Botanical recording, distribution maps and species frequency

T. C. G. RICH

The Annex, Newgale Farm, Priory Road, Forest Row, East Sussex, RH18 5JD

and

P. A. SMITH

University of Bath, School of Mathematical Sciences, Claverton Down, Bath, Avon, BA2 7AY

ABSTRACT

A standardised botanical survey technique was used to investigate sources of variation in botanical surveys used to produce distribution maps and assess species frequency. The most significant sources of variation between visits were the individual botanists; the number of habitats visited and length of route recorded also explained some variation. The number of records for each species increased proportionally with the amount of recording as species were encountered in essentially a random manner. The results demonstrate that as recording for atlas projects is unlikely to be comprehensive, care should be taken to obtain even coverage and minimise the variations in recording. Recommendations to improve the quality of atlas data are given.

KEYWORDS: Atlas maps, botanical surveys, plant distribution.

INTRODUCTION

Detailed information on the distribution of plants in Britain has been published for over 300 years. The quality of the information available has changed from simple lists of localities (e.g. Ray 1689), to catalogues of vice-counties (Watson 1883), or more recently to the "dot" maps such as those in the *Atlas of the British flora* (Perring & Walters 1962) and county tetrad (2 km × 2 km square) atlases (e.g. Hall 1980; Philp 1982) based on grid systems of different sizes. The use to which such data have been put has also changed from simple curiosity to phytogeography, and more recently to applied nature conservation and environmental impact assessment.

Dot maps are currently the popular means of presenting information about plant distributions. The grid systems delimit the areas to be recorded, and the resulting species distribution maps allow simple comparisons of species' distributions with environmental variables such as climate or soil types. They also provide information which has been used to assess frequency, especially rarity. For instance, nationally rare plants are those which occur in 1–15 hectads (10 km × 10 km squares) in the *Atlas of the British flora*, and nationally scarce species are those which occur in 16–100 hectads (Nature Conservancy Council 1989). Similar systems have also been applied at a county level; species with five or fewer tetrad records in Sussex (Hall 1980) are termed "very rare", those with 6–20 records are "rare", and so forth.

An assumption of using dot maps to assess frequency is that the number of dots estimates the frequency of the plant, and it is generally accepted that overall, the more records for a species, the more common it is likely to be. However, as the surveys for national or county atlases are not comprehensive, the number of dots is a relative and not an absolute estimate of frequency. Dot maps also give no indication of the actual number of plants, or, more importantly for conservation, of populations, since any one dot may represent anything from one plant or population to many thousands.

A second common assumption is that atlas data are equally representative of all species. Recent work has shown that this assumption cannot be justified as the recording behaviour and ability of individual botanists, the types of plants being recorded, and the survey techniques used, all give rise to marked variations in the number of records obtained for different species (Rich & Woodruff 1992).

The recorders who collect the data markedly affect the number of records. In many atlases, hectads or tetrads are usually allocated to individual recorders, and the differences in effort and expertise between recorders may result in localised concentrations of records or under-recorded areas. For instance, the area around the Moray Firth in Scotland was well recorded for the *Atlas of the British flora*, whilst South Wales was very under-recorded (Rich & Woodruff 1990). Similarly, the repeated concentrations of tetrad records within the same hectad boundaries for families such as Polygonaceae or Poaceae in Shropshire (Sinker *et al.* 1985) can only be due to recording. It is a common experience that most botanists know some species better than others, and Woodell (1975) demonstrated that independent visitors add significantly more species than repeat visits by the same recorder.

In some surveys where coverage is poor, the distribution maps are more representative of the distribution of recorders rather than of the species. This is well known for critical genera such as *Taraxacum* or *Rosa* (e.g. Graham & Primavesi 1993), and is probably also partly true for many other "difficult" groups such as some grass genera, or even conspicuous spring-flowering species such as *Anemone nemorosa* L. in remote areas (Rich & Woodruff 1990, 1992).

The time spent recording strongly affects the number of species found (Rich & Woodruff 1990, 1992). It is difficult to know how long should be spent recording to obtain reasonable coverage, and most atlases are recorded on an ad hoc basis with little attempt to control how much recording is actually done. Generally, the recorders carry on recording until they run out of time, or the law of diminishing returns comes into play and they feel further recording would be better directed to another area to improve overall coverage.

