The EU Butterfly Indicator for Grassland species: 1990-2017

Technical report

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Indicator source

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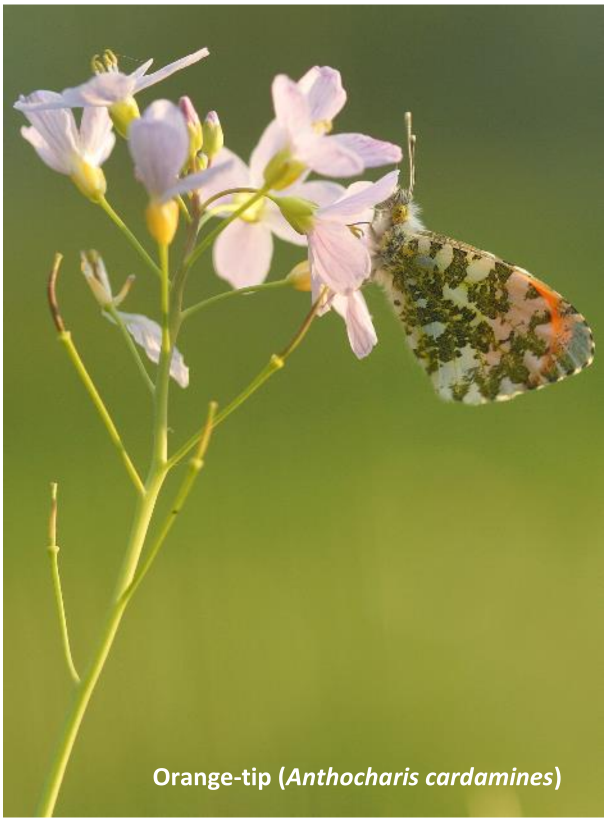
Content

Flower-rich grasslands have a high biodiversity and are important for many butterflies for reproduction and as nectar source.

Chapter 1 / Introduction

The EU Grassland Butterfly Indicator is one of the indicators of the status of biodiversity in the European Union. It is an abundance indicator based on data recording the population trends of seventeen butterfly species in 16 (see below) EU countries. This report presents the seventh version of this indicator now covering 28 years.


Orange-tip (*Anthocharis cardamines*)

At the Convention on Biological Diversity 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 provided a framework for the EU to meet its own biodiversity objectives and its global commitments as a party to the CBD. The Headline Target 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 increase the contribution of agriculture to biodiversity recovery. Europe now has one year left to intensify action to achieve this.

The EU biodiversity strategy 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 established specifically to assess biodiversity. The status indicators on species only cover birds, bats and butterflies, since these are the only taxa/species groups for which harmonized European monitoring data are available (EEA, 2012).

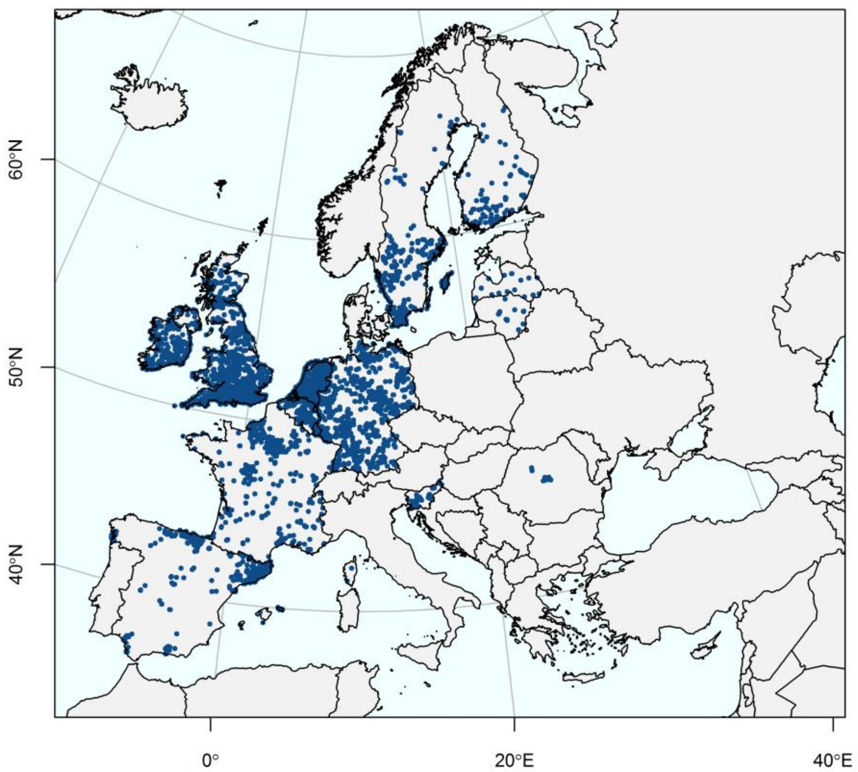
For the EU Grassland Butterfly Indicator the trends of seventeen widespread and characteristic grassland butterflies were assessed in 16 countries in the European Union. This technical report gives an overview of the method and results, and presents the indicator.

