DEVELOPMENT OF A FRAMEWORK FOR STRUCTURED SAMPLING OF ECOLOGICALLY SIGNIFICANT TERRESTRIAL FEATURES: AN EXAMPLE FROM VC40 SHROPSHIRE

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This paper seeks to develop a framework for use in structured sampling of ecologically significant features in studies of terrestrial taxa. It addresses the specific needs of those amateur studies, e.g. of less popular invertebrate groups, in which the number of fieldworkers engaged in data collection may be small, and where typical practice of unstructured sampling leads to biases that compromise data analysis and interpretation. Using the vice-county of Shropshire (vc40) as a worked example, the paper takes baseline data from 1985 that identify ecologically significant features in each hectad, and updates, selects and uses them to calculate a proportional distribution of those features across the 38 hectads most representative of them in Shropshire. Two suites of sites are then suggested to sample those features in the same proportions. A record card is also developed for use in capturing data so as to facilitate effective analysis. The paper identifies and discusses issues to be addressed when applying the framework, and suggests approaches to analysing data gathered from using it. Though the paper is initially motivated by the needs of amateur entomologists in Shropshire, the methodology used in developing the framework is adaptable to other taxa and other geographical regions.

INTRODUCTION

This paper follows on from the Invertebrate Challenge project that ran at FSC Preston Montford from 2011 to 2014 and led *inter alia* to the publication of Shropshire distribution atlases on a tetrad scale for less familiar invertebrate groups (Blunt, 2014; Boardman, 2014, 2016; Jones & Cheeseborough, 2014). This experience drew attention to the scale of the task: the biological recording unit of vice-county Shropshire (vc40), that also includes Telford & Wrekin, is large, contained in over 960 tetrads, and the volume of fieldwork needed to cover it evenly is formidable, especially as entomologists cannot usually mobilize large numbers of recorders.

Another issue raised by these atlases is the need for good quality data to facilitate analysis and interpretation of distributions. In amateur entomology, records usually come from opportunistic fieldwork and carry a strong risk of biases; these typically include, among others, uneven spatial coverage e.g. disproportionate sampling of more diverse sites such as nature reserves and neglect of less diverse ones such as farmland; seasonal bias through uneven recording activity over time; uneven sampling effort per visit including use of different sampling methods; and uneven detectability of taxa (Rich *et al*., 1996; Isaac *et al*., 2014). In fieldwork carried out largely by amateurs some standardization is therefore desirable to improve the quality of data and monitoring outputs (Rich *et al*., *loc. cit*.).

This paper aims to develop a model framework for standardized sampling of ecologically significant terrestrial features, using vc40 Shropshire as an example. Its focus is on amateur entomological studies as these provide the initial context. However, it is intended that the framework presented here may act as a model for similar frameworks for studying other taxa and other geographical areas. In developing the framework we have been conscious that amateur naturalists are volunteers who conduct fieldwork for enjoyment and may not be motivated to follow stricter scientific disciplines (Isaac & Pocock, 2015). A consideration, therefore, has been to make relatively light demands on data collection while applying enough rigour to facilitate effective analyses.

DEVELOPING THE FRAMEWORK

Chapter 3 of the *Ecological Flora of the Shropshire Region* (Sinker *et al*., 1985) (hereinafter 'the Flora') sets out the environmental background by examining the diverse influences on vascular plant distribution within the region. This work established "useful discriminants [of] those ecologically significant features which are of substantial extent or major importance" (Flora p. 67). This category, though not fully defined by the Flora, may be interpreted as referring to features in hectads judged to be significant for Shropshire as a whole. A further category, "significant occurrence," may be interpreted as referring to features that are judged to be significant within the context of the hectad. Using these categories the Flora created an environmental profile for each

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hectad within the Shropshire 'basic rectangle' of 42 hectads, i.e. six from west to east by seven from south to north (Figure 2).

We have utilized the information within the schedule of these environmental profiles to select appropriate features for incorporation into a framework, to calculate the number of samples needed to represent each feature proportionately, and to suggest two representative suites of sampling sites which reflect the geographical spread and extent of those features.

It should be noted that the environmental profiles identify major hydrological features (meres, large rivers, canals) but not smaller water bodies. They are appropriate for a framework for sampling terrestrial taxa including those associated with emergent vegetation, but not aquatic taxa. These latter are discrete and specialized groups for which smaller water bodies are often significant features; sampling methods for these groups are also specialized, and some habitat associations sought by this framework cannot readily be noted from above the water surface. We have consequently confined this framework to the needs of sampling terrestrial taxa and made no provision for aquatic sampling within it.

SELECTING THE ENVIRONMENTAL PROFILES

Environmental profiles of the 42 hectads within the basic rectangle are summarised in Table 3.6 of the Flora, reproduced here as Figure 1. The list of features in Figure 1 is as follows:

A	Altitude reaching over 1400 ft in parts	O	Overgrown canals, disused
B	Altitude between 1000 and 1400 ft in parts	P	Peatlands
C	Altitude between 600 and 1000 ft in parts	Q	Quarries and mines
D	Altitude descending below 200 ft in parts	R	Ravine woods
E	Exposed, steep S- or N-facing hillsides	S	Scarp woods
F	Fluvioglacial or terrace sands/gravels	T	Trust* reserves and other protected sites
G	Glacial moraine and boulder clay (till)	U	Upland heath, moor and rough grazing
H	Hills on Triassic sandstone	V	Valley and lowland mires and heath
I	Igneous, volcanic and Precambrian rocks	W	Woods, planted coniferous
K	Keele, Keuper and other base-rich beds	X	Extensive arable farms with large fields
L	Limestones with shallow soils	Y	Industry and urban development
M	Meres	Z	Railway sidings, motorways, airfields
N	Canals and large rivers		

* Where Trust refers to the Shropshire Trust for Nature Conservation, now the Shropshire Wildlife Trust

Before proceeding to use these environmental profiles checks were made for changes that have occurred between 1985 and the present. It was noted that changes to the canal network now bring more of it into navigable status, leaving fewer disused canals; hence we have merged features O and N into a single category "N: canals and large rivers". Disused airfields have been largely turned to other uses, and neither remaining airfields nor motorways are accessible for fieldwork; we have therefore interpreted Z as "transport infrastructure including disused railways and railway sidings".

