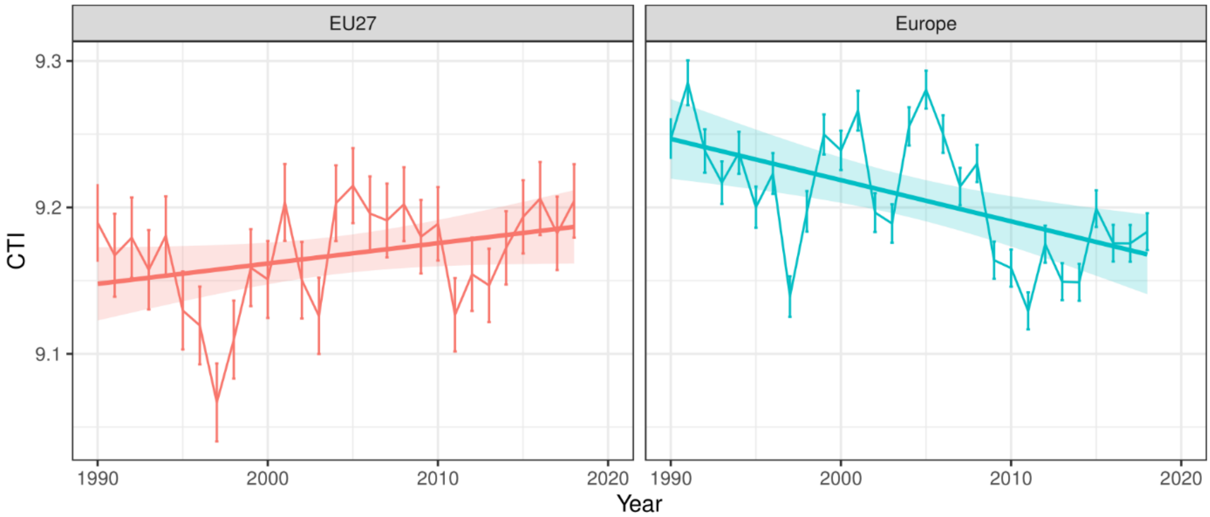


Figure 168 Community temperature index (CTI in °C) for EU27 and Europe.

Chapter 5 / Conclusions

- This report shows that it is possible to produce indices, trends and indicators for groups of butterflies, resulting in indicators for Widespread species, Grassland Butterflies, Woodland Butterflies, Urban butterflies and butterflies on Natura 2000 areas. The indicators are based on 22 national Butterfly Monitoring Schemes from across Europe, most of them members of the European Union (see Figure 4).
- The Grassland Butterfly indicator has declined by 30% since 1990 across pan-Europe and was broadly stable across the 17 Member States with schemes in the EU27. Grassland butterflies in the Atlantic biogeographical zone have shown declines over the period 1990 to 2018, mainly due to the intensification and loss of semi natural grassland in these regions.

Semi-natural grassland can be very rich in flowers and butterflies

- The Woodland Butterfly indicator is stable over the last 30 years, with a decline in the 1990s and an increase in the last ten years, both in Europe and the EU27. The recent increase might indicate the area and quality of woodland for butterflies is increasing, probably as a result of the increase in forest area as a result of agricultural land abandonment combined with the effects of climate change which makes the habitat more suitable for several species. In Sweden the woodlands are cut more often and as a result there are more butterfly-friendly grasslands available within them providing nectar and other resources, also used by woodland butterflies.

Most woodland butterflies are found in woodland edges

- The overall trend follows the European land use change trend, with a decrease in (extensive) grassland habitats and increase (and improvement) in forest habitats.
- By 2018, the indicator for the common and widespread species was stable with respect to 1990 levels, both in Europe and in the EU27. The indicator for the widespread species inside and outside Natura 2000 areas shows a stable trend for both areas.
- The Butterfly Climate Change Indicator does not provide a clear message, with an increase in the EU27 and a decline in Europe (and mainly in the United Kingdom). This indicator might be less suitable for future use. Almost all butterflies occurring on wetland are rare and threatened, with many wetlands are very hard to access for transect counts. As a result there was not enough data from wetland butterflies, making it not yet possible to calculate an indicator for this habitat yet.
- Rare and threatened species were severely under-represented, resulting in indicators which are mainly based on widespread species, classified in the EU Butterfly Red List 2010 as “Least concern”. In the near future there should be extra focus on these rare and threatened species, although counting butterflies in remote areas can be a challenge. At this point help from natural and national parks and other nature reserves could make a difference in future and could be subject of extra attention in the near future.
- Common and widespread butterflies seem to fare better in urban areas than outside. This could be due to data deficiencies, and may be because there is more attention to butterfly-friendly management in urban areas than outside, where intensive agriculture often dominates the landscape.

Rare species, like this* Coenonympha hero*, are still underrepresented.

References

August, T., Powney, G., Outhwaite, C. & Isaac, N., 2017. BRCindicators: Creating biodiversity indicators for species occurrence data. R package version 1.0.

Bar-On, Y.M., Phillips, R. & Milo, R., 2018. The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, 115(25), 6506-6511.

Brereton, T.M., Botham, M.S., Middlebrook, I., Randle, Z., Noble D., Harris, S., Dennis, E.B., Robinson A. & Roy, D.B., 2018. United Kingdom Butterfly Monitoring Scheme report for 2017. Centre for Ecology & Hydrology, Butterfly Conservation, British Trust for Ornithology and Joint Nature Conservation Committee.

Cardoso P., Barton P.S., Birkhofer K., Chichorro F., Deacon C., Fartmann T., Fukushima C.S., Gaigher R., Habel J.C., Hallmann C.A., Hill M.J., Hochkirch A., Kwak M.L., Mammola S., Ari Noriega J., Orfinger A.B., Pedraza F., Pryke J.S., Roque F.O., Settele J., Simaika J.P., Stork N.E., Suhling F., Vorster C. & Samways M.J., 2020. Scientists' warning to humanity on insect extinctions. Biological Conservation, 242: 108426. https://doi.org/10.1016/j.biocon.2020.108426

Dennis, E.B., Freeman, S.N., Brereton, T. & Roy, D.B., 2013. Indexing butterfly abundance whilst accounting for missing counts and variability in seasonal pattern. *Methods in Ecology and Evolution*, 4(7), pp.637-645.

Dennis, E.B., Morgan, B.J., Freeman, S.N., Brereton, T.M. & Roy, D.B., 2016. A generalized abundance index for seasonal invertebrates. *Biometrics*, *72*(4), 1305-1314.

Dennis, E.B., Morgan, B.J., Roy, D.B. & Brereton, T.M., 2017. Urban indicators for UK butterflies. *Ecological Indicators*, 76, 184-193.

Devictor, V., van Swaay, C., Brereton, T., Brotons, L., Chamberlain, D., Heliölä, J., Herrando, S., Julliard, R., Kuussaari, M., Lindström, Å., Reif , J., Roy, D.B., Schweiger, O., Settele, J., Stefanescu, C., Van Strien, A. Van, Turnhout, C., Vermouzek, Z., DeVries, M.W., Wynhoff, I. & Jiguet, F., 2012. Differences in the climatic debts of birds and butterflies at a continental scale. *Nature climate change*, 2(2), 121-124.

European Environment Agency (2012). Streamlining European biodiversity indicators 2020: Building a future on lessons learnt from the SEBI 2010 process. EEA Technical report No 11/2012.