Chapter 2 / Building the EU Grassland Butterfly Indicator

The EU Grassland Butterfly Indicator shows the population trend for seventeen typical grassland butterflies. This chapter gives a brief overview of the methods.

Countries

Butterfly monitoring enjoys a growing popularity in Europe. Map 1 shows the Butterfly Monitoring Schemes (BMS) contributing data to this indicator. Butterfly Monitoring Schemes are present in a growing number of countries and new ones are being initiated in many places, particularly facilitated by the partners of Butterfly Conservation Europe, through the **A**ssessing **B**utterf**L**ies in **E**urope (ABLE; https://butterfly-monitoring.net/able) project. However, long time-series are only currently available for a limited number of countries. For this updated indicator, data were used from 16 countries: Andorra, Belgium, Estonia, Finland, France, Germany, Ireland, Latvia, Lithuania, Luxembourg, Romania, Slovenia, Spain, Sweden, The Netherlands and the United Kingdom. The indicator included data from 19 Butterfly Monitoring Schemes in total; Spain has three schemes – Catalonia, Basque Country and other parts of Spain, Belgium has two (Flanders and Wallonia). Although there is a dataset available from Madeira, none of the grassland butterfly indicator species occur on this island. Other Butterfly Monitoring Schemes in Europe that are not within EU Member States were not included, e.g. Switzerland, Jersey and Norway.



Map 1: Locations of transects which have been used for the Grassland Butterfly Indicator. Locations for transects in Estonia were not available yet.

In this report, we update the EU Grassland Butterfly Indicator, first published by Van Swaay & Van Strien in 2005. The updated indicator not only has a longer time-series, with the 2017 field seasons now included, but also the method of calculating the indicator has been improved and enhanced. More transects now contribute to the indicator. For 2017 more than 3400 transects were used (Figure 1). 6200 different transects have been walked over this period across the EU; most of them repeatedly.

The method closely follows the one for the bird indicators (Gregory et al., 2005) and bat indicators (Van der Meij et al., 2014).

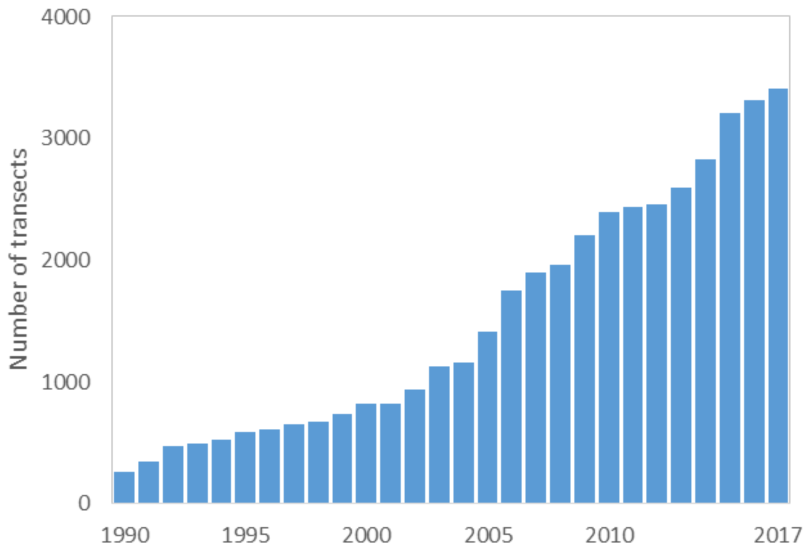


Figure 1: Number of transects each year used in the European Grassland Butterfly Indicator.

Fieldwork

The Butterfly Indicator is based on the fieldwork of thousands of trained professional and volunteer recorders, counting butterflies on more than 6200 transects scattered widely across the European Union (see map 1). These counts are made under standardised conditions. National coordinators collect the data and perform the first quality control. More details can be found in annex I.