We have additionally followed the Flora's (pp. 140-141) inclusion of temporary leys and re-seeded grassland as well as arable crops in category X (extensive arable farms with large fields), and its treatment (pp 115-117) of Shropshire's deciduous woodlands as sufficiently represented by the two categories of ravine woods and scarp woods. There are now more nature reserves and other protected areas, but new sites are often small, and we consider that their overall impact does not increase the proportional significance of this feature. Although there has been a spread in urban areas, no new stand-alone developments have occurred to extend the significance of this feature into new hectads. Subject to these interpretations and changes the environmental profiles identified in Figure 1 are considered a good representation of ecologically significant features of present-day Shropshire.

In developing this framework we judged that proportional representation of all 24 features in Figure 1 (reduced from 25 by merging N and O) cannot be achieved without increasing the number of samples beyond the important consideration of making 'relatively light demands' on amateur entomologists. Also, the presence and habitat variations influenced by some geological features (F, G, H, I, K, but not L) are considered too subtle to be applied in the field. Relief features A – E omit one altitudinal band (200-600ft); and while altitude influences the distributions of some taxa, e.g. microlepidoptera (Blunt, 2014), we treat it here as a continuum that can be adequately if not precisely proportionately represented by choice of sampling sites; as can steep S- and N-facing

hillsides. The remaining 14 features that represent hydrology, land use and one geological feature are therefore selected for the framework: these are L, M, N (including O), and P-Z.

	2	3	4	5	6	7
3	a B C - E f g - i k l - n - - q r s - U - W - y z	- - - d - F G - - k - - N - p q r s t - v w x y z	- - - - - F G - - - - M N o P q r - T - V w x - -	- - - - - f G - - k - m n - P - r - T - V w x - z	- - - - - f G h - k - - N - p - r - - - v w X y z	- - c - - f g H - k - m - - p Q r - t - v W x - -
2	- b C - E f g h I k L - - o p Q r S T U V w x y z	- - - d - F g H - - - - - O P q - s t - v w x y z	- - - - - f G h - - - m - - P - - s t - v w x - Z	- - c d e f g H - k - - - - p q r s t - v w X y z	- - - d - f g h - - - - - - p q - - t - v w X y z	- - - - - f g h - k - m N o P - r s - - v w x - -
1	- b C d E f g - I - - - N O p Q r s t u v w x - -	- b c D e f G h I k - m N - p q r s t u v w X y -	- - - d - F G - - - - m N - - q r s t - v w X Y Z	- - - D e f g - i k - m n o - q - s - - v w X Y Z	- - c D - f g - i k - - - o P q r s t - v w X Y Z	- - c d - f g h - k l - - o p Q - - - - - w X Y z
0	- b C - e f g - i k - m N O p q r s t u v W x y z	a b C - E f g - i k - - - - p Q R s T U - w x y -	a b C - E F g - I k - m - - - q R s T u - w x y z	- - c D e F G - i k - m N - p q r s - - v w X - z	- b C d E f g - I K L - N o - Q R S T u - w x Y z	- - - d - f g h - k - - n - p q r s - - - w X Y Z
9	- b c - E f G - I k - - n - - q R s t U - w - - -	A B C - E f g - I k - - - - - q r s T U - w - - -	A B C - E f g - I k l - - - - q r s t U - w x y -	- b C - E f G - i K L - - - - q r S - u v w x - -	- - C - e f g - - K l - - - - Q r s - u v w x y -	- - - d - F g h - k - - N - p q R s - - - w X y z
8	A B c - E - - - - - - - - - - q r s - U - w x - -	- b C - E f g - i k - - - - - q r s t u v W x - -	- b C - E f g - i K l - - - - q r S t u v w x - z	a b C - e f g - i K l - - - - q r s - U - w X - -	- b C - e - - - i K l - - - - q r s - u v w x - -	- - - d - f - h i K - - N - - q R s - - v w X y -
7	a B c - E - - - - - - - - - - q r s - u - w x y -	a B C - E f g - - k - - - - - q r s - u v W x - -	- b C - E f g - - K l - - - - q r S t u v W x - -	a b c - e f g - i K l - n - - Q r s t U - w x y z	a b c - e - - - i K l - - - p q r s t U v w x - -	- - c d e f - - - k - - N - - q R s T - v W x y z

FIGURE 1. Environmental profiles for the 42 hectads in the Shropshire 'basic rectangle'
(reproduced from Table 3.6 *Environmental profiles of the 42 10km x 10km squares in the Shropshire Rectangle* in Sinker *et al.*,1985).

- A lower case letter indicates significant occurrence, a capital letter substantial extent or major importance for the feature represented. *Every letter refers to the square* [hectad] *as a whole*: its local position is alphabetical, not geographical (i.e. not indicating the 'tetrad' in which it happens to be printed).
- The first line of letters in each square deals with relief; the second and third, with geology and hydrology; the fourth and fifth, with land use, including urban and industry.