Interpretation of frequency also depends on the scale at which it is measured. For instance in Kent, *Ranunculus lingua* L. and *Teesdalia nudicaulis* R. Br. have both been recorded from 15 tetrads (Philp 1982). The former, with a widespread, more or less random, scatter of records had been recorded from eleven hectads. The latter, which has a clumped distribution centred on Dungeness, has only been recorded from three hectads. This also shows that the type of distribution shown by a plant can also affect the number of records; the frequency of plants with dispersed distributions may be relatively over-represented compared to those with clumped distributions.

There are two main ways to provide good, comparative atlas data. First, record all areas comprehensively so that the records are independent of the botanists. This is the ideal approach but is impractical for anything more than very small areas, and requires large resources and botanists of consistently high quality. Also, as the actual number of species present in an area is not known, judgement of what is "comprehensively recorded" is usually subjective. From the experience of studies which have been assessed using the species-area relationship, comprehensive coverage is unlikely to be achievable; Dony (1976) managed 86% coverage for the *Bedfordshire plant atlas* and Rich & Woodruff (1990) found 49% coverage for the *Atlas of the British flora* (Perring & Walters 1962) and 56% for the B.S.B.I. Monitoring Scheme.

Second, use a standardised survey method where recording bias is minimised and equal effort is put into each area. Although the records are accepted from the outset as not comprehensive, the relative species frequencies should be representative of the flora as a whole provided equal treatment is given to all. Good comparable coverage can be obtained even with botanists of varying abilities, and a defined recording target is a useful incentive. There have been few attempts at standardised surveys. Good (1948) carried out a standard site survey in Dorset. The B.S.B.I. Monitoring Scheme was a standardised sample survey of Britain and Ireland but returned far from uniform coverage (Rich & Woodruff 1990). A standardised 1-km square survey, the *Flora of Ashdown Forest* (Rich *et al.*), is currently in preparation using experience gained from the results of the work presented in this paper.

Given the ad hoc basis of recording for most atlases, there has also been surprisingly little analysis to assess how representative the atlas data are, how they are affected by variations in recording, or how reliable the numbers of records are as an indication of the frequency of a species. A number of techniques have been developed to try to smooth the results of incomplete surveys (e.g. Le Duc, Hill & Sparks 1992; Osborne & Tigar 1992), but there have been few studies of how to improve the quality of the original data (e.g. Woodell 1975).

The object of this paper is therefore to investigate sources of variation in recording by using a standardised survey technique. The method we have chosen is to analyse the variation observed in repeated visits to tetrads, which correspond to the way atlases are currently recorded. In particular, factors affecting the number of species recorded, the relationships between different recording visits, and the effect of additional recording are addressed. The results are then used to make recommendations for improving the quality of atlas data.

We have chosen not to investigate how the number of species recorded by individuals or groups of botanists varies under standard conditions. There can be little doubt that a pair of botanists will record more than a single botanist, and perhaps three botanists more than two. Botanists should be free to choose their companions as recording is often a social event and must remain rewarding and enjoyable for all.

METHODS

Tetrads SU/8.2 K, L, Q and R (following standard B.S.B.I. tetrad nomenclature; Ellis 1986) were selected for survey near Midhurst, West Sussex (v.c. 13), on 18 and 19 July 1992. The tetrads were selected for convenience of access, the range of habitats present, and because T.C.G.R. knew them intimately and could verify the records. 29 volunteers with a range of botanical abilities representative of many national and county Flora projects recorded on one or both days. The weather was largely dry with light cloud, and did not influence the results.

Tetrad K contained a large area of heathland (Iping Common), areas of conifer plantation and improved farmland; this was selected as a species-poor tetrad for comparison with the other tetrads. Tetrads L and R were species-rich tetrads with pasture, arable, hedges, sunken lanes, semi-natural woodland, the River Rother, and villages. Tetrad Q was intermediate in apparent richness, with conifer plantations, semi-natural broad-leaved woodland, farmland and a disused brickworks and rubbish tip on the edge of Midhurst. All four tetrads had over 300 species recorded in them for the *Sussex plant atlas* (Hall 1980).