Gregory, R. D., Van Strien, A., Vorisek, P., Gmelig Meyling, A. W., Noble, D. G., Foppen, R. P., & Gibbons, D. W., 2005. Developing indicators for European birds. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1454), 269-288.

Gutierrez-Arellano, C. & Mulligan, M., 2018. A review of regulation ecosystem services and disservices from faunal populations and potential impacts of agriculturalisation on their provision, globally. *Nature Conservation,* 30, 1-39.

Henry, P.Y., Lengyel, S., Nowicki, P., Julliard, R., Clobert, J., Čelik, T., Gruber, B., Schmeller, D.S., Babij, V. & Henle, K., 2008. Integrating ongoing biodiversity monitoring: potential benefits and methods. *Biodiversity and conservation*, *17*(14), 3357-3382.

Kühn, E., Feldmann, R., Harpke, A., Hirneisen, N., Musche, M., Leopold, P. & Settele, J., 2008. Getting the public involved in butterfly conservation: lessons learned from a new monitoring scheme in Germany. *Israel Journal of Ecology & Evolution*, *54*(1), 89-103.

Metzger, M.J., Bunce, R.G., Jongman, R.H., Sayre, R., Trabucco, A. & Zomer, R., 2013. A high-resolution bioclimate map of the world: a unifying framework for global biodiversity research and monitoring. *Global Ecology and Biogeography*, *22*(5), pp.630-638.

Noriega, J.A., Hortal, J., Azcárate, F.M., Berg, M.P., Bonada, N., Briones, M.J.I., Del Toro, I., Goulson, D., Ibanez, S., Landis, D.A., et al., 2018. Research trends in ecosystem services provided by insects. *Basic and Applied Ecology* 2018, 26, 8–23, doi:10.1016/j.baae.2017.09.006.

Pellissier, V., Schmucki, R. Pe'er, G., Aunins, A., Brereton, T.M., Brotons, L., Carnicer, J., Chodkiewicz, T., Chylarecki, P., del Moral, J.C., Escandell, V., Evans, D. & Foppen, R., 2019. Effects of Natura 2000 on nontarget bird and butterfly species based on citizen science data. *Conservation Biology*, 1-11. DOI: 10.1111/cobi.13434

Pollard, E. & Yates, T.J., 1993. *Monitoring butterflies for ecology and conservation. The British butterfly monitoring scheme* (No. 333.955 P6).

Ram, D., Lindström Å., Pettersson L. B. & Caplat P., 2020. Forest clear-cuts as habitat for farmland birds and butterflies. *Forest Ecology and Management,* 473, 118239.

Samways M.J., Barton P.S., Birkhofer K., Chichorro F., Deacon C., Fartmann T., Fukushima C.S., Gaigher R., Habel J.C., Hallmann C.A., Hill M.J., Hochkirch A., Kaila L., Kwak M.L., Maes D., Mammola S., Noriega J.A., Orfinger A.B., Pedraza F., Pryke J.S., Roque F.O., Settele J., Simaika J.P., Stork N.E., Suhling F., Vorster C. & Cardoso P., 2020. Solutions for humanity on how to conserve insects. *Biological Conservation*, 242, 108427. https://doi.org/10.1016/j.biocon.2020.10

Sánchez-Bayo, F. & Wyckhuys, K.A., 2019. Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation*, 232, 8-27.

Schmucki, R., Pe'er, G., Roy, D.B., Stefanescu, C., Van Swaay, C.A.M., Oliver, T.H., Kuussaari, M., Van Strien, L. Ries, J. Settele, M. Musche, J. Carnicer, O. Schweiger, T. M. Brereton, A. Harpke, J. Heliölä, E. Kühn, & R. Julliard., 2016. A regionally informed abundance index for supporting integrative analyses across butterfly monitoring schemes. *Journal of Applied Ecology*, *53*(2), 501-510.

Schweiger, O., Harpke, A., Wiemers, M. & Settele, J., 2014. CLIMBER: Climatic niche characteristics of the butterflies in Europe. *ZooKeys*, 367, 65-84.

Seibold, S., Gossner, M.M., Simons, N.K., Blüthgen, N., Müller, J., Ambarlı, D., Ammer, C., Bauhus, J., Fischer, M., Habel, J.C. & Linsenmair, K.E., 2019. Arthropod decline in grasslands and forests is associated with landscape-level drivers. *Nature*, 574(7780), 671-674.

Soldaat, L.L., Pannekoek, J., Verweij, R.J., van Turnhout, C.A. & van Strien, A.J., 2017. A Monte Carlo method to account for sampling error in multi-species indicators. *Ecological indicators*, *81*, 340-347.

Sutherland, W.J. ed., 2006. *Ecological census techniques: a handbook*. Cambridge University Press.

Ubach, A., Paramo, F., Gutiérrez, C. & Stefanescu, C., 2019. Vegetation encroachment drives changes in the composition of butterfly assemblages and species loss in Mediterranean ecosystems. *Insect Conservation and Diversity*, 13(2), 151-161.

Van Klink, R., Bowler, D.E., Gongalsky, K.B., Swengel, A.B., Gentile, A. & Chase, J.M., 2020. Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, 368(6489), 417-420.

Van Swaay, C.A., Nowicki, P., Settele, J. & van Strien, A.J., 2008. Butterfly monitoring in Europe: methods, applications and perspectives. *Biodiversity and Conservation*, *17*(14), 3455-3469.

Van Strien, A.J., Swaay, C.A.M. van, Strien-van Liempt, W.T.F.H. van, Poot, M.J.M. & WallisDeVries, M.F., 2019. Over a century of data reveal more than 80% decline in butterflies in the Netherlands. *Biological Conservation*, 234, 116-122.

Van Swaay, C.A.M., Dennis, E.B., Schmucki, R., Sevilleja, C.G., Balalaikins, M., Botham, M., Bourn, N., Brereton, T., Cancela, J.P., Carlisle, B., Chambers, P., Collins, S., Dopagne, C., Escobés, R., Feldmann, R., Fernández-García, J. M., Fontaine, B., Gracianteparaluceta, A., Harrower, C., Harpke, A., Heliölä, J., Komac, B., Kühn, E., Lang, A., Maes, D., Mestdagh, X., Middlebrook, I., Monasterio, Y., Munguira, M.L., Murray, T.E., Musche, M., Õunap, E., Paramo, F., Pettersson, L.B,, Piqueray, J., Settele, J., Stefanescu, C., Švitra, G., Tiitsaar, A., Verovnik, R., Warren, M.S., Wynhoff, I. & Roy, D.B., 2019*. The EU Butterfly Indicator for Grassland species: 1990-2017: Technical Report*. Butterfly Conservation Europe & ABLE/eBMS (www.butterfly-monitoring.net)

Van Swaay, C.A.M. & van Strien, A., 2005. Using butterfly monitoring data to develop a European grassland butterfly indicator. *Studies on the ecology and conservation of Butterflies in Europe. Vol 1: General concepts and case studies*, pp.106-108.

Van Swaay, C., Warren, M., & Loïs, G., 2006. Biotope use and trends of European butterflies. *Journal of Insect Conservation*, 10(2), 189-209.

Van Swaay, C., Cuttelod, A., Collins, S., Maes, D., López Munguira, M., Šašić, M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M. & Wynhof, I., 2010. European Red List of Butterfies. Luxembourg: Publications Office of the European Union.

Wagner, D.L., 2020. Insect declines in the Anthropocene. *Annual review of entomology*, 65, 457-480.