ESTABLISHING THE SAMPLING AREA

The area covered by the Flora was greater than that of vc40, and included parts of vc39 (Staffordshire) to the east and vc47 (Montgomeryshire) to the west (Figure 2).
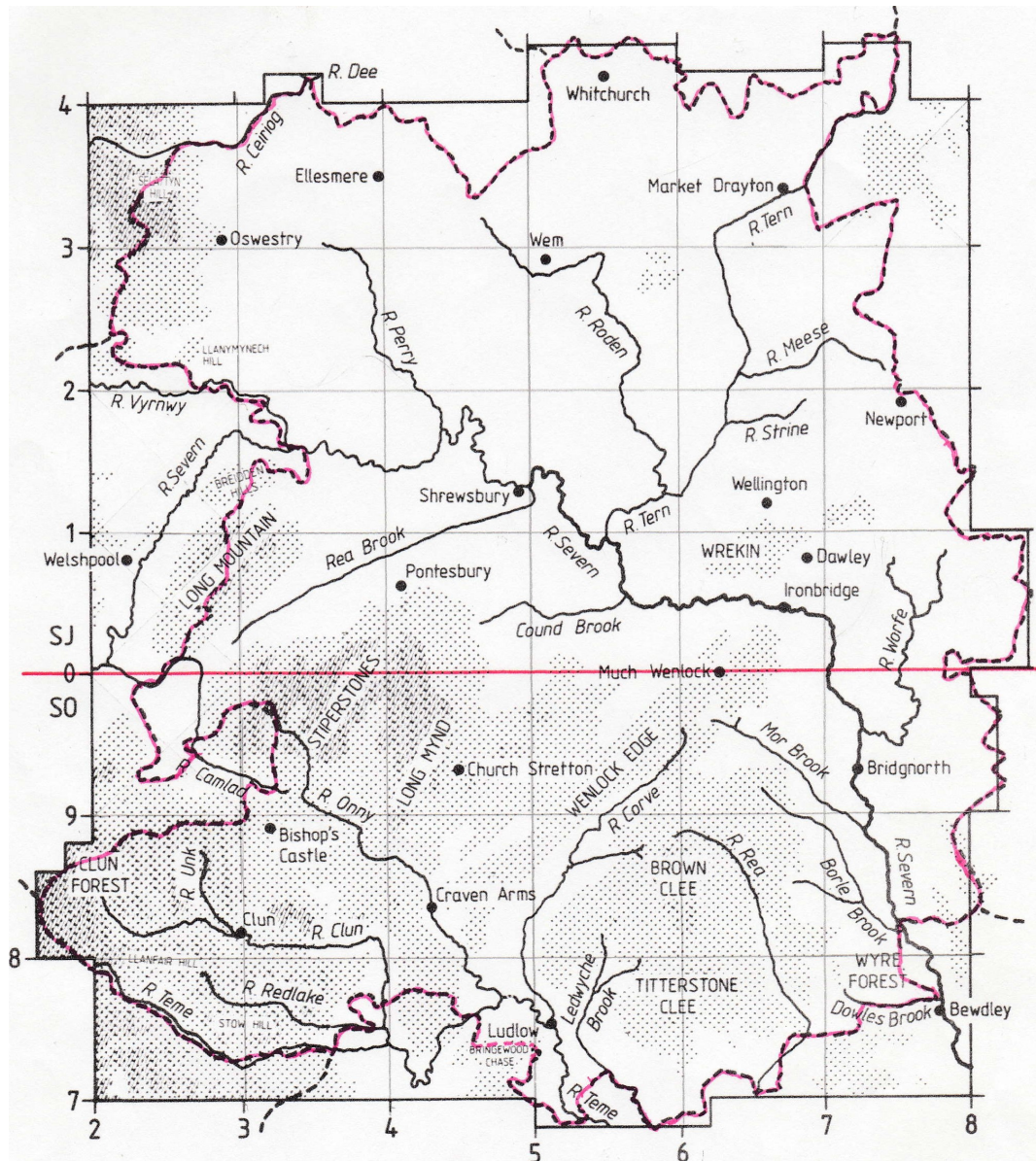

FIGURE 2. The main physical features of the Shropshire Region. The county outline is shown by a pecked line. Light shading indicates land over 500 feet (152 m); heavily shaded areas are over 1,000 feet (305 m) [Reproduced from p. xvi in Sinker *et al.*, 1985]

Figure 2 shows the Shropshire basic rectangle of 42 hectads, plus 50 tetrads around the margins that include small parts of vc40 where its boundaries extend beyond the basic rectangle. These tetrads consist of:
(a) on the southern margin – five tetrads adjacent to hectad SO57 and one adjacent to SO67.
(b) on the western margin – seven tetrads adjacent to hectad SO28.
(c) on the northern margin – two tetrads adjacent to hectad SJ33, ten adjacent to SJ53, five adjacent to SJ63 and six adjacent to SJ73.
(d) on the eastern margin – ten tetrads adjacent to hectad SJ70 and four adjacent to SO79.

These tetrads were examined on OS 1:25000 maps updated to 1998-2005, supplementing recording visits made to almost all of them by the authors in 2013, to determine the extent to which they might alter the significant ecological features applicable within neighbouring hectads and justify inclusion in the framework recording area. It was concluded that no boundary tetrad adds any significant feature not fully represented in an adjacent hectad selected for this framework; no further adjustments therefore need be made and all boundary tetrads are excluded from the sampling area.