To minimise variations due to individual recorders, a standardised recording technique was used. With a few minor exceptions, botanists worked in pairs and recorded for 2.5 hours in each tetrad. For subsequent sessions, individuals were rotated to different tetrads and paired with a different botanist. The recorders selected their own areas to survey within the allocated tetrad and marked the areas recorded on a map, and filled in details on the record cards designed to collect information about the recording. The length of the route searched (which gives an estimate of the total area covered) and the number of habitats recorded were noted. Recorders were asked not to discuss the project in detail during the course of the work.

Most species were identified in the field, but a few specimens were collected and checked by T.C.G.R. and others at the end of the recording sessions. Casuals and obviously naturalized species were recorded, but deliberately planted species were not recorded. Of the critical taxa, data for *Hieracium sabaudum* and *H. umbellatum* were included as they are the two common species known by many southern botanists, but two records of *Rubus procerus* and *R. spectabilis* were excluded from the analysis; no *Taraxacum* microspecies were recorded. The species recorded were checked and analysed in a computer database.

Each recorder was ranked for botanical ability on a scale between 1 (inexperienced) to 5 (experienced) by T.C.G.R., based on his knowledge of their expertise as botanists. A "recording quality score" was calculated for each card by adding the ranks of the two recorders together.

RESULTS

Despite each pair having a map of the tetrads and being aware that the recording was being analysed, two pairs strayed out of their tetrads. It was possible to correct one card, but the other was rejected. Table 1 summarises the general results. A total of 7254 records representing 634 species were collected on 41 cards, of which twelve were obvious errors (0·15% error rate). The number of species recorded per card ranged from 69 to 257. Five species (0·8%) were recorded on every card whilst 155 (24%) were recorded only once. Not every species which was known to be present in the area was recorded, and many species new to each tetrad were found. The routes noted on the maps showed that some parts of each tetrad were covered by several visits, whilst other parts were not visited at all.

'ABLE GENERAL RESULTS FROM THE TETRAD SURVEY AT MIDHURST, WEST SUSSEX
Standard errors are given in brackets.

	Tetrad				
	K		Q	R	Total
Number of cards	11	10	9	11	41
Total number of records	727	1807	1642	2078	7254
Mean length (km) of route recorded	3·0 (0·4)	3·2 (0·4)	2·9 (0·3)	2·8 (0·3)	
Mean no. habitats recorded	6·6 (0·9)	7·0 (0·7)	6·1 (0·6)	8·4 (0·6)	
Mean no. species recorded	157 (15·5)	181 (15·8)	182 (12·2)	189 (11·9)	
Mean recording quality	6·0 (0·6)	6·9 (0·5)	7·0 (0·4)	6·5 (0·5)	
Total no. species	404	426	413	428	634

The number of species recorded in an area is determined first by the actual number of species present, and secondly by the recording, which determines which species are actually found. During the survey the number of species was constant for each tetrad, so that differences within tetrads can only be explained by variation in recording. The variation in the number of species recorded was examined in relation to the following four variables:

1. differences between tetrads;
2. differences between recorders;
3. length of recording route; and
4. number of habitats visited.

DIFFERENCES BETWEEN TETRADS

Although tetrad K was chosen because it had large areas of species-poor heathland, there was little difference in the total number of species recorded for each tetrad, and no significant difference in the number of species per card between tetrads (ANOVA, $p = 0{\cdot}43$, d.f. = 40). Similarly there were no significant differences between the tetrads in the number of habitats recorded per card (ANOVA, $p = 0{\cdot}904$, d.f. = 40), or the recording quality score (ANOVA, $p=0{\cdot}549$, d.f. = 40). Hence all further analysis treats the four tetrads as a homogeneous area unless otherwise stated.

FACTORS AFFECTING THE NUMBER OF SPECIES RECORDED

The effect of individual botanists on the number of species is known to be a major source of variation (Rich & Woodruff 1990, 1992). Despite attempts to minimise this, the recording quality score still explained the most variation in the number of species recorded during the 41 visits (Fig. 1; $r^2 = 0{\cdot}506$, $p<0.001$). Both the length of recording route (Fig. 2; $r^2 = 0{\cdot}148$, $p=0{\cdot}017$) and the number of habitats visited (Fig. 3; $r^2 = 0{\cdot}220$, $p=0{\cdot}005$) also explained significant variation in the data. However, these latter two are not independent as the number of habitats visited increased as the length of the recording route increased, and once the number of habitats has been accounted for, the length of recording route contributes little extra in explaining the variation in the number of species found.