WallisDeVries, M.F. & van Swaay, C.A.M., 2017. A nitrogen index to track changes in butterfly species assemblages under nitrogen deposition. *Biological Conservation,* 212, Part B, 448-453.

Annexe I / Schemes contributing to indicators

Since the start of the first Butterfly Monitoring Scheme in the UK in 1976 more and more countries have joined in. This Annexe summarises the most important features of the schemes used for the EU Grassland Butterfly Indicator.

BMS_ID	Country	Area represented (km2)	Starting year	Average transect length (km)	Mean number of transects which have contributed 2016-2018	Mean number of counts on a transect per year	Counts by (v=volunteers, p=professionals)	Method to choose sites (f=free, c=by co-ordinator, g=grid, r=random, u=unknown)
ATBMS	Austria	6126	2013	0.1	13	3	p	u
BE-WABMS	Belgium	10204	2010	-	-	-	p	c
BEBMS	Belgium	12671	1991	0.8	13	14	v	f
CHBMS	Switzerland	40260	2003	2.4	91	7	p	g
CZBMS	Czechia	58857	2010	2.3	23	12	p	f
DEBMS	Germany	333350	2005	0.4	470	15	v	f
EEBMS	Estonia	30081	2004	1.8	9	6	p	c
ES-CBBMS	Spain	10071	2010	1.8	51	9	v 70%. p 30%	f
ES-CTBMS	Spain	33885	1994	1.6	90	26	v	f
ESBMS	Spain	406019	2014	1.5	85	12	v ~50%. p ~50%	f
FIBMS	Finland	210336	1999	2.8	45	11	v ~80%. p ~20%	f for v, c for p
FRBMS	France	497048	2005	2.4	93	4	v	~50% f - ~50% r
HUBMS	Hungary	19468	2016	0.7	7	20	v	c
IEBMS	Ireland	64167	2008	3.0	115	16	v	f
ITBMS	Italy	57076	2016	0.7	7	6	v	c
LTBMS	Lithuania	16242	2009	1.1	1	8	v	f
LUBMS	Luxembourg	2456	2010	0.8	80	5	v ~10%. p ~90%	r
LVBMS	Latvia	52589	2015	1.5	24	3	p	g
NLBMS	Netherlands	33542	1990	0.6	803	13	v	f
NOBMS	Norway	162654	2009	1.6	52	3	v -100%	g
RO-ANDBMS	Romania	1632	2013	1.0	-	4	v-60%. p-40%	c
ROBMS	Romania	212	2014	0.7	7	5	v	c
SEBMS	Sweden	374959	2009	2.5	207	5	v ~90%. p ~10%	f
SIBMS	Slovenia	13266	2007	1.4	8	7	v	c
UKBMS	United Kingdom	238391	1976	1.9	2350	15	v	f

Annexe II / Statistical method

Data collection

All data was first collected at a regional or national level (see Annexe I), and after validation added to the eBMS database. This is a standardised database containing the following tables:

1. Butterfly count data table
2. Monitoring visit table
3. Site geographical information table
4. Habitat type table
5. Habitat type description table
6. Species name table

Widespread butterfly indicator

Step 1 – produce species site indices

For each species and year, flight periods were estimated based on climate zones (Schmucki et al., 2016) using the spline formulation of the generalised abundance index approach (GAI, Dennis et al., 2016). The climate zones are based on those defined in Metzger et al. (2013), but with further geographic stratification. The estimated flight period curves were used to estimate the missing counts and site indices were produced for each species, site, year combination. To avoid including highly unreliable abundance estimates, we excluded site indices calculate with less than 10% of the flight period monitored (Schmucki et al. 2016). We also excluded, if present, values that are more than 3 Standard Deviation above the national geometric mean – this threshold corresponds to the 99.7 percentile of a normal distribution and will remove extreme outliers from the data set.

To be able to produce suitable estimates of precision of the subsequent indices, indicators and trends, a bootstrapping approach was taken, as is typical for these modelling approaches, to account for sources of uncertainty from multiple model stages (Dennis et al. 2013). Hence the site indices were randomly resampled 1000 times while keeping the number of transects sampled per year the same as in the original data. The subsequent stages of analysis (steps 2-4) were then applied to each bootstrap, which could then be combined to produce confidence intervals.

Step 2 - species collated indices

- Species site indices were combined to produce density estimates for each BMS but stratified by biogeographical region (BGR), where for some monitoring schemes sites are classified within multiple BGR. Hence for each BMS/BGR combination, per species, a Poisson GLM with site and year effects, as well as the proportion of the flight period surveyed as a weighting (Brereton et al., 2018), was applied to the site indices. For a given species, this produced estimated butterfly densities (number of butterflies estimated per hectare) per BMS/BGR.
- Next these densities were combined to densities per BGR as a whole. Estimating butterfly densities per BGR directly would not account for variation among BMS, so for example a BMS with many sites but potentially representing a minimal area of the species' range within a BGR would dominate the predictions, compared to a BMS with fewer transects that might spatially represent a large part of the species range.
- Firstly several filters are applied to ensure only reliable species' densities contribute to the indicators, whilst aiming to maximise representativeness and use of the data collected. We filter each case (i.e. time series of annual densities for a given species/BMS/BGR) to the first year

beyond which counts were made on at least 10 sites each year, and the given species was counted on 5 or more sites. Any cases where fewer than 3 years remain in the series are then excluded, and any extreme outliers were also filtered out. These criteria may be stricter than those used for scheme/country-level analyses where greater scrutiny/expert knowledge may be made.

- Given that the start year varies among BMS, prior to combining densities from multiple BMS, missing values in the annual density estimates must first be interpolated. Missing values were estimated by taking the density from the first available year, and scaling it based on the average trend (in terms of multiplicative change from the mean density) from other BMS (within the given BGR) with available data for that year.
- Species densities per BGR are then estimated by taking a weighted mean of species densities per BGR/BMS, where the species range for the given BMS/BGR are used as a weighting. These densities per BGR were calculated based on using BMS from EU27 and Europe.

Step 3 - species collated indices for EU27 and Europe

Species BGR densities were converted to collated indices (on the log10 scale) and any cases with gaps of more than 10 years were omitted. Then species collated indices for EU27 and Europe were produced by fitting a Poisson GLM with BGR and year effects as well as a weighting.

The weightings were based on the product of species' range and population density at BGR level. Population density was taken as the mean population density per 1km^2 across years for a given species and BGR, as calculated in step 2. Species' range (distribution area in hectares) was estimated per BGR as the overlap between the species distribution map (from www.iucnredlist.org), within regions represented by monitoring schemes only. For migrant species no weightings were used. Where a species is only present, or only sufficiently monitored, in a single BGR, the collated index for that BGR was taken as the index for EU27/Europe for that species. For the EU27 and pan-Europe widespread butterfly indicators, 67/148 and 71/167 species indices, respectively, were produced from data from a single BGR.

Step 4 - producing EU27/European indicators

The European or EU indices were combined by taking the geometric mean of the indices. The BRCindicators R package (August et al., 2017) was used, to account for missing values, in particular the late entry of some species. A smoothed indicator was produced using a loess smooth with span=0.75 and degree=2 (as in Soldaat et al., 2017). The same approach was applied to produce multi-species indices and smoothed indicators for each of 1000 bootstraps, from which quantiles were taken to produce 95% confidence intervals around the indicators. All values were rescaled such that the smoothed indicator started at 100.
Trends were estimated by applying linear regression to the smoothed indicator (and similarly to unsmoothed species-level EU27/European indices). Trends were estimated for each bootstrap, from which 95% confidence intervals around the actual trend were produced and used to assess significance. Trends were classified based on the multiplicative slope estimate, as in TRIM (Pannekoek & van Strien, 2005).
Indicators of widespread butterflies per BGR were also produced, by applying the same indicator methodology to the BGR level species indices produced in steps 2-3.