We have also omitted from the framework sampling area four hectads within the basic rectangle (SO29, SJ20, SJ21, SJ73). The reasons for the omissions are:

- the hectad contains a very small part of vc40 within its boundary (SJ21, SJ73)
- the significant ecological features of the hectad apply to that part which is not within vc40, and the part of vc40 within the hectad is less than 50% (SJ20, SO29)

Thus the sampling area adopted in this paper comprises 38 hectads within the basic rectangle.

CREATING THE SAMPLING LISTS

The 14 ecological features selected for these 38 hectads were given a numerical weighting to establish comparable values for the features and allow their significance to be demonstrated in the selection of sampling sites, as shown in Table 1. This weighting used a score of 1 for the Flora's "features of significant occurrence" and 2 for "features of substantial extent or major importance", these categories being represented by lower and upper case letters in Figure 1. An exercise carried out using weightings of 1 and 3 produced an almost identical proportional distribution of the features and was rejected in favour of the 1–2 format. The bottom of Table 1 shows the weighted scores for each feature converted to a percentage of the whole set of samples, expressed to one decimal place. These percentages are then used to establish a proportional value for each feature across 38 hectads, to two decimal places in order to more accurately allocate the number of samples required. These proportional values are then converted to numbers of samples (rounded up or down as appropriate) required to achieve proportional coverage for each feature in the sampling area as a whole. This calculation produced a deficit of one sample, which we have added to feature L (limestones with shallow soils) as we feel the importance of this feature is under-represented by a single sample.

These sample numbers were then used to select representative sites. OS 1:25000 maps were examined to identify sites within hectads that represent features of substantial extent/major importance and those of significant occurrence. Appropriate sites were then chosen for each hectad (Appendix 1) in accordance with the calculated number of samples required for each feature in Table 1. Most choices were made from the authors' knowledge of vc40, but where lack of knowledge or doubts about the suitability of sites to represent particular features arose these issues were tackled in one of the following ways:

1. Local advice on the nature and suitability of proposed site(s) was obtained.
2. Physical checks were made on some sites for their local features and access.
3. Where lack of access from a public thoroughfare or difficulty of terrain precluded the choice of proposed sites suitable alternatives were sought.

A first selection of sites (Distribution A in Appendix 1) was attempted from features of substantial extent/major importance, though difficulties of accessibility did not allow this approach to be fulfilled in every hectad. Consideration was then given to establishing a second selection because:

4. Hectad SJ43 contains Shropshire's main concentrations of both meres (M) and peatlands (P); a second distribution would allow both major features to be represented for this hectad.
5. It gives an opportunity to increase the number of samples for features with few samples required by the framework, thus improving statistical analysis.
6. It allows a wider geographical spread of features across Shropshire.
7. It allows a broader representation of features that have diverse habitats, e.g. industry/urban development; transport infrastructure.

A second selection of sites was therefore made (Distribution B in Appendix 1). A different ecological feature is represented by the two distributions in 36 hectads; only in SO38 and SO59 are the same features represented in both distributions, through difficulties of incorporating alternatives. Distribution A sites sample features of substantial extent/major importance in 29 of 38 hectads and features of significant occurrence in 9; the figures for Distribution B are 15 and 23 respectively.

TABLE 1. Calculation of weighted values for hectads and features selected for the framework

HECTAD	FEATURE														TOTAL
	L	**M**	**N**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**	
SJ22	2	-	1	1	2	1	2	2	2	1	1	1	1	1	18
SJ23	1	-	1	-	1	1	1	-	2	-	2	-	1	1	11
SJ30	-	-	-	1	2	2	1	2	2	-	1	1	1	-	13
SJ31	-	1	2	1	1	1	1	1	1	1	1	2	1	-	14
SJ32	-	-	2	2	1	-	1	1	-	1	1	1	1	1	12
SJ33	-	-	2	1	1	1	1	1	-	1	1	1	1	1	12
SJ40	-	1	-	-	1	2	1	2	1	-	1	1	1	1	12
SJ41	-	1	2	-	1	1	1	1	-	1	1	2	2	2	15
SJ42	-	1	-	2	-	-	1	1	-	1	1	1	-	1	9
SJ43	-	2	2	2	1	1	-	2	-	2	1	1	-	-	14
SJ50	-	1	2	1	1	1	1	-	-	1	1	2	-	1	12
SJ51	-	1	1	-	1	-	1	-	-	1	1	2	1	2	11
SJ52	-	-	-	1	1	1	1	1	-	1	1	2	1	1	11
SJ53	-	1	1	2	-	1	-	2	-	2	1	1	-	1	12
SJ60	2	-	2	-	2	2	2	2	1	-	1	1	2	1	18
SJ61	-	-	1	2	1	1	1	1	-	1	1	2	2	2	15
SJ62	-	-	-	1	1	-	-	1	-	1	1	2	1	1	9
SJ63	-	-	2	1	-	1	-	-	-	1	1	2	1	1	10
SJ70	-	-	1	1	1	1	1	-	-	-	1	2	2	2	12
SJ71	1	-	1	1	2	-	-	-	-	-	1	2	2	1	11
SJ72	-	1	2	1	-	1	1	-	-	1	1	1	-	-	9
SO27	-	-	-	-	1	1	1	-	1	-	1	1	1	-	7
SO28	-	-	-	-	1	1	1	-	2	-	1	1	-	-	7
SO37	-	-	-	-	1	1	1	-	1	1	2	1	-	-	8
SO38	-	-	-	-	1	1	1	1	1	1	2	1	-	-	9
SO39	-	-	-	-	1	1	1	2	2	-	1	-	-	-	8
SO47	1	-	-	-	1	1	2	1	1	1	2	1	-	-	11
SO48	1	-	-	-	1	1	2	1	1	1	1	1	-	1	11
SO49	1	-	-	-	1	1	1	1	2	-	1	1	1	-	10
SO57	1	-	1	-	2	1	1	1	2	-	1	1	1	1	13
SO58	1	-	-	-	1	1	1	-	2	-	1	2	-	-	9
SO59	2	-	-	-	1	1	2	-	1	1	1	1	-	-	10
SO67	1	-	-	1	1	1	1	1	2	1	1	1	-	-	11
SO68	1	-	-	-	1	1	1	-	1	1	1	1	-	-	8
SO69	1	-	-	-	2	1	1	-	1	1	1	1	1	-	10
SO77	-	-	1	-	1	2	1	2	-	1	2	1	1	1	13
SO78	-	-	2	-	1	2	1	-	-	1	1	2	1	-	11
SO79	-	-	2	1	1	2	1	-	-	-	1	2	1	1	12
TOTAL	16	10	31	23	40	39	38	30	29	27	43	49	28	25	428
% OF TOTAL	3.7	2.3	7.2	5.4	9.4	9.1	8.9	7.0	6.8	6.3	10.1	11.5	6.5	5.8	100
% OF 38	1.41	0.97	2.74	2.04	3.57	3.46	3.38	2.66	2.58	2.39	3.84	4.37	2.47	2.20	38
NO. OF SAMPLES	2**	1	3	2	4	3	3	3	3	2	4	4	2	2	38

