

# Developing and launching a wider countryside butterfly survey across the United Kingdom

T. M. Brereton · K. L. Cruickshanks ·  
K. Risely · D. G. Noble · D. B. Roy

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**Abstract** Many butterfly species that were historically common throughout the UK are thought to have declined due to land use intensification, whilst others have increased regionally due to climate change. Population trends in these species are inadequately assessed by current monitoring programmes: the UK Butterfly Monitoring Scheme (UKBMS) mainly samples semi-natural habitats; coarse-scale distribution recording under-estimates declines in population abundance. We designed a scheme (the wider countryside butterfly survey—WCBS) to provide unbiased abundance trends for widespread butterfly species across the whole countryside. The WCBS has been developed over a 3 year pilot study, culminating in a UK-wide roll out in 2009. After testing a range of survey methods, the scheme involves visiting randomly selected 1-km squares at least twice during July–August and walking a linear transect route, counting the number of individual butterflies seen within 5 m. A method for volunteer recorders to collect abundance data on non-lepidopteran insects was also tested. The results of the first year of the WCBS and future plans for the scheme will be described.

**Keywords** Biodiversity · Generalist species · Volunteer monitoring schemes · Occupancy · Survey design · Invertebrate monitoring methods

## Introduction

Due to the efforts of thousands of amateur and professional recorders, more is probably known of the butterfly fauna of the UK than any country on the planet (Fox et al. 2006). Data come from two main sources. The Butterflies for the New Millennium (BNM) project collects data from ‘casual’ sightings to document changes in butterfly distribution; the dataset currently comprises more than 6.25 million records (Butterfly Conservation unpublished data). The UK Butterfly Monitoring scheme (UKBMS) collects data on butterfly abundance recorded at a network of sites monitored each year using a peer-reviewed methodology (Pollard 1977; Pollard and Yates 1993); the dataset currently comprises 3.85 million counts from 1,726 sites recorded since 1973 (Brereton et al. this volume).

In spite of this wealth of data, we still lack an unbiased assessment of abundance trends for many wider countryside butterflies, defined as species with relatively high mobility that occur in a range of habitat types across the landscape including those heavily modified by human activity (Asher et al. 2001). Wider countryside species comprise half of the UK’s butterfly species and have their main breeding populations in the general countryside, where relatively few UKBMS sample sites are located (Pollard et al. 1995; Greatorex-Davies and Roy 2001; Pywell et al. 2004; Brereton et al. this volume). These data deficiencies are of potential concern because recent research indicates that many of these species underwent substantial declines in local and regional abundance during

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T. M. Brereton (✉) · K. L. Cruickshanks  
Butterfly Conservation, Manor Yard, East Lulworth,  
Wareham, Dorset BH20 5QP, UK  
e-mail: tbrereton@butterfly-conservation.org

K. Risely · D. G. Noble  
British Trust for Ornithology, The Nunnery,  
Thetford, Norfolk IP24 2PU, UK

D. B. Roy  
NERC Centre for Ecology and Hydrology, Maclean Building,  
Benson Lane, Crowmarsh Gifford, Wallingford,  
Oxfordshire OX10 8BB, UK

the 20th century, that were largely undetected by monitoring and mapping schemes (Cowley et al. 1999; Leon-Cortes et al. 1999; León-Cortés et al. 2000). Agricultural intensification has been highlighted as a major cause of generalist and specialist species declines across the whole of Europe (van Swaay 1990) and continues to be a factor in the decline of widespread species of other well monitored taxa, including birds (Donald et al. 2001). The decline of once common taxa associated with lowland farmland is one of the most pressing issues in UK biodiversity conservation (Krebs et al. 1999; Aebischer et al. 2000; Vickery et al. 2004; Firbank et al. 2008). Habitat loss, including through urban development and afforestation has also been an important major factor in the decline of common butterflies (Asher et al. 2001). In the latest review of priority species (UKBAP 2007), two wider countryside butterfly species Small Heath (*Coenonympha pamphilus*) and Wall Brown (*Lasiomata megera*) were added to the list for the first time, owing to recent rapid declines in both range and abundance (Fox et al. 2006, Fox et al. 2010).

Currently, abundance trends in wider countryside butterflies are derived from the UKBMS and largely inferred from data derived from sampling higher quality semi-natural habitat and protected areas in the lowland areas of central and southern UK. Sites are selected by recorders rather than through a random sampling framework. Provisional analysis suggests that abundance trends in wider countryside species from UKBMS sample sites may be representative of the wider population (Brereton et al. this volume). However, it can be argued that species trends are being assessed from too small a proportion of the population and from a fundamentally inappropriate survey design (Buckland et al. 2005). For example, the Meadow Brown *Maniola jurtina* is widespread on intensively managed farmland (Asher et al. 2001) which extends over nearly half of the UK landscape (Carey et al. 2008) but these habitats account for less than 6% of UKBMS monitoring sites (UKBMS unpublished data). A bigger concern is that ongoing species declines may currently be under-estimated, and that wider countryside butterflies may have undergone more extreme declines as has been seen in other north European countries (e.g. the Netherlands, van Swaay et al. 2006; van Dyck et al. 2009) and has been demonstrated for common moths in the UK (Conrad et al. 2006). Due to deficiencies in sample coverage of intensively managed/modified habitats, stable or positive trends and northward range expansions shown in some wider countryside species attributable to climate warming (Roy et al. 2001; Fox et al. 2006) may possibly be masking regional declines due to land management change.