Grassland butterfly indicator

Site indices were produced as in step 1 for the widespread butterfly indicator. The methodology then follows that of the previous version of the grassland butterfly indicator (Van Swaay et al. 2019). Species collated indices were produced for each monitoring scheme using a Poisson GLM with site and year effects, as well as the proportion of the flight period surveyed as a weighting (Brereton et al., 2018). A collated index for EU27/Europe was then produced for each species by fitting a Poisson GLM to the scheme-level indices with scheme and year effects as well as weighting based on the product of the total area (km^2) that a given species occupies in the relevant country (or part of country for certain schemes) and the species' population density. The EU27/Europe indices for the 17 grassland species were then combined as in step 4 for the widespread butterfly indicator.

Woodland butterfly indicator

The methodology for the woodland butterfly indicator for EU27/Europe follows that of the widespread butterfly indicator. Using the same filters of the species-level indices resulted in 33 of 67 species contributing to the indicator.

Urban butterfly indicator

This indicator is based on all species for which trends can be calculated on transects classified as urban. We classified as urban every BMS transect located within 500 m from an urban area. These urban areas were defined based on the density and continuousness of the impervious surface. Using the high-resolution map of the impervious surface across Europe, we considered each pixel (20 x 20 m) having more than 50% of its area covered in impervious surfaces as an urban pixel (following the EEA definition). Urban areas were delimited by counting the number of urban pixels within 100 x 100 m area tiles; each tile with more than 50% of its pixels classified urban are then considered as urban. To ensure spatial continuity and include urban green space, each tile located within 200 m of an urban tile is also included in the urban area. We used the resulting map to classify transects as urban or non-urban; transects located inside or within 500 m from an urban area being urban and all others as non-urban.

For a direct comparison of urban and non-urban butterfly populations, prior to step 3 of the indicator production, species BGR densities were filtered to the same subset of species/year/BGR combinations for both urban and non-urban, before being combined to the European level.

Natura 2000 indicator

This indicator is based on all species for which reliable trends can be calculated on transects for which the centroid lies inside or within a 1 km radius of a Natura 2000 site. For this classification, we used the map Natura 2000 End 2019 released by the EEA on the 21st of April 2020 (PERMALINK) and overlaid the BMS transects to classify them Natura 2000 or outside non-Natura 2000.

For a direct comparison of butterfly populations inside and outside Natura 2000, prior to step 3 of the indicator production, species BGR densities were filtered to the same subset of species/year/BGR combinations for both inside and outside Natura 2000, before being combined to the European level.

Additional notes

Bootstrapping throughout all model stages, i.e. including stage 1 would ensure full error propagation throughout the workflow, whereas currently bootstrapping occurs from stage 2 onwards. This has benefits of computational efficiency, and we would expect greater variation through variation in sites (as currently accounted for), than through variation in the flight period estimation.

Potential biases

Although the Butterfly Monitoring Schemes are very similar, there are differences in the choice of location, number of counts, corrections for unstratified sampling, etc. These are summarised in annexe I. These changes can potentially lead to biases. It is also important to note that in countries where the choice of the location for the transect is free (Anexe I), there tends to be an oversampling in species-rich sites, nature reserves or regions with a higher butterfly recorder density. The trend of butterflies within nature reserves may be expected to be better than in the wider countryside since the management of these reserves focuses on reaching high biodiversity and positive population trends. This suggests that the grassland indicator is probably a conservative measure of the real trend across the European landscape. There is a risk that the decline in the population size of butterflies is more severe than the indicator shows. We hope to be able to test this in future.

Annexe III / Butterfly Indicator species list

Overview of the species which have been selected as indicator species. For the grassland and woodland indicator species list, there is also a column indicating if there was enough data for the species to be used in the indicator. Indicator lists are for the whole of Europe (van Swaay et al. 2006).

Species	Grassland Indicator species	Used in the Grassland Indicator	Woodland Indicator species	Used in the Woodland Indicator	Wetland Indicator species
Erynnis tages	x	x			
Spialia sertorius	x	x			
Ochlodes sylvanus	x	x			
Anthocharis cardamines	x	x			
Lycaena phlaeas	x	x			
Cupido minimus	x	x			
Phengaris arion	x	x			
Phengaris nausithous	x	x			
Cyaniris semiargus	x	x			
Polyommatus icarus	x	x			
Lysandra bellargus	x	x			
Lysandra coridon	x	x			
Euphydryas aurinia	x	x			
Lasiommata megera	x	x			
Coenonympha pamphilus	x	x			
Maniola jurtina	x	x			
Thymelicus acteon	x	x			
Apatura ilia			x	x	
Apatura iris			x	x	
Apatura metis			x		
Aporia crataegi			x	x	
Araschnia levana			x	x	
Argynnis laodice			x		
Argynnis pandora			x	x	
Argynnis paphia			x	x	
Boloria euphrosyne			x	x	
Boloria graeca			x		
Brintesia circe			x	x	
Carterocephalus silvicola			x	x	

Species	Grassland Indicator species	Used in the Grassland Indicator	Woodland Indicator species	Used in the Woodland Indicator	Wetland Indicator species
Celastrina argiolus			x	x	
Coenonympha arcania			x	x	
Coenonympha hero			x	x	
Coenonympha leander			x		
Colias caucasica			x		
Erebia aethiopellus			x		
Erebia aethiops			x	x	
Erebia cyclopius			x		
Erebia euryale			x		
Erebia ligea			x	x	
Erebia neoridas			x		
Erebia zapateri			x		
Euphydryas intermedia			x		
Euphydryas maturna			x	x	
Fabriciana elisa			x		
Favonius quercus			x	x	
Gonepteryx farinosa			x		
Gonepteryx maderensis			x		
Gonepteryx rhamni			x	x	
Hipparchia fagi			x	x	
Hipparchia hermione			x	x	
Hipparchia maderensis			x		
Hipparchia mersina			x		
Hipparchia syriaca			x		
Issoria eugenia			x		
Kirinia climene			x		
Kirinia roxelana			x		
Laeosopis roboris			x		
Lasiommata deidamia			x		
Lasiommata maera			x	x	
Lasiommata petropolitana			x	x	
Leptidea morsei			x		
Libythea celtis			x	x	
Limenitis camilla			x	x	
Limenitis populi			x	x	
Limenitis reducta			x	x	

Species	Grassland Indicator species	Used in the Grassland Indicator	Woodland Indicator species	Used in the Woodland Indicator	Wetland Indicator species
Lopinga achine			x		
Melitaea aetherie			x		
Neptis rivularis			x		
Neptis sappho			x		
Nymphalis antiopa			x	x	
Nymphalis polychloros			x	x	
Nymphalis vaualbum			x		
Nymphalis xanthomelas			x		
Pararge aegeria			x	x	
Pararge xiphia			x		
Pieris balcana			x		
Polygonia c-album			x	x	
Pseudochazara tisiphone			x		
Satyrium acaciae			x	x	
Satyrium ilicis			x	x	
Satyrium pruni			x		
Satyrium w-album			x	x	
Thecla betulae			x	x	
Tomares callimachus			x		
Agriades optilete					x
Boloria aquilonaris					x
Boloria eunomia					x
Boloria freija					x
Boloria frigga					x
Coenonympha oedippus					x
Coenonympha tullia					x
Colias palaeno					x
Erebia disa					x
Erebia embla					x
Oeneis jutta					x
Pyrgus centaureae					x