** Rounded up to achieve total of 38 samples

The full descriptions of the features coded in the above table are: **L** = Limestone with shallow soils **M** = Meres

N = Canals & large rivers   **P** = Peatlands   **Q** = Quarries & mines   **R** = Ravine woods   **S** = Scarp woods

T = Trust reserves & other protected sites   **U** = Upland heath , moor & rough grazing   **V** = Valley & lowland mires & heath

W = Woods, planted coniferous   **X** = Extensive arable farms with large fields   **Y** = Industry & urban development

Z = Transport infrastructure including disused railways & railway sidings

FRAMEWORK RECORD CARD

For data collection from framework sites a Framework Record Card has been developed, shown in Appendix 2 as a completed example. The card was field-tested by eight Shropshire entomologists (in addition to the authors), and suggestions for improvement were offered by four; these are incorporated into its design. The record card draws on the Butterfly Site Recording Form developed by Butterfly Conservation with the Biological

Records Centre (Figure 1.4 in Harding *et al*., 1995), amended to reflect the specific context of the framework and aims of analysis. The Framework Record Card thus omits observer's address and nearest town and adds major feature sampled, altitude, fieldwork methods used, and weather conditions. Abundance ranges follow those of Cham *et al*. (2014) for dragonfly recording as we feel they show more typical patterns of invertebrate abundances, especially at the lower end of the range, than those used by Harding *et al*. (*loc. cit*.) for butterflies. Importantly, the Framework Record Card allows the presence and abundance of each species to be correlated with each habitat sampled on a site. Habitats are thus site-specific, and we omit the general habitat categories used by Harding *et al*. (*loc. cit*.). This Framework Record Card may be further adjusted by Project Co-ordinators to meet the needs of recording specific taxa, as discussed below.

<div align="center">APPLYING THE FRAMEWORK</div>

The framework has been developed for use by a Project Co-ordinator organizing fieldwork for a recording programme. In the Shropshire model it requires recording visits to selected sites in 38 hectads, for which we suggest two site selections, shown in Appendix 1. These are not interchangeable as the two selections sample different ecological features in nearly all hectads: all A Sites should thus be sampled, or all B Sites, or all of both. These selections are not prescriptive; a Project Co-ordinator may substitute a different site in a hectad, provided that the same feature is sampled in that hectad, or may select a completely new suite of sites using the data in Figure 1 and Table 1.

A recording programme using this framework can be adapted to targeted taxa as follows:

Length of programme. This should be long enough to fulfil programme aims but not so long as to be compromised by mobility of species; e.g. a five-year recording period used by Asher *et al*. (2001) for butterflies did not eliminate potential evidence of dispersal from breeding sites. For mobile taxa the length of a programme should ideally be as short as is consistent with reasonable coverage.

Timing of visits. This should reflect the phenologies of targeted taxa. For example, to record a representative range of microlepidoptera species on a site, fieldwork should be carried out in two time-frames (spring–mid July; mid-July–October) (authors' data). Recording of other taxa may necessitate different timing structures. The framework for Shropshire requires 38 or multiples of 38 recording visits to be completed within the duration of the recording programme.

Time spent recording. A standardized recording time per visit should be established, taking account of difficulties in finding targeted taxa and time needed to sample less diverse sites adequately: for example, 60 minutes per visit may be enough to record a representative sample of invertebrates on an arable site. Standardized timing is likely to result in different proportions of available species being detected on less and more diverse sites; but representativeness of a site's fauna rather than comprehensiveness should be the aim.

Fieldwork methods. These should be standardized for all samples and incorporate methods normally used to detect the targeted taxa.

Personnel. In a structured survey of the flora of Ashdown Forest, Rich *et al*. (1996) sought to improve detection of species and reduce bias arising from different levels of recorders' expertise by involving more than one field-worker in recording each sampling unit. A similar approach is recommended for programmes using the present framework.