In 2017 more than 55,880 km of transect walks were made (more than 1.4 times around the Earth), more than 90% of them by volunteers, monitoring each transect an average of 15 times per year This is a considerable contribution by individual citizens to EU policy evaluation and development.

Grassland butterflies

The same selection of grassland butterflies has been used for this updated indicator as in the previous versions. European butterfly experts selected species they considered to be characteristic of European grassland and which occurred in a large part of Europe, covered by the majority of the Butterfly Monitoring Schemes and having grasslands as their main habitat (Van Swaay et al., 2006). The species are listed in figure 2.

Figure 2: Seventeen butterflies were used to build the EU Grassland Butterfly Indicator, comprising seven widespread and ten specialist species.

Population trend

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' collated indices were produced for each monitoring scheme using a Poisson General Linear Model (GLM) with site and year effects, as well as the proportion of the flight period surveyed as a weighting. A collated index for the EU was produced for each species by fitting a Poisson GLM to the scheme-level collated indices with scheme and year effects as well as a weighting.

The EU indices for the 17 species were combined by taking the geometric mean of the indices using the BRCindicators R package (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 indices of species rather than abundances 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 method can be found in annex II. Although the Butterfly Monitoring Schemes are very similar, there are differences among countries in choice of location, number of counts, etc. These are summarised in annex I.

Marsh Fritillary (*Euphydryas aurinia*), a species of the Habitats Directive (Annex II).

Chapter 3 / Species trends

The EU Grassland Butterfly Indicator is built from EU species trends described in chapter 2. In this chapter, we give an overview of the trends of grassland butterflies in the European Union.

In the EU six species show a decline and seven are stable. Four species show an increase (table 1). This means that overall grassland species are still declining.

Table 1: EU trends of the 17 butterfly species of the European Grassland Butterfly Indicator. For the trend classification see annex II.

Trend	Species	Trend classification
Decline: 6 species	*Lasiommata megera*	strong decline
	Coenonympha pamphilus	moderate decline
	Lycaena phlaeas	moderate decline
	Ochlodes sylvanus	moderate decline
	Polyommatus icarus	moderate decline
	Thymelicus acteon	moderate decline
Stable: 7 species	*Anthocharis cardamines*	stable
	Cupido minimus	stable
	Cyaniris semiargus	stable
	Erynnis tages	stable
	Lysandra bellargus	stable
	Lysandra coridon	stable
	Maniola jurtina	stable
Uncertain: 4 species	*Euphydryas aurinia*	uncertain
	Phengaris arion	uncertain
	Phengaris nausithous	uncertain
	Spialia sertorius	uncertain

When interpreting the species trends it is important to note that:

- 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 each year.
- Large year-to-year fluctuations or a low number of transects, can cause large standard errors, leading to uncertain trends.

A large number of male Adonis Blues (*Lysandra bellargus*) can color a grassland.

- In almost half of the EU countries, Butterfly Monitoring Scheme data was available. The ABLE project has been set up to increase the coverage, especially in Eastern and Southern Europe. This indicator is built with data which has been collected before the start of the ABLE project in December 2018. The trends shown only represent the countries in map 1, which means they are based on a wide range of countries, including larger ones such as France, Germany and the United Kingdom. Extra data that will be gathered from other countries in the EU will make the results more representative in the future.
- New countries have joined in, new data have become available in existing schemes, the method for trend calculation has been improved, and two years extra data have been added. These developments can lead to changes in trends as compared to previous versions of the indicator. In some cases this even can lead to a change in the direction of the trend.

Meadow Brown (*Maniola jurtina*), probably one of the most common butterflies on grasslands.

Chapter 4 / The indicator

The European Grassland Butterfly Indicator has been updated using data available from contributing Butterfly Monitoring Schemes.

Figure 3 shows the European Grassland Butterfly Indicator for these EU-countries. The indicator is based on the geometric mean of the supra-national species trends (as in the bird indicators, Gregory et al., 2005) as detailed in chapter 3. As well as the yearly index-values of the indicator, a flexible trend with confidence intervals is presented (see annex II). The confidence limits of the indicator incorporate the uncertainty from the underlying species indices.