A previous obstacle to improved monitoring coverage of wider countryside habitats in the UK (Pollard and Greatorex-Davies 1997) has been the likely low diversity of butterflies encountered for the a high level of recording

effort. Up to 26 surveys per annum are required for Pollard Walk methods used in the UKBMS (Pollard 1977; Pollard and Yates 1993). A consensus has developed amongst the recording and scientific community which started in the mid-1990s (Pollard and Greatorex-Davies, 1997), that a more efficient scheme based on random sampling is required to generate more accurate abundance trends for widespread butterfly species. Given that butterfly population trends are regarded as a good indicator of the state of the environment by the UK Government (Defra 2006), data from such a scheme have a number of potential policy applications related to priority issues in the wider countryside, including assessment of climate change impacts and mitigation measures, impacts of new urban development and the potential benefits of agri-environment schemes on biodiversity (UK Biodiversity Partnership 2007).

In 2004, Butterfly Conservation (BC) and the Centre for Ecology & Hydrology (CEH) secured resources from a consortium of government agencies led by the Department of the Environment food and Rural Affairs (Defra) to develop a wider countryside butterfly monitoring method. The development of a new method requires consideration of a number of fundamental design and practical issues including (1) which sampling framework to adopt, (2) what field methods to employ, (3) when and how often to sample, (4) assessment of scheme power (5) identifying who will do the sampling, (6) how will data and recorders be co-ordinated and (7) data analysis and reporting methods. In this paper we will describe how these issues were considered in relation to a new component of the UKBMS—the wider countryside butterfly survey (WCBS). We will describe the design issues investigated, field testing and other method and scheme validation work carried out over 4 years, approaches to co-ordination and partnerships and preliminary results from the launch of the WCBS in 2009. We conclude by outlining the future plans for the scheme.

### Designing the scheme

Methodological issues were investigated through consultation with a number of experts, field testing by volunteers and research projects targeted at specific design issues.

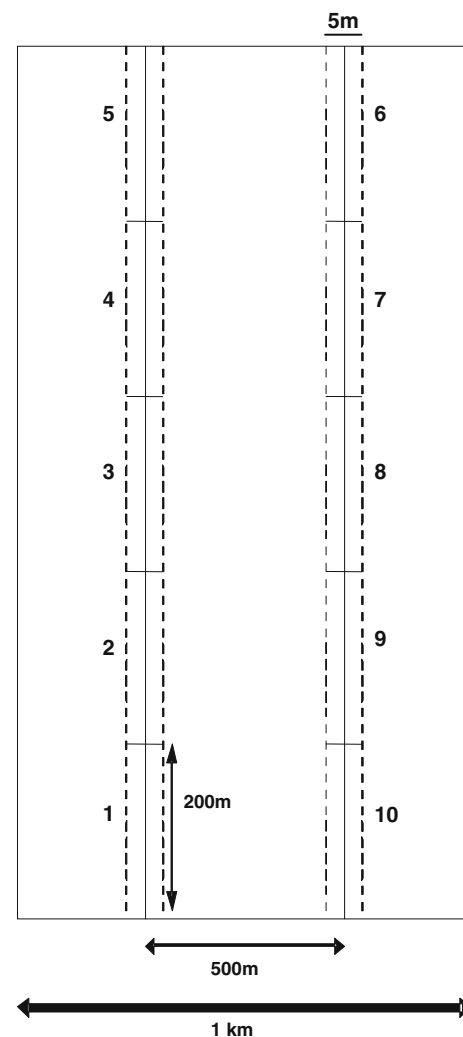
### Sampling framework

The remit of the WCBS was to produce unbiased abundance indices and trends for wider countryside species that were representative of the whole of the countryside. Primary design considerations were the need for a random sampling framework and practical consideration of the suitability of field methods for the volunteer recorders who would complete the surveys. For a combination of

scientific and practical reasons, it was decided to adopt the broad sampling framework used for the Breeding Bird Survey (BBS) co-ordinated by the British Trust for Ornithology (BTO). The BBS uses 1-km grid squares of the Ordnance Survey national grid system as the unit of sampling. This was assessed as a convenient sampling unit for volunteer recorders, is readily identifiable in the field, is a scale at which climate and environmental data are readily available and is a unit that is commonly used by other national monitoring programmes in the UK in addition to the BBS (e.g. Countryside Survey, Common Plants Survey, National Bat Monitoring Programme). In the BBS, 1-km squares are selected by stratified random sampling. Regions receive a differing number of randomly selected squares, with the number of allocated squares being proportional to regional recorder density (a measure of likely participation levels). During the consultation process, no major scientific concerns were identified in using the BBS design to sample butterflies, but a number of practical advantages were identified, including the potential to involve BTO recorders in recording their squares and the potential to analyse changes in bird and butterfly abundance from the same sample areas. Note, however, that a decision was made that the WCBS would use a range of other randomly selected 1-km squares (again stratified by recorder density) in addition to BBS squares, to enable participation by butterfly recorders not involved in the BBS.

#### Field methods

A number of sampling methods within 1-km squares were considered, including point counts (transects; Buckland 2006), practical routes (e.g. following only footpaths) and different types of linear transects (e.g. zig zag walks versus evenly spaced parallel lines). For both scientific and practical reasons, it was decided to follow the approach used by bird recorders in the BBS by recording along two linear transects ('survey lines'), but making adaptations for butterflies using Pollard Walk recording criteria (Pollard 1977; Pollard and Yates 1993). The BBS method involves counting all animals detected along two evenly spaced (ideally 500 m apart) parallel 1-km long survey lines subdivided into sections (Fig. 1), with birds seen/heard assigned to one of three distance bands. Adaptation of the BBS method for butterflies included recording (1) in a more restricted area than for birds (within an imaginary 5 m box), (2) at different times of the day (between 10:45 and 15:45) (3) at different times of the year (predominantly summer rather than spring) and (4) under set weather conditions proven as suitable for butterfly activity. The similarity of the method to the BBS provided the added benefit that BTO recorders could potentially take part on their existing squares by making separate 'butterfly visits' in the summer months.