Decisions on these issues made by a Project Co-ordinator may require corresponding adjustments to the Framework Record Card.

When carrying out fieldwork within this framework, recorders should ensure that only the target ecological feature is sampled in each hectad. This will be pre-determined by the framework and should be notified to recorders by the Project Co-ordinator. The ecological feature may involve more than one habitat, and species observed in each habitat should be recorded separately on the Framework Record Card. Parts of a hectad that do not contain the specified ecological feature should not be recorded on the Framework Record Card.

At sites abutting hectad or vice-county boundaries recorders should ensure that only the target hectad is sampled. Such sites are italicized in Appendix 1.

A recorder who continues recording at a site beyond the time period set for the recording visit should complete the Framework Record Card for the set time period only. Records made beyond that time should not be entered on the Framework Record Card.

ANALYZING THE DATA

The framework is designed to give good representative data for 14 ecologically significant features in studies of terrestrial fauna. It does not offer wide spatial coverage of hectads. For distribution atlases and other studies where this is important the framework may be used as a discrete data collection programme within wider fieldwork that may also collect data from unstructured recording. In these circumstances it is important that framework data are collected and analysed separately from other data.

Framework sites do not typically represent single habitats but usually have more than one habitat; and different sites representing an ecological feature may sometimes differ widely in their habitats, e.g. reserves/other protected sites; industry/urban development sites. Separate recording of site habitats is included on the Framework Record Card, allowing analyses on two sets of criteria: (a) habitat and (b) hydrology/land use. The following analyses are suggested among others:

Relationships to altitude and climate. In a Shropshire context, Distribution A sites (Appendix 1) include 4-5 above 425m and 6-5 at 305-425m (depending on site chosen in SO37), 3 at 185-305m, 17 at 60-185m and 8 below 60m; numbers for Distribution B sites are 5, 5, 4, 20 and 4 respectively. These numbers are considered to be a reasonable representation of the range and distribution of altitudes in vc40, where altitude is a useful proxy measure for regional climate.

Relationships to habitats. The Framework Record Card requires data to be separated according to habitats represented on a site. This significantly improves on common practice among amateur entomologists, who seldom record habitat data, or aggregate data from different habitats, as in Harding *et al*. (1995).

Relationships to hydrology and land use. While ecological studies of taxa in relation to habitats are standard, this other focus is less so. The framework offers separate opportunities for both analyses.

Identification of communities. The study of vegetation communities has developed over many decades but invertebrate studies remain largely focused on the individual species. The framework invites the possibility of identifying invertebrate communities associated with hydrology/land use features and/or habitats.

SUMMARY

This framework has been developed to meet the needs of structured sampling of selected ecologically significant features, using vc40 Shropshire as an example. It can be used as a sampling programme in its own right or superimposed on a wider recording programme as a data subset for separate analysis. It is designed specifically for studying terrestrial species and to be completed, with iterations, by relatively few fieldworkers over a relatively short time-frame, e.g. 2-5 years.

In developing the framework we have sought a flexible model that may be used in a range of contexts. While its initial motivation is to meet the needs of invertebrate recording and analysis, the framework may also be appropriate for studies of other taxa. It would further allow a different selection of ecologically significant features, or a different selection of sites from those suggested in Appendix 1, including a random selection. In site selection, however, we have found that issues of accessibility by public rights of way and available parking impose strong constraints, so that features allocated to hectads in Figure 1 sometimes have no public access. The great majority of sites suggested in Appendix 1 are publicly accessible, and only a very few require landowners' permission to visit. Finally, our methodology may also be adapted to studies of other vice-counties or geographical areas. In this last situation, however, we should note that our approach owes much to Table 3.6 in Sinker *et al*., (1985) (Figure 1 in this paper), which has been our starting point. It is fortunate that this information is available; should our approach be used elsewhere the appropriate environmental profiles would first have to be established before any similar framework development could be initiated.

Ecological Flora of the Shropshire Region, widely referred to as 'Sinker's Flora', was a ground-breaking work that informs and inspires to this day. Our paper is just one example of this.

REFERENCES

Asher, J., Warren, M., Fox, R., Harding, P., Jeffcoate, G. & Jeffcoate, S. (2001). *The millennium atlas of butterflies in Britain and Ireland*. Oxford University Press, Oxford.

Blunt, G. (2014). *The smaller moths of Shropshire: their status, distribution and ecology*. Field Studies Council, Telford.

Boardman, P. (2014). *A provisional atlas of the shieldbugs and allies of Shropshire*. Field Studies Council, Telford.

Boardman, P. (2016). *Shropshire craneflies*. Field Studies Council, Telford.

Cham, S., Nelson, B., Parr, A., Prentice, S., Smallshire, D. & Taylor, P. (eds.) (2014). *Atlas of dragonflies in Britain and Ireland*. Field Studies Council, Telford.

Harding, P.T., Asher, J. & Yates, T.J. (1995). Butterfly monitoring 1 – recording the changes. In Pullin, A.S. (ed.) (1995). *Ecology and conservation of butterflies* pp. 3-22. Chapman & Hall, London.

Isaac, N.J.B. & Pocock, M.J.O. (2015). Bias and information in biological records. *Biological Journal of the Linnaean Society* **115**(3), 522-531.

Isaac, N.J.B., van Strien, A.J., August, T.A., de Zeeuw, M.P. & Roy, D.B. (2014). Extracting robust trends in species' distributions from unstructured opportunistic data: a comparison of methods www.biorxiv.org/content/biorxiv/early/2014/07/10/006999.full.pdf (accessed 12 December 2018).