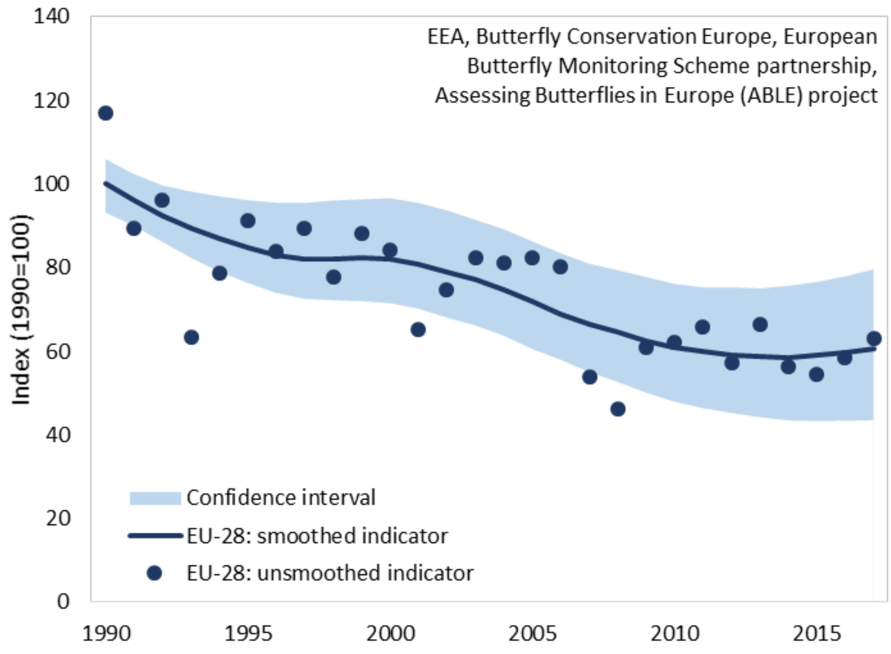


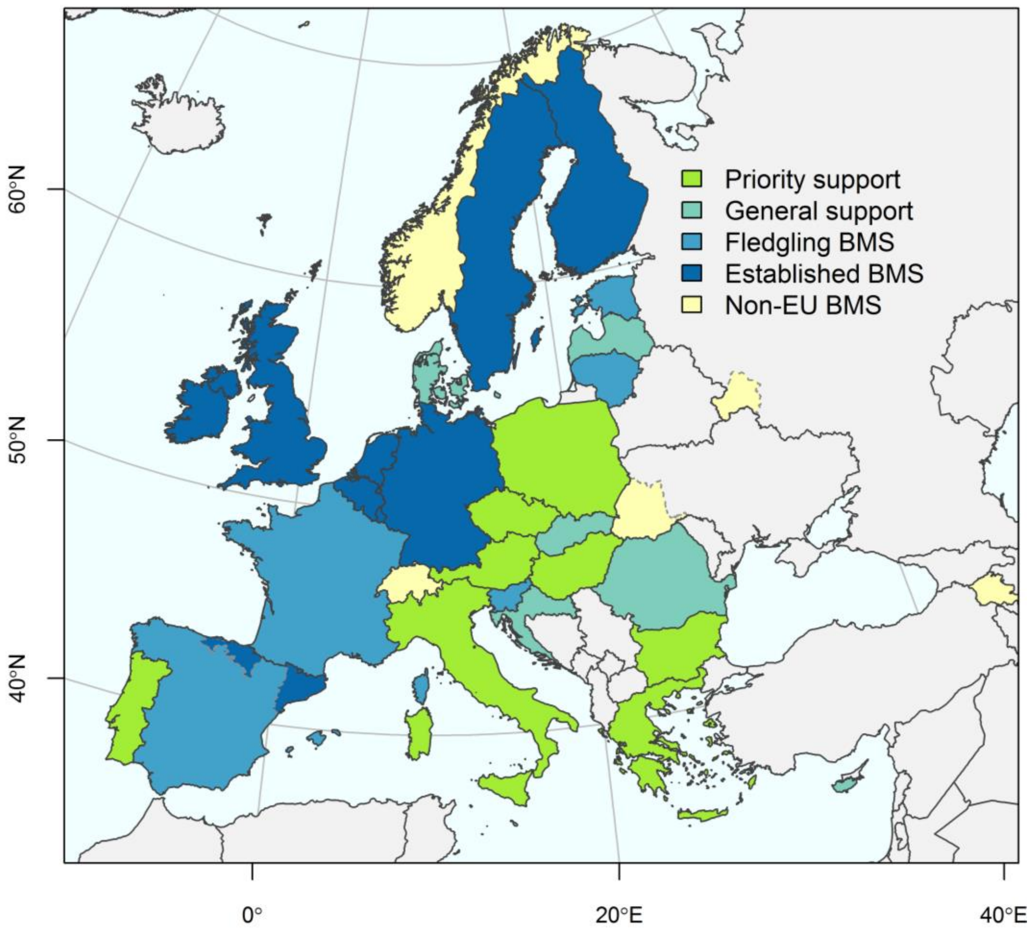
Figure 3: The Grassland Butterfly Indicator for the EU. The indicators are based on the countries in map 1 in the EU and characteristic grassland butterfly species in figure 2. The shaded areas represent the 95% confidence limits surrounding the smoothed trend.