**Fig. 1** Sampling design within a 1-km square. *Parallel survey lines* can run north–south or east–west through the square. Deviations from this design following paths and linear features are accepted for ease of surveying

A number of more detailed refinements were considered and tested in an effort to make the scheme more attractive to potential recorders and thus increase participation levels. These included assessing (1) whether transect width could be widened to increase the number of butterflies counted (2) whether the time of day recording period could be extended to give greater flexibility in when recording could be carried out and (3) if other insect groups (e.g. syrphid flies, day-flying moths (lepidoptera), *Bombus* species, odonata, orthoptera) could be monitored as part of the survey, to increase returns from survey effort.

The application of distance sampling (Buckland et al. 2001) along survey lines was tested as an approach to widening the recording area. Distance sampling has further benefits in that it enables (1) detectability (which diminishes with distance) to be accounted for and (2) absolute density to be estimated as done for birds in the BBS

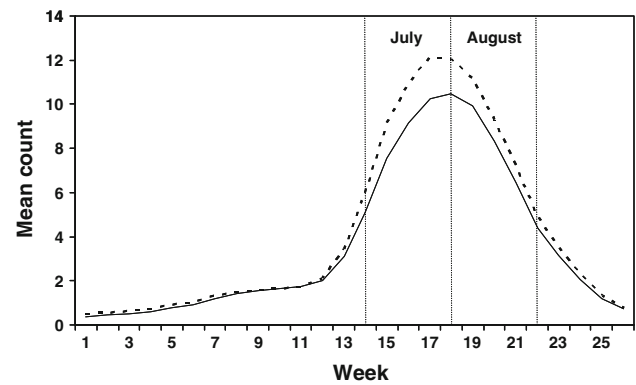
(Newson et al. 2008). Pilot studies in 2005 showed that increasing the transect width from 2.5 to 5 m, increased the number of butterflies seen by a third. However, distance sampling proved unworkable on practical grounds (1) because of the difficulties of having to maintain recording quality in a ‘worse cast scenario’ with potentially large numbers of fast flying individuals of different species over short distances and time spaces and (2) because butterflies have a biased distribution towards linear features—to effectively sample this through distance sampling would be impractical (i.e. would involve lots of survey lines running perpendicular to linear features i.e. into crops and closed canopy forest) (Isaac et al. in review).

For time of day criteria, field studies were carried out to determine if butterfly abundance across wider countryside butterfly species and groups varied over the day, including immediately before and after conventional BMS recording times (10:45–15:45). Log-linear modelling (Poisson regression) was used to test and estimate differences between time periods and interaction effects. The results showed that for sites largely unshaded during the morning or late afternoon periods and when weather conditions were within BMS criteria (Pollard 1977), the recording window could be extended by up to 2 h—with additional recording permissible from 09:30–10:45 and 15:45–16:30 (Cruickshanks et al. in prep).

During the design phase there was considerable interest amongst the recording community and policy makers in using the WCBS to generate abundance data on a broader range of insect groups. The pilot studies indicated that only day-flying moths and dragonflies could be recorded at the same time as butterflies, due to them having similar search images. In terms of other insect groups, it was considered best to have optional, supplementary recording following completion of butterfly recording, with the assumption that a sufficient number of recorders would take part to make the surveys scientifically worthwhile. These could take a number of forms, including repeat annual surveys for specific species/groups or periodic surveys for different species/groups on a rolling programme. For this, a range of survey methods were tested for individual species and groupings over the pilot studies, with an Insect Flower Search method tested widely during 2009 (see below).

Timing of visits and number of visits required within a season and across sites

Seasonal variation in butterfly abundance on UKBMS transect routes demonstrates that the optimal time to concentrate sampling for almost all wider countryside species is during July and August (70% of the flight period; Fig. 2). Only one wider countryside butterfly species, the Orange-



**Fig. 2** Seasonal pattern of mean abundance of butterflies recorded on UKBMS transects. Mean number of individuals per transect locations are given for all species (solid line) and 20 species classified as wider countryside species (dashed line). Week 1 = April 1st and week 26 = the end of September

tip *Anthocharis cardamines* has its main flight period outside of July and August.

A power analysis was used to determine the sample size that was likely to be required to detect moderate declines (25%) in 20 of the target wider countryside species (all except canopy-dwelling species) over a short time period (10 year) with reasonable precision. The power analysis used existing UKBMS transect data to test the efficiency of reduced sampling (e.g. only three to four visits) versus a more intensive, 26-week scheme for detecting trends. The power analysis is reported in detail elsewhere (Roy et al. 2007) and is only briefly summarised here. Overall, 80% power (5% significance level) for detecting a 25% decline in abundance over 10 years could be achieved with 430 sites visited three times in July–August and 630 sites with two visits in the same period. These figures highlight substantial efficiency savings, with only a doubling of the number of sites required in the full 26-week scheme (based on an analysis of 180 sites) to achieve the same power to detect trends.