Annexe IV / Additional graphs

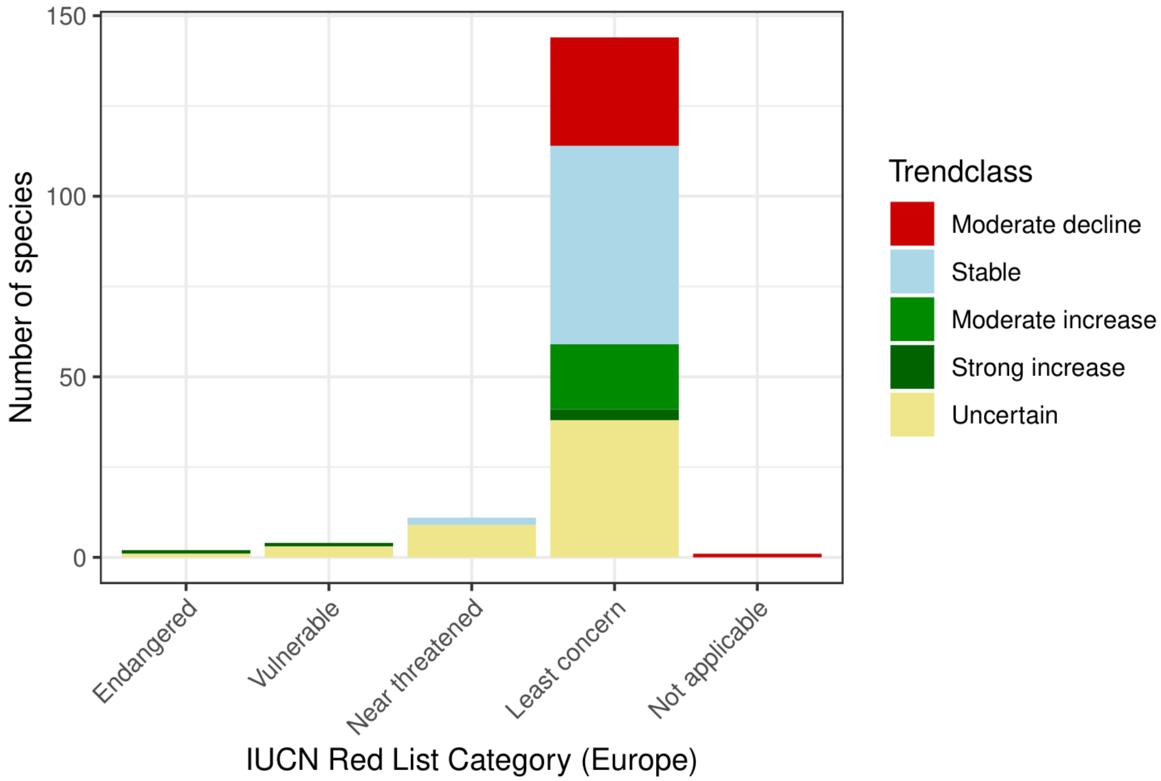


Figure 17: Number of species with trends per IUCN Red List category (Van Swaay et al., 2010) excluding the species for which no data was available for trend calculation in this project (see Figure 65).

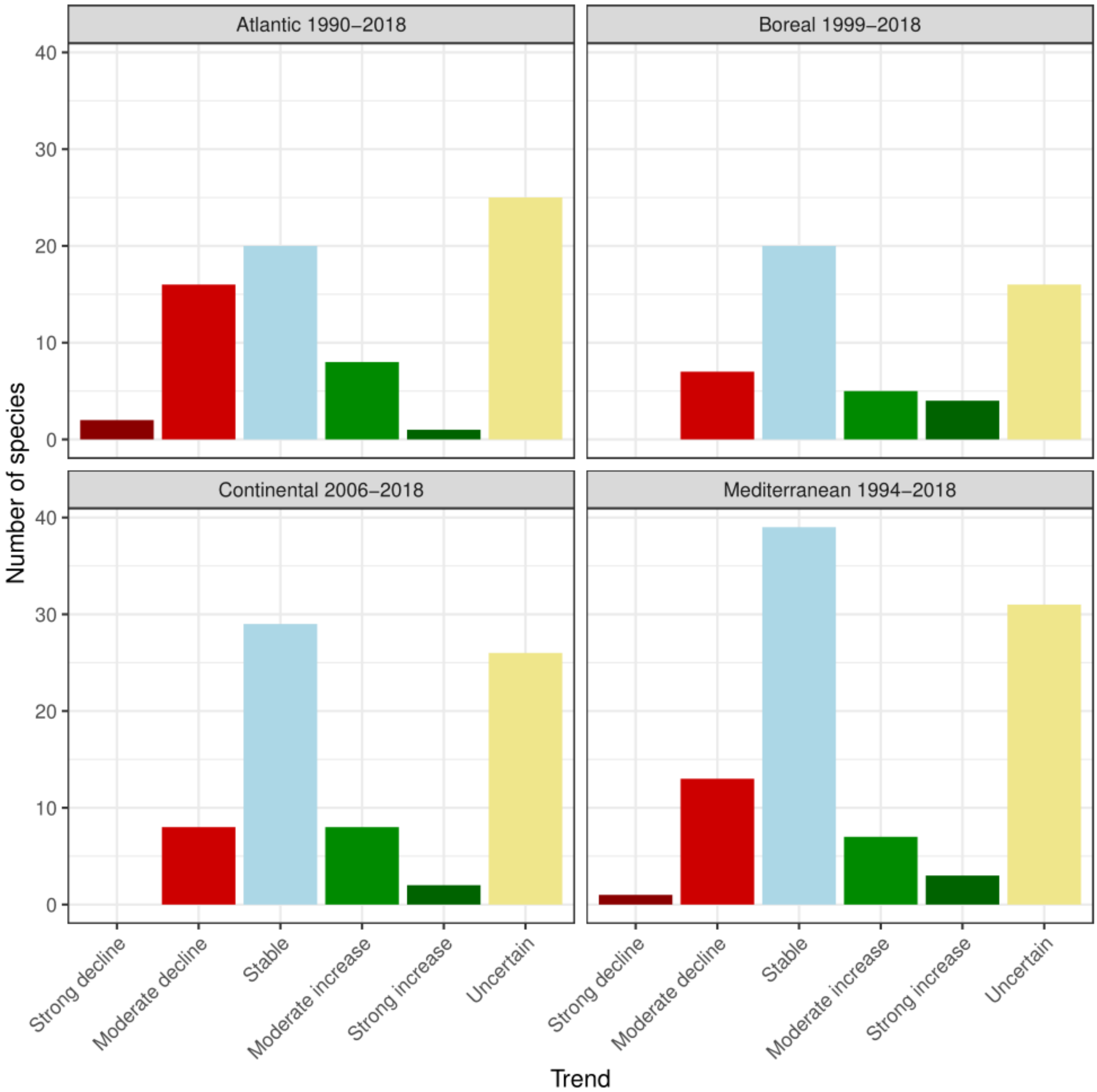


Figure 20: Number of widespread species per trend class per Biogeographical region in Europe excluding Data deficient species (see Figure 767).