The indicator shows a significant decline of 39%, most of which occurred in the periods 1990-1998 and 2002-2012. The rate of decline seems to have slowed in the last five years compared with the previous period. So far, 1990-1992 represent the best years for butterflies in the smoothed indicator, with 2007 and 2008 as the years with the lowest population-indices on average, based on the unsmoothed indicator. Interpretation of the trend and driving factors has been included in previous reports (e.g. Van Swaay et al, 2016)

Chapter 5 / Developing butterfly monitoring and improving indicator production across Europe

Butterflies are among the few species groups where large-scale, continent-wide monitoring is feasible. The **A**ssessing **B**utterf**L**ies in **E**urope (ABLE) project was initiated in December 2018, with the aim to create a representative butterfly monitoring network across as many EU countries as possible in order to improve the targeting and efficiency of conservation measures within the European Union. To do this, the ABLE project will develop a suite of indicators that can inform EU biodiversity and land use policies, including the Common Agricultural Policy. The data will also be used to help assess the health of Europe's pollinators as part of the implementation of the EU Pollinator Initiative.

The project will involve thousands of volunteers across Europe who will contribute data in a standardised way into a central database (the European Butterfly Monitoring Scheme - eBMS). It builds on existing Butterfly Monitoring Schemes that are running in twenty countries, but will extend these to other countries that currently do not have schemes (map 2). Target countries include Austria, Bulgaria, Croatia, Cyprus, Denmark, Greece, Hungary, Italy, Latvia, Malta, Poland, Portugal, Slovakia.



Map 2: Status of Butterfly Monitoring Schemes (BMS) in Europe.

The ABLE project is a partnership between Butterfly Conservation Europe, the Centre for Ecology and Hydrology (UK), the Helmholtz Centre for Environmental Research (UFZ, Germany), Dutch Butterfly Conservation and Butterfly Conservation (UK). It is funded by a service contract from the European Union Directorate for the Environment, for an initial period of two years from 2019-20.

The progress of the ABLE project can be followed at https://www.butterfly-monitoring.net/able

With increased coverage, the geographical scope of the butterfly indicator is improving rapidly. This makes butterflies, after birds, the next group for which European trends can be established and used for the evaluation of changes in biodiversity. The farmland bird and grassland butterfly indicators are now used in the indicator 'abundance and diversity of groups of species' (European Environment Agency, 2012). This is one of the few 'direct' core biodiversity indicators, as most of the others represent pressures on biodiversity or social responses to biodiversity loss (Levrel et al., 2010).

The Common Blue (*Polyommatus icarus*) can still be found on many grasslands.

Chapter 6 / Conclusions

- This report gives an update of an indicator for Grassland Butterflies in the European Union, which gives the trend of a selection of butterflies characteristic of European grasslands.
- The indicator is based on regional and national Butterfly Monitoring Schemes from across the European Union (see map 1).
- The results show that the index of grassland butterfly abundance has declined by 39% since 1990, indicating a dramatic loss of grassland biodiversity.
- In North-western Europe, intensification of farming has been identified as the most important threat to grassland butterflies, while abandonment of grasslands is more important in other parts of Europe (Van Swaay et al., 2016). Protecting remaining semi natural-grasslands in these areas and reversing fragmentation is essential to halt further losses.
- The challenge now is to halt the losses and start the recovery. An urgent programme to halt abandonment of semi natural grassland and restore it to good ecological condition is required both inside and outside Natura 2000 sites. Action is also needed to halt losses of semi natural grassland extent and quality which are still occurring through agricultural intensification and eutrophication. The adverse effects of pesticides on butterflies also need to be reduced.
- The ABLE project aims to extend the network of Butterfly Monitoring Schemes over new countries in the EU, to make future Butterfly Indicators even more representative.
- In the next year the ABLE project will develop new indicators, including one for woodland, wetland and climate change, and improve on existing methods.