For practical reasons a mandatory two visit scheme in July and August was proposed. Three visits was not considered to be practical, particularly for established BBS recorders, as it would require more effort by bird recorders than completing bird surveys on their squares. Furthermore, reducing the number of required visits to a minimum would again make the scheme more appealing to a wider range of potential recorders.

### Assessing potential sampling bias of the scheme

Bias through sampling along actual rather than ideal routes

Butterflies show a clumped distribution towards linear features in the wider countryside (Asher et al. 2001). This

was demonstrated in the pilot studies, where in samples squares ( $n = 10$ ) there were significantly fewer butterflies in open habitats compared with linear habitats ( $F_{(1,78)} = 41.24$ ,  $P < 0.001$ ). ‘Actual’ WCBS routes are more likely to oversample linear features such as footpaths along hedgerows, field margins and woodland edges compared with ‘ideal’ routes (randomly available habitat—see Fig. 1) due to ease of access. Again, this was supported by results from a sample ( $n = 10$  squares) in the pilot studies, where for example, open habitats comprised over 80% of available habitat, but accounted for only 9% of habitat along actual routes. To assess the potential impact of oversampling of linear features, research was carried out on arable farms in southern England in 2006 to investigate the extent to which butterfly diversity differed between actual and ideal survey routes. The study showed that, on average approximately, 40% fewer species (mean  $n = 7$  random route and  $n = 12$  survey lines;  $t = 3.176$ ,  $P = 0.011$ ) and less than half the number of butterflies were present on ‘actual’ compared to ‘ideal’ routes (mean  $n = 50$  individuals per square ideal route and  $n = 120$  actual route;  $t = 2.9$ ,  $P = 0.017$ ). Therefore actual transects may overestimate butterfly species diversity and abundance.

Do the survey lines effectively sample/represent what is in the square?

Birds are generally detectable at far greater distances than butterflies, consequently a much larger proportion of bird diversity present in the square is likely to be detected through the sampling effort. This is illustrated by the differences in strip widths and areas sampled. In the BBS, relative bird density is estimated over a minimum of 20% of the square, whilst for butterflies only 1% of the surface area of the square is sampled in the WCBS. Surveys were carried out to investigate what was seen along survey lines in relation to more extensive surveys of squares (up to 6% of the surface area of squares surveyed). Four to fivefold increases in coverage within individual squares yielded two to four times more species and two to six times more individuals. However, across squares, only four additional species (18% of species) were detected by the more extensive sampling, with butterfly abundance often extremely low or absent in intensively managed agricultural fields. Thus it was concluded that the survey lines adequately sampled the species complement present across squares.

### Testing the WCBS with volunteer recorders

The WCBS was widely tested by volunteer recorders between 2005 and 2008. There were two main objectives to

the pilot studies (1) assessing the likely levels of recorder participation and survey coverage that would be achieved if the scheme was launched nationally and (2) determining whether the method is likely to detect the target wider countryside species in sufficient quantity to be able to general national indices and trends.

### Volunteer participation

The most extensive testing was undertaken in 2008, with 310 squares sampled in selected regions through the combined efforts of BC and BTO volunteers. The level of participation by both recorder types approximately doubled expectations and feedback was very positive. A questionnaire indicated that three quarters of participants would be prepared to take part in a WCBS on an annual basis. Moreover, by extrapolating to all areas of the UK, it was predicted that in the region of 1,400 squares (approximately half each covered by BC and BTO recorders) could potentially be sampled in a fully-funded WCBS. The results gave real encouragement to the possibility of rolling out the scheme nationally.

### Species seen in the pilot studies

On average, nearly 100 individuals of ten species were seen per square based on two visits, indicating that typical WCBS visits were likely to be of sufficient interest to recorders to merit their participation. Thirty-eight species were seen across squares receiving two summer visits. Nearly all wider countryside species (24 of 25) were present in more than 3% of squares surveyed. Therefore a scheme achieving the predicted uptake of more than 1,000 squares would likely yield abundance data for each of these species in more than 30 squares—a statistically valid sample size for generating UK-wide indices and trends.

### Launching the WCBS in 2009

#### Sampling strategy and co-ordination

To capitalise on the success of the pilot studies, a decision was made by BC/BTO/CEH to launch the WCBS in 2009, albeit on a limited budget. The scheme was operated by extending two existing co-ordination mechanisms. Butterfly recorders were organised through a network of local champions within each BC branch (local areas) overseen by a central co-ordinator. Volunteers contributing to the BTO BBS were co-ordinated centrally by the BBS National Organiser. Resources provided for recorders included downloadable recording forms, guidance notes, identification guides and online data entry facilities. WCBS





**Fig. 3** Location of WCBS sampling squares in 2009. Filled black squares ( $n = 360$ ) represent squares sampled by BTO BBS recorders, gray triangles ( $n = 403$ ) by BC recorders, whilst open gray squares ( $n = 343$ ) represent squares allocated to BC or BTO recorders that subsequently were not sampled

survey squares were selected from two sources. Squares were selected at random, stratified by recorder density for each BC Branch (as measured by the number of active members per branch) and made available to BC recorders. BTO recorders were asked to sample their BBS squares, which had previously been determined by stratified random sampling (pool of 3,211 surveyed squares in 2008). In total, recorders signed up to survey 1,001 squares (Fig. 3), including 11% of BBS squares.

#### Field methods

The WCBS method used was the same as described above for the pilot study, with refinements including dragonfly and day-flying moth recording during the butterfly survey and an extended time period from 09:30–16:30. Surveyors were requested to undertake a minimum of two visits to squares over July and August, with visits spaced at least 10 days apart. Optional visits were encouraged between May and September, but targeted over the May to June period to pick up Orange-tip and other spring flying species. The importance of following the ideal route as closely as possible to limit bias in habitat sampling was emphasised.