Jones, N. & Cheeseborough, I. (2014). *A provisional atlas of the bees, wasps and ants of Shropshire*. Field Studies Council, Telford.

Rich, T., Donovan, P., Harmes, P., Knapp, A., McFarlane, M., Marrable, C., Muggeridge, N., Nicholson, R., Reader, M., Reader, P., Rich, E. & White, P. (1996). *Flora of Ashdown Forest*. Sussex Botanical Recording Society.

Sinker, C.A., Packham, J.R., Trueman, I.C., Oswald, P.H., Perring, F.H. & Prestwood, W.V. (1985). *Ecological flora of the Shropshire region*. Shropshire Trust for Nature Conservation, Shrewsbury.

APPENDIX 1

SUGGESTED DISTRIBUTIONS OF FEATURES AND SITES WITHIN THE FRAMEWORK

NB: italics denote that the site is adjacent to a hectad or vice-county boundary. For full description of Features, see main text.

Distribution A

Hectad	Feature	Suggested site(s) with grid refs
SJ22	**P** – Peatlands	Sweeney Fen SJ274250
SJ23	**W** – Woods, planted coniferous	*Selattyn Hill[* SJ2534 (park at SJ252340)
SJ30	**Q** – Quarries & mines	Poles Coppice SJ3904 or Nills Hill quarry SJ3905
SJ31	**T** – Trust reserves	Holly Banks reserve SJ3318
SJ32	**X** – Extensive arable farms	Footpath Aston Locks-West Felton SJ3325 or farmland between Rednal & railway SJ3627 from SJ363278
SJ33	**N** – Canals & large rivers	*Canal at Lockgate Bridge- Lower Frankton* starting at SJ369311
SJ40	**T** – Trust reserves	Earl's Hill reserve SJ4004
SJ41	**Y –** Industry/urban development	Shrewsbury: Longdon Rd. cemetery SJ4811 or Shropshire Wildlife Trust garden SJ498123
SJ42	**M** – Meres	Fenemere SJ4422, Marton Pool SJ4423,, Berth Pool SJ4223 or Birchgrove Pool SJ4323
SJ43	**P** – Peatlands	*Bettisfield Moss* SJ4734, SJ4835
SJ50	**N** – Canals & large rivers	R. Severn at Cressage SJ5904, SJ5905
SJ51	**Z** – Transport infrastructure	Severn Way along road from Poynton to Poynton Green SJ570178 to SJ568188
SJ52	**W** – Woods, planted coniferous	Corbet Wood, Grinshill SJ5223
SJ53	**V** – Valley & lowland mires & heath	Prees Heath SJ5536, SJ5636
SJ60	**L** – Limestone with shallow soils	Windmill Hill, Much Wenlock SJ6201
SJ61	**Y –** Industry/urban development	Telford: Silkin Way (Bratton to Tee Lake) starting at SJ633140
SJ62	**X** – Extensive arable farms	Fields at Dodecote Grange from parking spot at SJ680225
SJ63	**X** – Extensive arable farms	Fordhall Farm arable area SJ6432
SJ70	**Z** – Transport infrastructure	Telford: roadsides at *Halesfield* SJ7104, SJ7105 or *Tweedale* SJ7004
SJ71	**Q** – Quarries & mines	Granville CP reclaimed spoil tip SJ7113
SJ72	**N** – Canals & large rivers	*Goldstone-Soudley canal* SJ7029, SJ7128, SJ7227
SO27	**W** – Woods, planted coniferous	Kinsley Wood SO2972
SO28	**U** - Upland heath/moor, grazing	*Lower Short Ditch* SO2288
SO37	**W** – Woods, planted coniferous	Black Hill SO3278, SO3279, SO3378, SO3379 or Hopton Titterhill SO3477, SO3577
SO38	**S** – Scarp woods	Clunton Coppice SO3480
SO39	**T** – Trust reserves	*Nipstone Rock* SO3596
SO47	**S** – Scarp woods	*Lower Whitcliffe* SO475738
SO48	**S** – Scarp woods	Harton Hollow SO4887, SO4888
SO49	**U** - Upland heath/moor, grazing	Long Mynd summit ridge SO4193, SO4194
SO57	**Q** – Quarries & mines	*Titterstone Clee quarries* SO5977
SO58	**X** – Extensive arable farms	Diddlebury arable fields north of parking spot at SO508854
SO59	**L** – Limestone with shallow soils	Grassland at Lea Quarry SO5998 or edge of *Blakeway Coppice* SO5897, SO5998
SO67	**V** – Valley & lowland mires & heath	Cramer Gutter SO7964, SO7965
SO68	**U** - Upland heath/moor, grazing	*Rough grassland at Brown Clee* SO6085
SO69	**Q** – Quarries & mines	Bridgwalton quarries/Pam's Pools SO6891, SO6892
SO77	**R** – Ravine woods	*Longdon Wood at Dowles Brook* SO7476, SO7576
SO78	**R** – Ravine woods	Borle Brook SO7282, SO7383
SO79	**R** – Ravine woods	*Badger Dingle* SO7699, SO7799