Wet flower-rich haymeadow, full of orchids and butterflies.

References

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

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.

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

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.

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

Kühn, E., Feldmann, R., Harpke, A., Hirneisen, N., Musche, M., Leopold, P. and 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), pp.89-103.

Levrel, H., Fontaine, B., Henry, P.Y., Jiguet, F., Julliard, R., Kerbiriou, C. and Couvet, D., 2010. Balancing state and volunteer investment in biodiversity monitoring for the implementation of CBD indicators: A French example. *Ecological economics*, *69*(7), pp.1580-1586.

Metzger, M.J., Bunce, R.G., Jongman, R.H., Sayre, R., Trabucco, A. and 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.

Pollard, E. and Yates, T.J., 1993. *Monitoring butterflies for ecology and conservationthe british butterfly monitoring scheme* (No. 333.955 P6).

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, and R. Julliard., 2016. A regionally informed abundance index for supporting integrative analyses across butterfly monitoring schemes. *Journal of Applied Ecology*, *53*(2), pp.501-510.

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

Sutherland, W.J. ed., 2006. *Ecological census techniques: a handbook*. Cambridge university press.

Van der Meij, T., Van Strien, A.J., Haysom, K.A., Dekker, J., Russ, J., Biala, K., Bihari, Z., Jansen, E., Langton, S., Kurali, A. and Limpens, H., 2015. Return of the bats? A prototype indicator of trends in European bat populations in underground hibernacula. *Mammalian biology*, *80*(3), pp.170-177.

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

Van Swaay, C.A.M., Plate, C.L. and Van Strien, A.J., 2002. Monitoring butterflies in the Netherlands: how to get unbiased indices. In *Proc Exp Appl Entomol* (Vol. 13, pp. 21-27).

Van Swaay, C.A.M., van Strien, A.J., Aghababyan, K., Åström, S., Botham, M., Brereton, T. Carlisle, B., Chambers, P., Collins, S., Dopagne, C., Escobés, R., Feldmann, R., Fernández-García, J.M., Fontaine, B., Goloshchapova, S., Gracianteparaluceta, A., Harpke, A., Heliölä, J., Khanamirian, G., Komac, B., Kühn, E., Lang, A., Leopold, P., Maes, D., Mestdagh, X., Monasterio, Y., Munguira, M.L., Murray, T., Musche, M., Õunap, E., Pettersson, L.B., Piqueray, J., Popoff, S., Prokofev, I., Roth, T., Roy, D.B., Schmucki, R., Settele, J., Stefanescu, C., Švitra, G., Teixeira, S.M., Tiitsaar, A., Verovnik, R., Warren, M.S. (2016). *The European Butterfly Indicator for Grassland species 1990-2015*. Report VS2016.019, De Vlinderstichting, Wageningen

Van Swaay, C.A.M. and 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.

Annex I / Butterfly Monitoring Schemes in the indicator

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

Field methods

All schemes apply the method developed for the UK Butterfly Monitoring Scheme (Pollard & Yates, 1993). The counts are conducted along fixed transects of 0.5 to 3 kilometres consisting of component sections, but the exact transect length varies among countries. The fieldworkers record all butterflies 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. Visits are only conducted when weather conditions meet specified criteria. The recommended number of visits varies from every week in e.g. the UK, Catalonia and the Netherlands to 3-5 visits annually in France (table 2).

Transect selection

To be able to draw proper inferences on the temporal population trends at national or regional level, transects should best be selected in a grid, random or stratified random manner (Sutherland, 2006). Several recent schemes, e.g. in Switzerland and France, have been designed in this manner (Henry et al., 2008). If a scheme aims to monitor rare species, scheme coordinators preferably to locate transects in areas where rare species occur, leading to an overrepresentation of special protected areas. In the older schemes, such as in the UK and the Netherlands, but also in the recently established scheme in Germany, 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 undersampling of the wider countryside and urban areas (Pollard & Yates, 1993), though this is not the case in all countries (e.g. Germany, Kühn et al., 2008). Obviously, in such a case the trends detected may be only representative for the areas sampled, while their extrapolation to national trends may produce biased results. Such bias can however be minimized by post-stratification of transects. This implies a posteriori division of transects by e.g. habitat type, protection status and region, where counts per transect are weighted according to their stratum (Van Swaay et al., 2002).