An additional optional component to the WCBS was a rapid survey for selected other insect species, to be completed at the end of the survey. The primary purpose of this was to further evaluate the extent to which a large body of recorders would be prepared to record other insect groups for which there are currently no national data on abundance trends. The *Insect Flower Search* involved counting the numbers of 12 selected insect species on flower heads in a 1 m wide strip to one side of the butterfly transect route over a 10 min period. The twelve species were: Common Carder Bumblebee (*Bombus pascuorum*), Marmalade Hoverfly (*Episyrphus balteatus*), Common Red Soldier Beetle (*Rhagonycha fulva*), Red-tailed Bumblebee (*Bombus lapidarius*), Hoverfly (*Sericomyia silentis*), the Hoverfly (*Chrysotoxum bicinctum*), Great Pied Hoverfly (*Volucella pellucens*), Thick-legged Flower Beetle (*Oedemera nobilis*), Duck-billed Hoverfly (*Rhingia campestris*), Common Malachite Beetle (*Malacius bipustulatus*), Black and Yellow Longhorn Beetle (*Rutpela maculata*) and the wasp beetle (*Bombus pascuorum*). Recorders were encouraged to note other insect species present identifiable to species level, whilst basic habitat recording (nectar abundance on a scale from 1 to 5) was also completed as part of the survey (see [www.ukbms.org.uk](http://www.ukbms.org.uk)).

#### Participation levels

In total, 1,642 visits were made to 763 1-km squares by 611 recorders, who collectively walked 3,300 km of survey line. BC volunteers sampled 53% of squares, whilst BBS recorders sampled 47%, with regional differences apparent between the two groups (Fig. 3). During July and August, 597 squares (80%) received the required two visits. Optional, extra visits included ~200 in the spring. Recording standards and data quality were thought to be high, with only 0.2% of records obvious misidentifications based on species known distributions and flight times. Of those who participated, more than 70% used the online system for submitting their data.

#### Butterfly species

Over the 1,642 visits, recorders counted in excess of 119,000 individual butterflies, with an average visit during July and August yielding approximately 80 individuals of 8 species. In total, more than three-quarters (47 of 58) of the UK's regularly occurring (breeding species and annual migrants) butterfly species were recorded (Table 1). Sufficient coverage to compile national relative abundance indices (i.e. present in at least 30 squares) was achieved for all of the target wider countryside species, with the exception of Scotch Argus, *Erebia aethiops* (found in only 17 squares).

**Table 1** Abundance and occupancy figures for 46 butterfly species based on two summer visits to 593 squares

Species	Occupancy			Abundance		
	No. squares	%	Rank	Total counted	% of all butterflies counted	Rank
Large White <i>Pieris brassicae</i> <sup>a</sup>	534	89.4	1	14,817	15.71	2
Meadow Brown <i>Maniola jurtina</i> <sup>a</sup>	521	87.3	2	15,281	16.20	1
Small White <i>Pieris rapae</i> <sup>a</sup>	518	86.8	3	13,489	14.30	3
Painted Lady <i>Vanessa cardui</i> <sup>b</sup>	493	82.6	4	6,803	7.21	6
Gatekeeper <i>Pyronia tithonus</i> <sup>a</sup>	450	75.4	5	10,520	11.15	4
Speckled Wood <i>Parage aegeria</i> <sup>a</sup>	441	73.9	6	4,825	5.11	8
Green-veined White <i>Pieris napi</i> <sup>a</sup>	429	71.9	7	8,505	9.02	5
Peacock <i>Inachis io</i> <sup>a</sup>	408	68.3	8	2,632	2.79	10
Small Tortoiseshell <i>Aglais urticae</i> <sup>a</sup>	358	60.0	9	2,642	2.80	9
Comma <i>Polygobia c-album</i> <sup>a</sup>	319	53.4	10	1,058	1.12	12
Red Admiral <i>Vanessa atalanta</i> <sup>b</sup>	303	50.8	11	910	0.96	14
Ringlet <i>Aphantopus hyperantus</i> <sup>a</sup>	278	46.6	12	5,446	5.77	7
Common Blue <i>Polyommatus icarus</i> <sup>a</sup>	233	39.0	13	1,643	1.74	11
Small Copper <i>Lycaena phlaeas</i> <sup>a</sup>	156	26.1	14	379	0.40	20
Small Skipper <i>Thymelicus sylvestris</i> <sup>a</sup>	139	23.3	15	897	0.95	15
Brimstone <i>Gonepteryx rhamni</i> <sup>a</sup>	109	18.3	16	277	0.29	22
Large Skipper <i>Ochlodes sylvanus</i> <sup>a</sup>	106	17.8	17	403	0.43	19
Small/Essex Skipper <sup>a</sup>	98	16.4	18	960	1.02	13
Small Heath <i>Coenonympha pamphilus</i> <sup>a</sup>	81	13.6	19	422	0.45	17
Wall Brown <i>Lasionmata megera</i> <sup>a</sup>	66	11.1	20	405	0.43	18
Holly Blue <i>Celastrina argiolus</i> <sup>a</sup>	64	10.7	21	95	0.10	27
Essex Skipper <i>Thymelicus lineola</i> <sup>a</sup>	62	10.4	22	261	0.28	23
Brown Argus <i>Plebeius agestis</i> <sup>a</sup>	58	9.7	23	194	0.21	24
Marbled White <i>Melanargia galathea</i> <sup>a</sup>	51	8.5	24	476	0.50	16
Silver-washed Fritillary <i>Argynnis paphia</i>	41	6.9	25	139	0.15	26
Clouded Yellow <i>Coleus croceus</i> <sup>b</sup>	31	5.2	26	88	0.09	28
Purple Hairstreak <i>Neozephyrus quercus</i> <sup>a</sup>	19	3.2	27	50	0.05	29
Orange Tip <i>Anthocharis cardamines</i> <sup>a</sup>	11	1.8	28	13	0.01	35
White Admiral <i>Limenitis camilla</i>	10	1.7	29	49	0.05	30
Scotch Argus <i>Erebia aethiops</i> <sup>a</sup>	9	1.5	30	379	0.40	20
Grayling <i>Hipparchia semele</i>	9	1.5	30	169	0.18	25
Dark Green Fritillary <i>Argynnis aglaja</i>	9	1.5	30	18	0.02	33
Chalk-hill Blue <i>Polyommatus coridon</i>	7	1.2	33	21	0.02	32
Small Pearl-bordered Fritillary <i>Boloria selene</i>	3	0.5	34	16	0.02	34
Small Blue <i>Cupido minimus</i>	3	0.5	34	6	0.01	36
White-letter Hairstreak <i>Satyrrium w-album</i> <sup>a</sup>	3	0.5	34	3	<0.01	38
Adonis Blue <i>Polyommatus bellargus</i>	2	0.3	37	25	0.03	31
Brown Hairstreak <i>Thecla betulae</i>	2	0.3	37	3	<0.01	38
Green Hairstreak <i>Callophrys rubi</i>	2	0.3	37	3	<0.01	38
Silver-studded Blue <i>Plebeius argus</i>	2	0.3	37	2	<0.01	42
Large Heath <i>Coenonympha tullia</i>	1	0.2	41	6	0.01	36
Lulworth Skipper <i>Thymelicus acteon</i>	1	0.2	41	3	<0.01	38
Dingy Skipper <i>Erynnis tages</i>	1	0.2	41	2	<0.01	42
Pearl-bordered Fritillary <i>Boloria euphrosyne</i>	1	0.2	41	1	<0.01	44
Purple Emperor <i>Apatura iris</i>	1	0.2	41	1	<0.01	44
Wood White <i>Leptidea sinapis</i>	1	0.2	41	1	<0.01	44