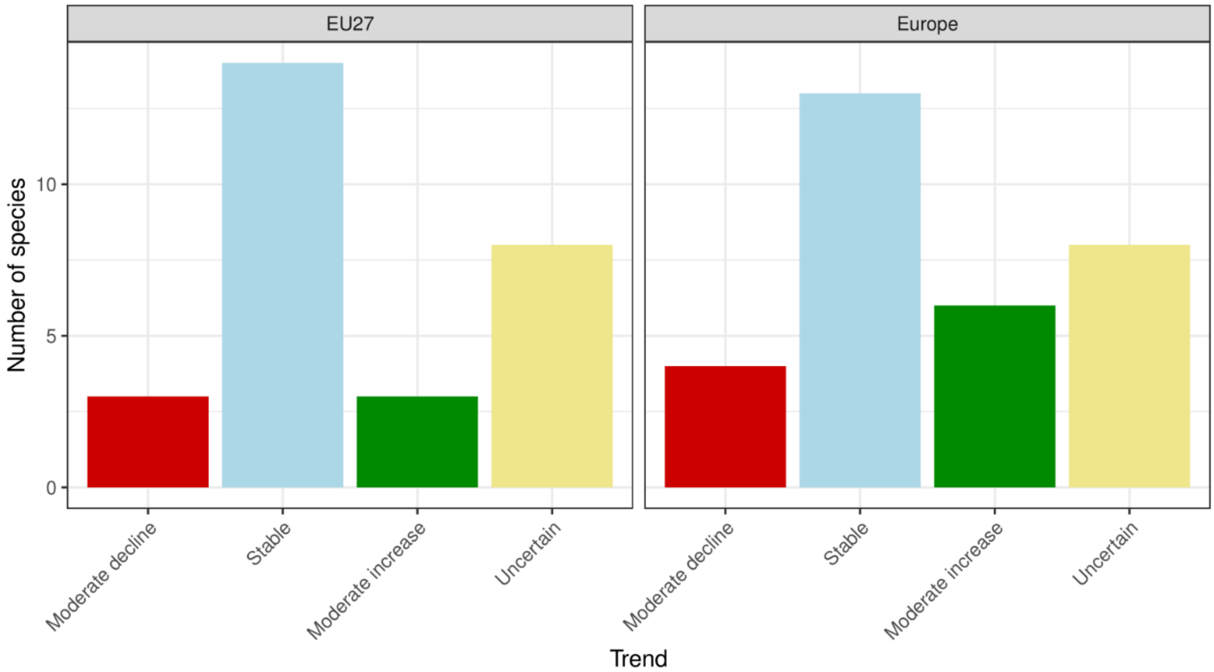


Figure 181: Number of woodland species per trend class in the EU27 and Europe. Species with no data or trends for less than 13 years are excluded.

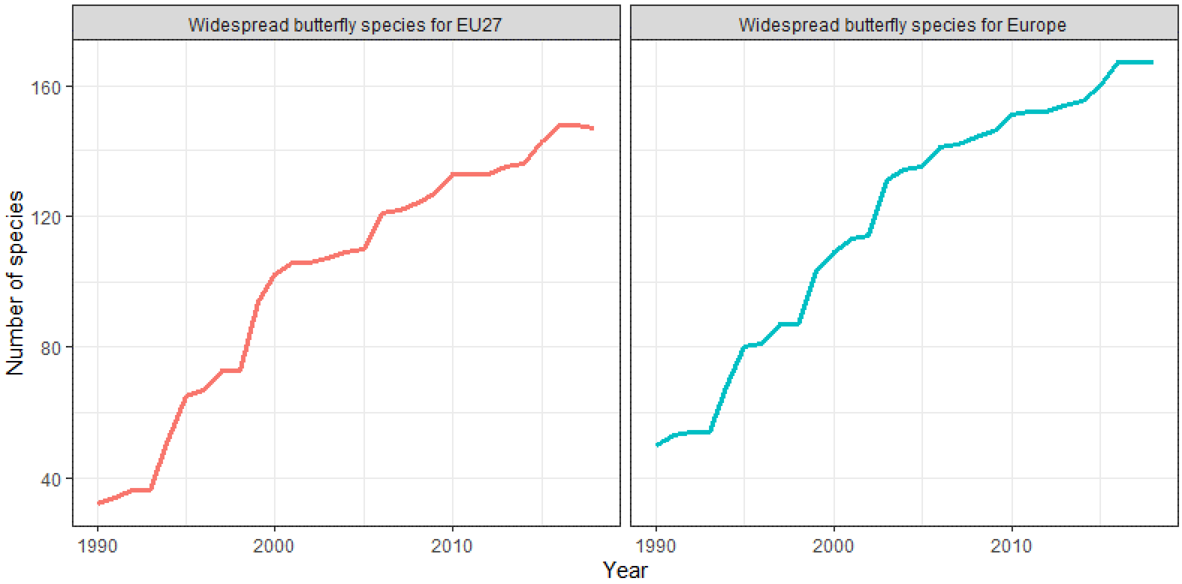


Figure 192: Number of species contributing per year to the widespread butterfly indicator for EU27 and Europe.

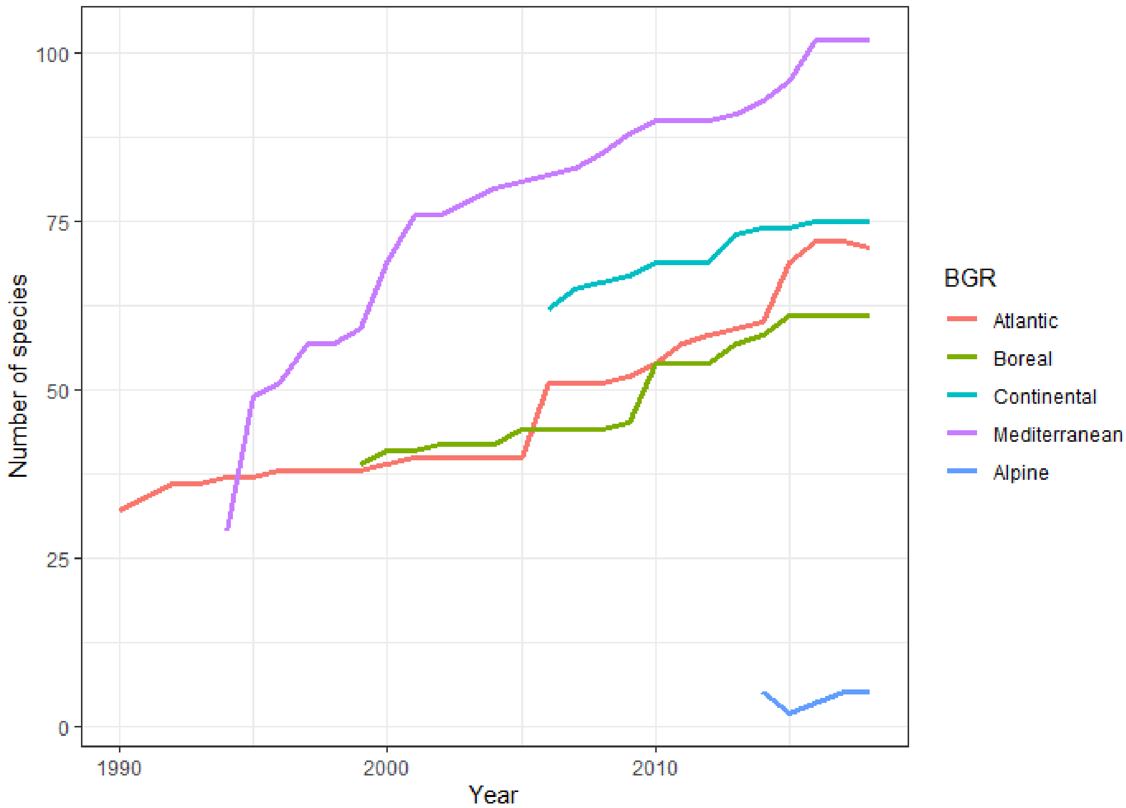


Figure 203: Number of species contributing per year to the widespread butterfly indicators per biogeographical region (BGR) for EU27.