Distribution B

Hectad	Feature	Suggested site(s) with grid refs
SJ22	**L** – Limestone with shallow soils	Llynclys Hill SJ2723
SJ23	**Q** – Quarries & mines	*Craignant quarry SJ252349*
SJ30	**R** – Ravine woods	*Hope Valley SJ3300, SJ3301*
SJ31	**W** – Woods, planted coniferous	*Nesscliffe Hill Country Park SJ3819*
SJ32	**P** – Peatlands	Rednal Moss via gate at SJ34812736
SJ33	**Q** – Quarries & mines	*Ifton Meadows SJ3137*
SJ40	**Z** – Transport infrastructure	*Redhill old railway sidings SJ4609*
SJ41	**Q** – Quarries & mines	Shrewsbury: Radbrook post industrial site SJ4710
SJ42	**S** – Scarp woods	Wood at Lower Rd., Myddle SJ4723
SJ43	**M** – Meres	Colemere SJ4333 or The Mere (Ellesmere) SJ4034, SJ4035
SJ50	**R** – Ravine woods	Stevenshill Wood SJ5503
SJ51	**V** – Valley & lowland mires & heath	*Shawbury Heath southern part SJ5419*
SJ52	**V** – Valley & lowland mires & heath	*Shawbury Heath northern part SJ5320, SJ5420*
SJ53	**T** – Trust reserves	Brown Moss SJ5639
SJ60	**R** – Ravine woods	Benthall Edge Wood SJ6603
SJ61	**P** – Peatlands	Weald Moors at Wall Farm SJ680179
SJ62	**Z** – Transport infrastructure	Hodnet-Wollerton disused railway SJ6228, SJ6229
SJ63	**N** – Canals & large rivers	Market Drayton: canal SJ6735 to SJ6738 or R. Tern SJ6733
SJ70	**Y –** Industry/urban development	Stafford Park industrial estate SJ7108
SJ71	**N** – Canals & large rivers	Newport canal basin SJ7419
SJ72	**X** – Extensive arable farms	Harper Adams arable SJ7120, SJ7121 parking at SJ715214 or SJ707211, or Shropshire Lavender at Pickstock SJ7223
SO27	**U** - Upland heath/moor, grazing	Offa's Dyke at Lanfair Hill SO2579
SO28	**W** – Woods, planted coniferous	*Long Plantation SO2087 to SO2188*
SO37	**S** – Scarp woods	Bucknell Wood deciduous wood SO339736
SO38	**S** – Scarp woods	Sunnyhill Wood, Bury Ditches SO3283
SO39	**U** - Upland heath/moor, grazing	Stiperstones summit ridge SO3697 to SO3698
SO47	**X** – Extensive arable farms	Bromfield arable SO485770 to SO495768
SO48	**W** – Woods, planted coniferous	Callow Hill at Flounder's Folly SO4585, SO4685
SO49	**T** – Trust reserves	Long Mynd at Wild Moor SO4296
SO57	**Y –** Industry/urban development	Ludlow castle walk from SO509745
SO58	**Q** – Quarries & mines	*Abdon Burf quarry, Brown Clee SO5986*
SO59	**L** – Limestone with shallow soils	Marked Ash meadows SO5190
SO67	**U** - Upland heath/moor, grazing	Clee Hill *Cornbrook*-Doddington road SO6075 to SO6176
SO68	**W** – Woods, planted coniferous	*Woolers Wood, Brown Clee SO6086*
SO69	**X** – Extensive arable farms	Spoonhill Wood arable north from SO609955
SO77	**T** – Trust reserves	*Knowles Coppice meadow SO763765*
SO78	**X** – Extensive arable farms	Arable fields nr. Dudmaston sawmill SO7689
SO79	**N** – Canals & large rivers	R. Severn north of Bridgnorth SO7193 to SO7197

APPENDIX 2
FRAMEWORK RECORD CARD (completed example)

Date 5th May 2019			**Hectad** SJ43	**Location** Bettisfield Moss

Major feature sampled (*pre-determined*) ł P
ł L = limestones with shallow soils   M = mere   N = canal/river   P = peatland   Q = quarry/mine   R = ravine wood
S = scarp wood   T = reserve/protected site   U = upland heath/moor/rough grazing   V = valley mire/lowland heath
W = plantation wood   X = arable farmland   Y = industry/urban   Z = transport infrastructure

Monad(s) SJ4735, SJ4835	**Altitude** 85m

Details of habitat(s) sampled
H1 Deciduous woodland fringing open heath. Much birch (both species)
H2 Open heath with dry-heath and wet-heath vegetation
H3 _

Recorder(s) Ian Thompson, Godfrey Blunt

Methods used (B = beating, S = sweep-netting, V = visual search) B, S, V

Weather Dry, cloudy with sunny spells.   **Time spent recording** 1hr

Habitat	Taxon	Col 1	Col 2	Col 3	Comments inc. details of foodplant(s) used
H1	Two-spot ladybird	B	A		Beaten from alder in shaded woodland
H1	Birch shieldbug	B	A,L		Beaten from silver birch
H1	Seven-spot ladybird	B	A.L	C	Inc. mating pair and larva on common nettle
H1	Harlequin ladybird	A	A		On fence post in shaded woodland
H2	Birch shieldbug	A	A		On downy birch sapling in centre of Moss
H2	Sloe bug	A	A		Swept from rough grass beside track
H2	Seven-spot ladybird	C	A,L		Congregation on trackside shrubs

Use the following codes:
Habitat column: **H1, H2, H3** = habitats as described separately above
Col 1 (Number)   **A** = 1   **B** = 2-5   **C** = 6-20   **D** = 21-100   **E** = 101-500   **F** = 500+
Col 2 (Stage)   **A** = adult   **T** = teneral   **P** = pupa/cocoon   **L** = larva/nymph/immature   **E** = egg
Col 3 (Breeding evidence) **C** = courtship/mating   **O** = ovipositing   **M** = mine(s)   **G** = gall(s)