<sup>a</sup> Wider countryside species<sup>b</sup> Regular migrant species

Optional spring visits improved coverage for several species, including Brown Argus (*Plebeius agestis*), Wall Brown (*Lasiommata megera*) but especially Orange-tip which was found in 65 squares. The most widely recorded species over the core July and August period was the Large White (*Pieris brassicae*) occurring in nearly 90% of squares, whilst the most abundant species was Meadow Brown (*Maniola jurtina*) with over 15,000 individuals counted (Table 1). Two satyrids (Meadow Brown and Gatekeeper, *Pyronia tithonus*) and three Whites (Large White; Small White, *Pieris rapae*; Green-veined White, *Pieris napi*) accounted for two-thirds of all butterflies counted. During July and August the three regular migrants species Red Admiral (*Vanessa atalanta*), Painted Lady (*Vanessa cardui*) and Clouded Yellow (*Coleus croceus*) comprised nearly one in ten of all butterflies counted, chiefly because 2009 was one of the best years since 1996 for the Painted Lady (UKBMS unpublished data).

Although habitat specialists (low mobility species chiefly restricted to semi-natural habitats) comprise more than half of UK butterfly species (Asher et al. 2001), they accounted for less than 0.5% of the total number of butterflies counted on WCBS squares in July and August. The most widely recorded habitat specialist was the Silver-washed Fritillary (*Argynnis paphia*), occurring in 52 squares.

Through the pilot studies, 310 squares were surveyed in 2007 and 192 in 2008, whilst 100 squares have been surveyed in all 3 years from 2007 to 2009, enabling comparisons of abundance between years. On average, butterfly abundance on WCBS squares in 2009 was nearly a third higher than 2008 (a similar change to that detected on transect sites, UKBMS unpublished data), with one to two more species seen per visit. 2009 was a particularly good year for the Large White and as previously mentioned the Painted Lady.

#### Other insects

Dragonflies and day-flying moths were recorded in 383 squares (50% of the total). Fifty-two species of moth (439 individuals) were counted in 233 squares. A migrant species, the Silver-Y (*Autographa gamma*) was the most widespread and abundant species, with 194 individuals counted from 152 squares. The only other moderately widespread species was the Six-spot Burnet (*Zygaena filipendulae*) with 49 individuals counted in 40 squares. Twenty-eight species (plus 3 'Unidentified' groups) of dragonfly (2,370 individuals) were counted in 285 squares. Common Darter (*Sympetrum striolatum*) was the most widespread species (24% of squares), closely followed by Brown Hawker (*Aeshna grandis*) (21%) and Southern Hawker (*Aeshna cyanea*) (21%). The most abundant

species was the Common Blue Damselfly (*Enallagma cyathigerum*) accounting for 31% of all individuals seen.

The Insect Flower Search was completed on 40% of squares, with one or more target species detected on 81% of surveys. Across squares, all of the 12 target species were detected, with four species occurring in more than half of the squares sampled. These were Common Carder Bumblebee, Marmalade Hoverfly, Common Red Soldier Beetle and Red-tailed Bumblebee. In contrast, six species occurred in fewer than 10% of squares. The Common Carder Bumblebee was the most widespread species being present in 71% of squares, whilst Marmalade Hoverfly was the most abundant species totalling 34% of all individuals seen.