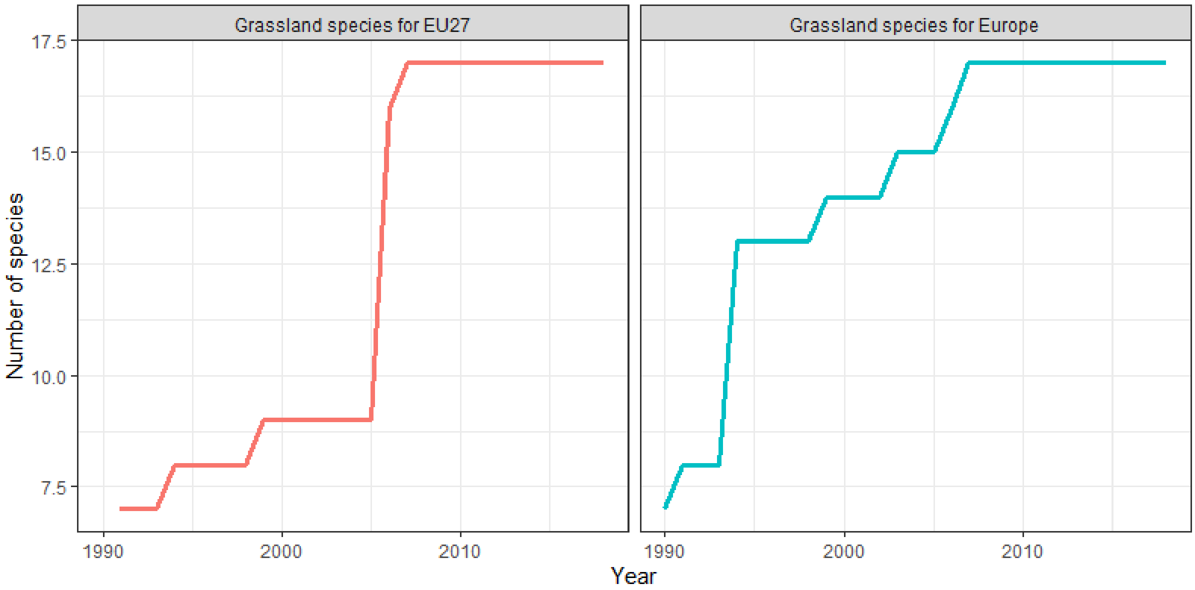


Figure 214: Number of species contributing per year to the grassland butterfly indicators for EU27 and Europe.

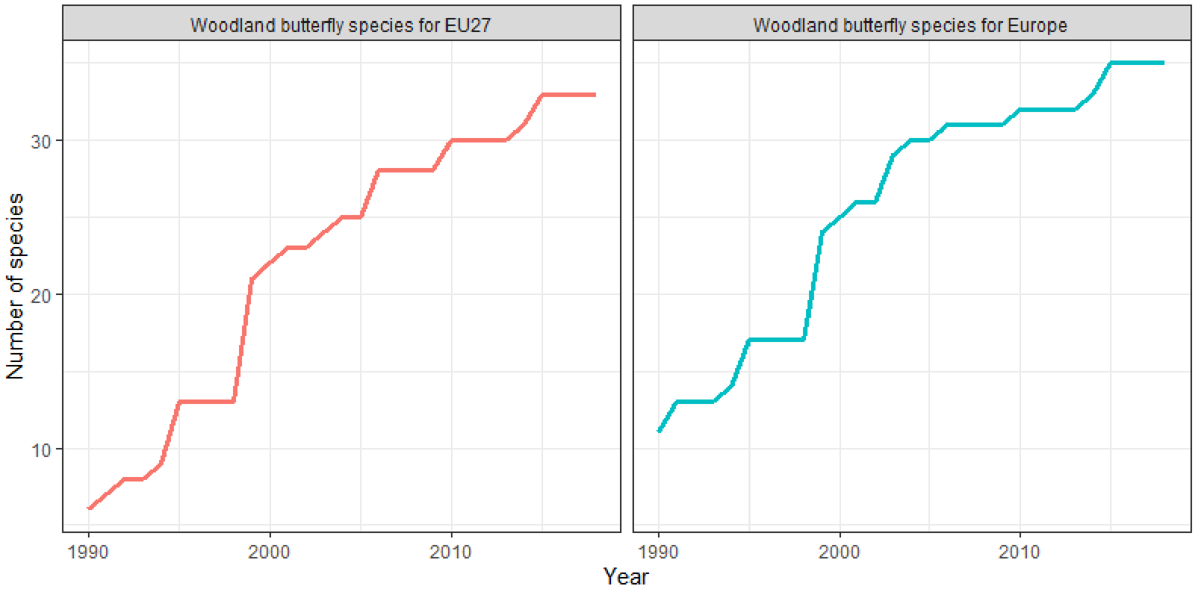


Figure 225: Number of species contributing per year to the woodland butterfly indicators for EU27 and Europe.