Species set

The grassland indicator is based on seven widespread grassland species (*Ochlodes sylvanus, Anthocharis cardamines, Lycaena phlaeas, Polyommatus icarus, Lasiommata megera, Coenonympha pamphilus* and *Maniola jurtina*) and ten grassland-specialists *(Erynnis tages, Thymelicus acteon, Spialia sertorius, Cupido minimus, Phengaris arion, Phengaris nausithous, Lysandra coridon, Lysandra bellargus, Cyaniris semiargus* and *Euphydryas aurinia*). See also figure 2.

Table 2: Characteristics of the Butterfly Monitoring Schemes used for the EU Grassland Butterfly Indicator.

Country	Starting year	Area represented (w=whole country, r=region)	Average transect length (km)	Mean number of transects which have contributed 2015-2017	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)	representative for agricultural grassland*	Nature reserves overrepresented*
Belgium – Wallonie	2006	r	0.6	54	3	p	c	yes	no
Belgium – Flanders	1991	r	0.8	10	15	v	f	no	no
Germany	2005	w	0.5	437	14	v	f	yes	no
Spain (Basque Country)	2010	r	1.8	54	8	v~70%. p~30%	f	yes	yes
Spain – Catalonia	1994	r	1.6	88	24	v	f	yes	no
Spain (excl. Catalonia and Basque Country)	2015	r	1.5	60	12	v~50%. p~50%	f	yes	yes
Finland	1999	w	3	46	14	v~80%. p~20%	f for v	yes	no
France	2005	w	2.6	110	4	v	f ~50% c~50%	yes	no
Ireland	1992	w	3	116	13	v	f	yes	no
Lithuania	2009	w	1.1	7	9	v	f	no	no
Luxembourg	2010	w	0.8	55	4	v~10%. p~90%	r	yes	no
Latvia	2015	w	1.4	18	3	p	c	yes	no
Netherlands	1990	w	0.6	574	14	v	f	yes	no
Romania (Amiga)	2013	r	1	4	4	p	c	yes	no
Romania (Adept)	2014	r	0.7	8	5	v~60%. p~40%	c	yes	no
Sweden	2010	w	1.6	190	4	v~90%. p~10%	f	yes	no
Slovenia	2007	w	1.4	8	8	v	c	yes	no
United Kingdom	1990	w	2.1	1483	19	v	f	yes	yes

Annex II / Statistical method

We used the following procedure to compute the grassland indicator.

Data collection
All data was first collected at a regional or national level (see table 2), 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

National indices
We used this database to calculate national indices for each species for which monitoring data were available:

- **Stage 1 – estimating phenology**
  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.
- **Stage 2 – producing species scheme/country level collated indices**
  Site-level indices were produced by estimating the missing counts using the flight phenology computed from the GAI above, and 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), applied to the site indices scaled to densities per 0.5 ha (based on 5m wide sampling and transect lengths standardized to 1km). Site indices were then randomly resampled 1000 times, while keeping the number of transect sampled per year equal to the original data, to produce 1000 collated indices per species and monitoring scheme.

  The national indices were checked for reliability and magnitude of confidence intervals. Indices were not used if the time series were very short or based on a few sites or observations only.

Supra-national indices
In the next step we combined national indices to produce EU collated indices.

- **Stage 3 – producing species EU collated indices**
  Collated indices with negative estimates were filtered out. A collated index for the EU was produced for each species by fitting a Poisson GLM to the scheme-level collated indices with scheme and year effects as well as a weighting. Prior to fitting, any index values (on the log10 scale with a mean of 2) less than zero or greater than 4 were omitted.

  The weightings were 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. Population density was taken as the mean population density per $1km^2$ across years for a given species and monitoring scheme. The weightings were rescaled to sum to 1 for a given species, across the relevant monitoring schemes. The same approach was taken for each of 1000 bootstraps to produce 1000 EU collated indices for each species.

EU indicator

- **Stage 4 – generating the EU indicators**
  The EU indices for the 17 species 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% CI around the indicators. All values were rescaled such that the smoothed indicator started at 100.

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 choice of location, number of counts, corrections for unstratified sampling, etc. These are summarised in annex 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 (table 2), 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 a 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 actually more severe than the indicator shows. We hope to be able to test this in future.