#### Habitat coverage

To assess whether the squares sampled in 2009 were a representative sample of the UK landscape, broad habitats (Jackson 2000) sampled in the WCBS squares were compared to their occurrence across the UK as a whole using the national Land Cover Map dataset (Fuller et al. 2002). No difference was found between the proportions of land cover types within the WCBS squares sampled in 2009 (N = 757 squares, excluding Northern Ireland) and the proportions found across the UK (*t*-test,  $t = 0.00$ ,  $P = 1$ ; Table 2).

## Discussion

#### Overall evaluation of scheme design

The WCBS borrows heavily from the BBS survey method developed by the BTO, with fine-tuning made for butterflies. In addition to copying a sound scientific design, there are a number of benefits in using the BBS survey design for butterflies. The BBS is a widely regarded scheme (e.g. data used to compile a governmental biodiversity indicator of sustainable development), that has been peer reviewed and thoroughly tested (Greenwood et al. 1995). During the first year of the WCBS, encouraging BBS bird recorders to participate by surveying their squares effectively doubled the coverage that would have been achieved using only established (UKBMS) butterfly recorders. There is considerable further potential to improve coverage with bird recorders, as there are three times more bird recorders contributing to the BBS than there are butterfly recorders in the UKBMS. The combined efforts of bird and butterfly recorders (accounting for overlap), could potentially yield a WCBS sampling 4,000 or more squares. There are also efficiency savings in using BBS squares, because survey routes have already been established.



**Table 2** Broad habitats sampled by WCBS squares in 2009 in comparison to the proportions found across the whole UK (CEH Land Cover Map)

Broad habitat	Land cover map ( <i>N</i> = 242,308 squares)	WCBS in 2009 ( <i>N</i> = 757 squares)
Broadleaved, mixed and yew woodland	6.31	10.24
Coniferous woodland	5.35	3.78
Arable and horticulture	23.45	33.92
Improved grassland	20.15	22.97
Neutral grassland	5.28	4.30
Calcareous grassland	4.40	5.88
Acid grassland	6.04	2.04
Bracken	0.78	0.36
Dwarf shrub heath	10.83	2.65
Fen, marsh and swamp	0.08	0.11
Bogs	2.12	0.72
Standing open water and canals	0.87	0.40
Montane habitats	1.64	0.00
Inland rock	0.90	0.68
Built-up areas and gardens	6.69	10.81
Supra-littoral rock	0.02	0.00
Supra-littoral sediment	0.09	0.14
Littoral rock	0.06	0.02
Littoral sediment	1.19	0.31
Inshore sublittoral	3.73	0.67

However, use of the BBS and bird recorders imposes a number of constraints. A mandatory limit of two summer visits was imposed, because it was thought unrealistic to request bird recorders (chiefly volunteering for a bird monitoring organisation) to put more effort into sampling butterflies than birds. Although efficiency increases with fewer visits (Roy et al. 2007), if occupancy is low then an unrealistic number of sample squares may be required to detect short-term trends with a two visit scheme. A further constraint in the BBS is that section lengths are fixed at 200 m long, rather than variable according to habitat type, making fine-scale habitat analysis more complicated.

There is a tendency for BBS routes to oversample linear features and WCBS routes established by butterfly recorders showed a similar bias. This sampling bias is not a major concern in bird recording as sampling is likely to detect a good proportion of birds present in squares from sampling routes, due to birds being apparent (seen or heard) well beyond survey lines. However, this is not the case for butterflies. Although WCBS results from 2009 indicates that overall sample squares are representative of the UK in habitat terms, within square sampling bias towards linear habitats needs to be accounted for to avoid overestimating absolute butterfly abundance. We suggest it

is preferable to account for sampling bias post hoc through a weighting procedure (van Swaay et al. 2002), because eliminating sampling bias in the field would likely involve considerable access problems for volunteer recorders including physical obstacles, potential crop damage and negotiating access permissions as well as spending more time in areas with few or no butterflies; all these factors would be unpopular and threaten the long-term viability of the scheme.

Distance sampling methods were considered in the survey design to enable absolute density estimates to be derived, but rejected on practical grounds. As a consequence, the WCBS generates only relative density estimates and an assumption is made that a constant proportion of butterflies are detected at sample sites. There is a need to test this assumption using long term changes in detection probabilities using UKBMS data and methods to analyse multiple visits as applied for butterflies (Kéry and Plattner 2007, Pellet 2008).

Only limited testing of habitat survey methods was undertaken in the pilot studies. Further research is required as the WCBS would be improved through the incorporation of a habitat survey component specific to butterflies, to aid interpretation of butterfly distribution and trends.

Data quality is a potential issue in the WCBS which relies heavily on bird recorders whose primary interest and recording skills are in another taxonomic group. However, few obvious errors were evident in the survey results in terms of unusual counts, dates or distributions (0.2% of records) and a proportion of these may have been data input errors. The provision of free identification sheets to recorders may have helped to reduce misidentifications. A preliminary analysis of field validation data (squares repeat sampled by both volunteers and professionals) showed that results were extremely similar, again indicating that error rates were low and data quality was high. However, sample sizes were low and more research is required (and planned) in this area.