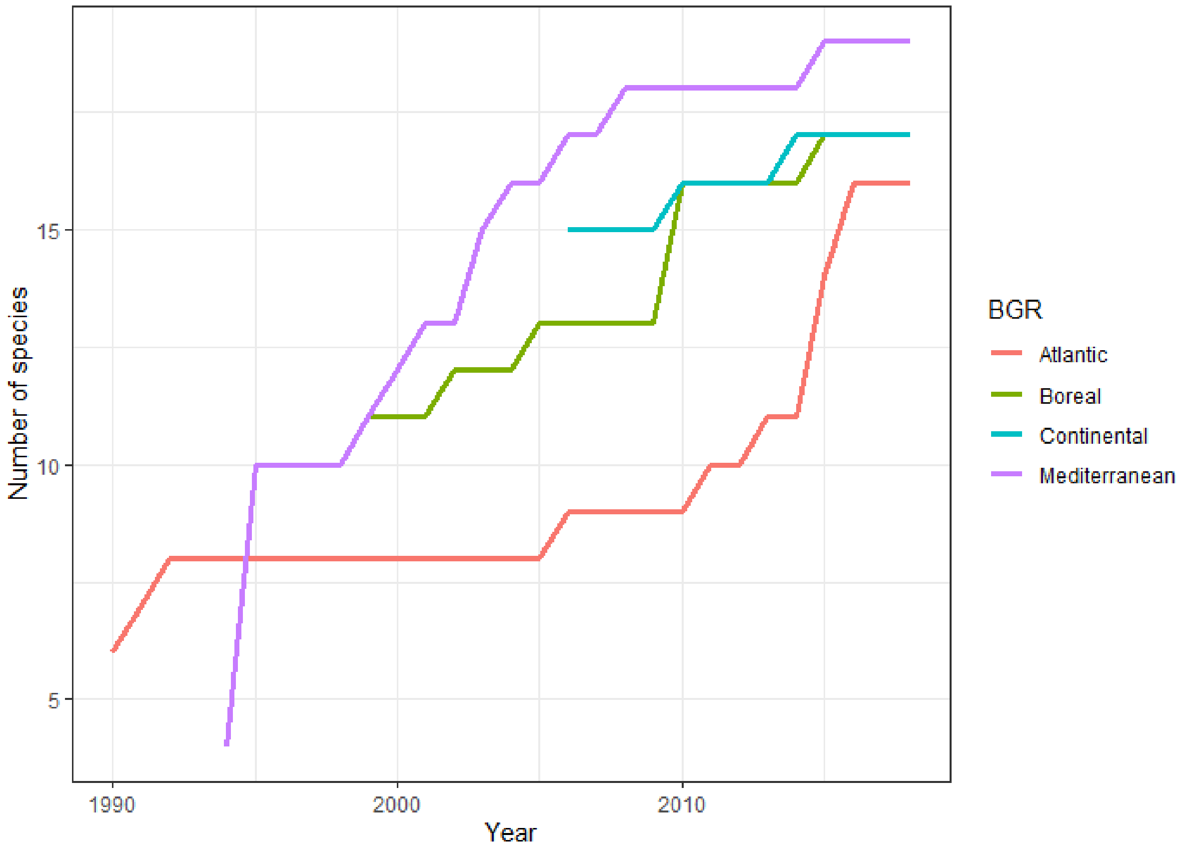


Figure 236: Number of species contributing per year to the woodland butterfly indicators per biogeographical region (BGR) for EU27.

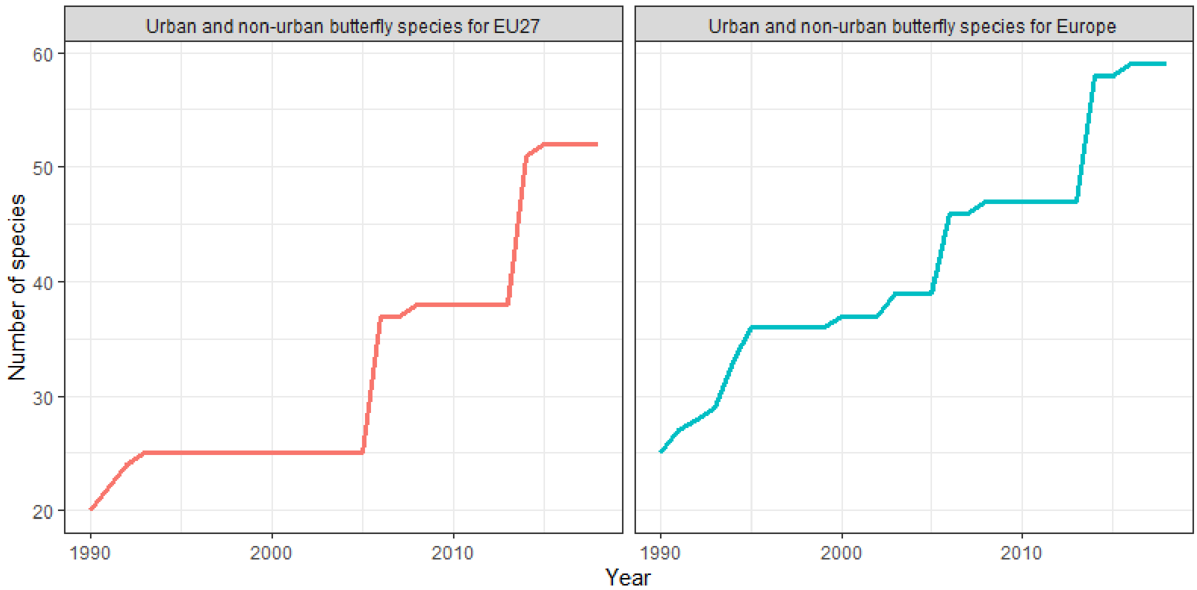


Figure 24: Number of species contributing per year to the urban and non-urban butterfly indicators for EU27 and Europe. The number of species was fixed to be the same for urban and non-urban for direct comparison.

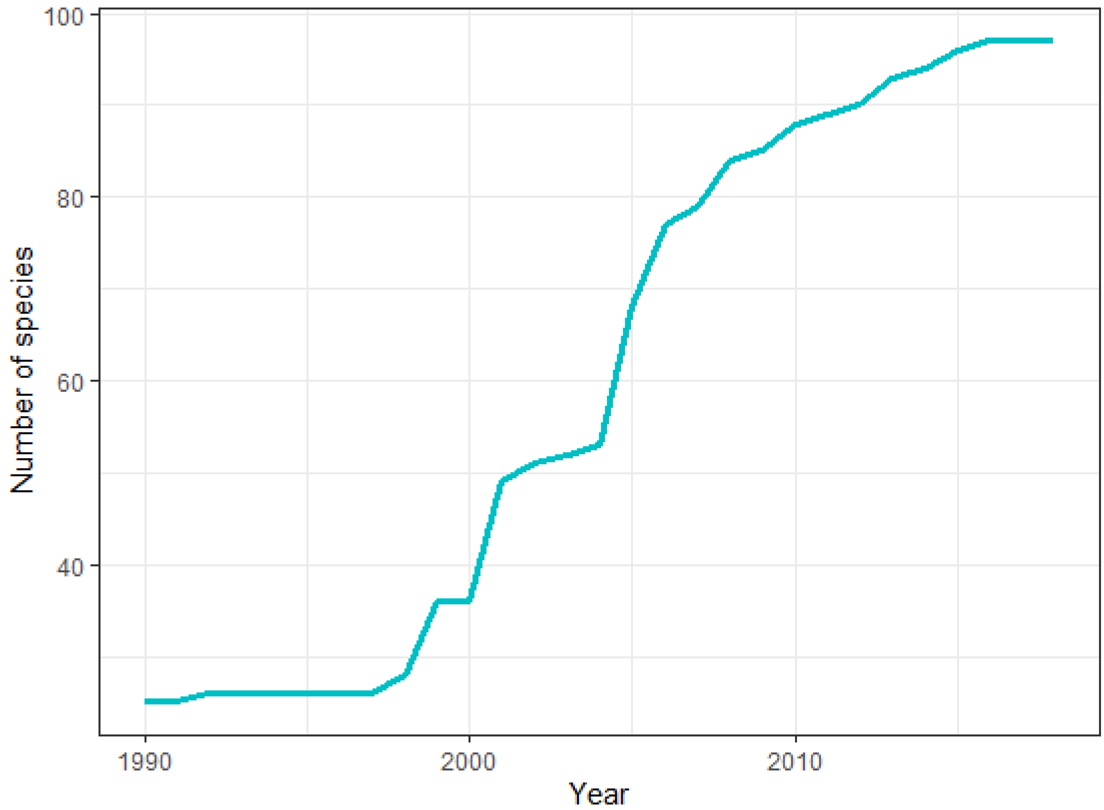


Figure 25: Number of species contributing per year to the Natura 2000 and Outside Natura 2000 butterfly indicators for EU27. The number of species was fixed to be the same for Natura 2000 and Outside Natura 2000 for direct comparison.

Annexe V / Glossary

- ABLE: Assessing ButterfLies in Europe: an EU project aiming at capacity building for butterfly monitoring, collecting butterfly monitoring data into the eBMS, producing tools for analysis of the data and produce trends and indicators.
- BGR: Biogeographical Region
- BMS: Butterfly Monitoring Scheme
- CBD: Convention on Biological Diversity
- eBMS: European Butterfly Monitoring Scheme, the database that holds all butterfly monitoring data.