#### Evaluation of results from the first year of the survey

The WCBS represents the first UK-wide assessment of the distribution and abundance of common and widespread butterflies using a scientific sampling framework. Moreover it is the first scheme in the UK to assess multi-species invertebrate abundance through random sampling. In total, 763 1-km squares were sampled primarily by volunteer recorders, which we believe is a considerable achievement for a first year especially given limited publicity, a late announcement to the roll out, poor weather in some regions and the scheme running on minimal resources. To put this into context, it took nearly 30 years to achieve a similar level of site coverage through the UKBMS. The involvement of bird recorders was particularly beneficial in

improving geographical coverage in regions with few BC recorders.

Volunteer recorders signed up to surveying ~1,000 squares, but only ~75% of these were ultimately surveyed, with final coverage ~15% less than expected. Whilst poor weather over the summer was undoubtedly a contributory factor, these figures highlight the need to better predict coverage in scheme planning. To achieve coverage of more than 1,000 squares, a fully resourced scheme is required to improve promotion, facilitate training and to allow a longer lead in time for the survey to gain momentum.

There is a potential concern due to not all allocated BBS and BC squares being sampled. With surplus squares, recorders may choose those squares where butterfly diversity is likely to be higher, which could lead to overestimates of occupancy and abundance at a national scale. Sampling bias is currently being investigated and will be accounted for when abundance indices and trends are estimated.

More than three-quarters (47 of 58) of the UK's regularly occurring butterfly species were recorded. The scheme successfully detected patterns in butterfly distribution and abundance evident in results from other butterfly recording and monitoring schemes, including a substantial Painted Lady (*Vanessa cardui*) migration (Fox et al. in press), highly restricted distributions in the majority of habitat specialist species (Cowley et al. 1999) and an absence of the Wall Brown across much of central Great Britain (Fox et al. 2006). In particular, abundance of the majority of habitat specialist was extremely low, because these species have highly restricted distributions within semi-natural habitats, confirming the need for other sampling approaches.

All of the target wider countryside species (except Scotch Argus) were detected in a sufficient number of squares (more than 30) to enable a UK-wide abundance index to be compiled, showing that the scheme successfully delivered on its primary purpose. However, no individual species was found in 630 or more squares (maximum 534 for Large White), which is the average number of occupied squares required to detect a 25% change over 10 years. These results suggest that scheme power may be low to detect trends over the short term with the current emphasis on two visits and that optional visits should be encouraged, especially amongst BC recorders. Moreover, optional visits proved valuable in 2009, particularly in the spring, and enabled a baseline to be established for Orange-tip.

On average, recorders counted approximately 80 individual butterflies of eight species per single survey made over the July and August period, confirming that an 'average WCBS' visit is likely to yield a reasonable butterfly return. This was especially so given that it was a below average year for butterflies (UKBMS unpublished data). Over the same period, an average of 130 butterflies

from ten species was seen on UKBMS butterfly transects of similar survey length (UKBMS unpublished data). It is encouraging that butterfly diversity for an average visit is not vastly different to transects, as it gives hope that volunteers will find visits sufficiently rewarding to repeat them regularly in future years.

Through a combination of the UKBMS site-based monitoring network and the WCBS, we believe suitable survey methods and adequate sampling strategies are now in place to enable UK-wide assessments of abundance for 53 of the 58 regularly occurring species. Exceptions include montane specialist species such as Mountain Ringlet and canopy-dwelling forest butterflies such as Purple Emperor. The WCBS has highlighted the problems in achieving sampling coverage in some regions, particularly in upland areas where recorded densities are low and the combination of remoteness, steep terrain and a cool climate present considerable recording challenges. This is a wider recording problem affecting other taxa (JNCC unpublished data) and differing approaches may be required to fill coverage gaps in remote areas, including employing contractors or recruiting/training new types of volunteers (e.g. hill walkers). We recommend periodic surveys as a more realistic tool for monitoring montane species, whilst research is required to develop improved monitoring methods for canopy species.

The primary purpose of the Insect Flower Search was to help assess interest levels amongst volunteers in counting numbers of less well studied insect groups and for which national abundance trends are unavailable. The results were encouraging, with 40% of recorders taking part, whilst participation might have been even higher if this component had been made a mandatory part of the WCBS. Moth and dragonfly recording was also well supported during butterfly surveys. However, as the survey routes inevitably included little aquatic habitat, the dragonfly results will have been biased in favour of the more mobile, less habitat-specific species. Nevertheless, these results indicate that there is considerable potential to use the WCBS to collate national abundance data on other insect species. This is important in biodiversity monitoring terms, as insects comprise 56% of known species (Groombridge 1992).

#### Future plans and prospects

BC, CEH and the BTO aim to run the WCBS on an annual basis, at least for the next 5 years. This will enable a fuller validation of the scheme and an assessment of whether trends in common and widespread butterfly species from WCBS sites are similar to trends obtained from UKBMS transects. The WCBS will be repeated in 2010 with similar levels of resourcing, with a target of maintaining or possibly exceeding coverage levels achieved in the first survey

year. Extra visits will be encouraged, as will new recording in areas where coverage was poor in 2009, whilst more validation surveys will be carried out.

The UK was the first country to develop a national scheme to monitor butterfly abundance. The Butterfly Monitoring Scheme, established in 1976 (now the UKBMS) has inspired many others and 17 schemes now operate across Europe, with more planned (van Swaay et al. 2008). The WCBS represents another step forward, by incorporating a random sampling framework into the survey design that should enable unbiased indices to be generated that are representative of the whole landscape. Therefore, the WCBS provides a new monitoring protocol that could help other countries establish efficient and effective butterfly monitoring schemes. This is increasingly important given that butterflies have now been adopted as biodiversity indicators at a European level.

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