RELATIONSHIP BETWEEN RECORDING TRIPS

The cumulative increase in the number of species recorded for the whole area is shown in Fig. 4. Initially the number of species rises rapidly, and thereafter the rate of addition declines as the number of cards increases. With one exception, every card contributed some unique species to this curve. The curve does not reach an asymptote even after 41 recording visits to the whole area, suggesting more species would be found by further recording. A comparison with records published in Hall (1980), Briggs (1990), records held by T.C.G.R., Mrs P. Donovan, F. Rose and species listed in a subsequent exercise in 1993 indicates that at least another 88 species (including spring-flowering species and casuals) have been recorded for these tetrads since 1966.

The 24% of the species which were only recorded once during the survey reflects a real problem for a field recorder trying to get comprehensive coverage. Both rare and common species may be widely scattered and unevenly distributed around each recording area, and the probability of

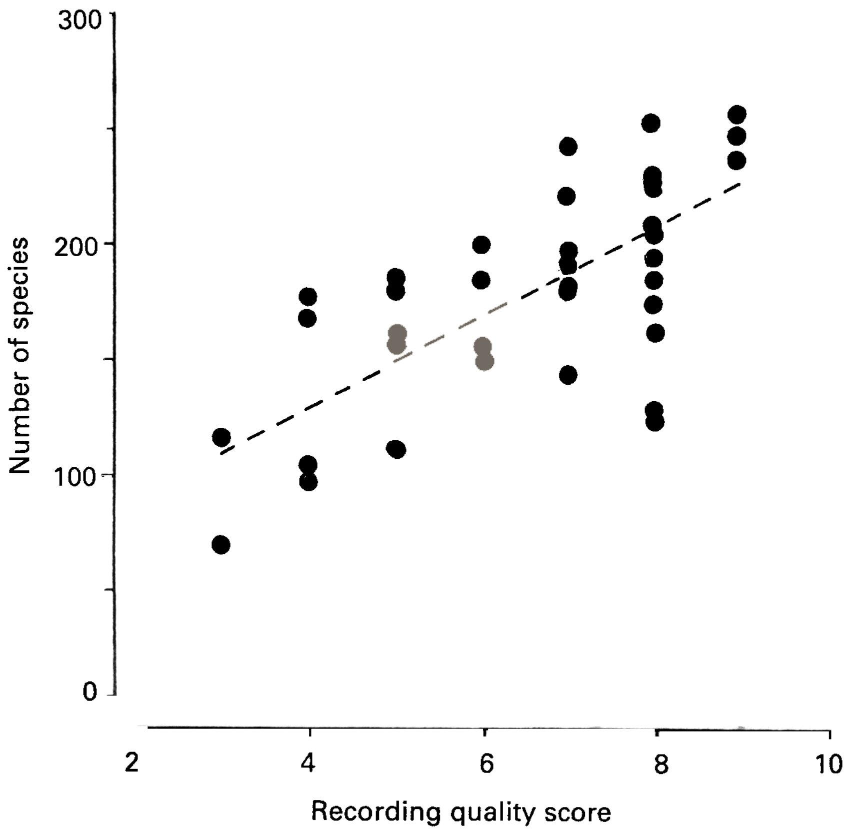

FIGURE 1. Relationship between the number of species recorded and the recording quality score for each card during 41 visits to tetrads at Midhurst, West Sussex. Each botanist was ranked between 1 (inexperienced) and 5 (experienced), and the ranks added together to give the recording quality score (a high score indicates more experienced botanists). A linear regression line is fitted to indicate the variation in the data.

recording them is simply a function of time and ensuring as many habitats and areas are recorded as possible.

As the routes recorded in most surveys overlapped with other visits to the same tetrad, the similarities between surveys were investigated to establish the most efficient way of adding new species. The numbers of species in common between pairs of recording visits in tetrad K, expressed as a percentage of the total number of species recorded from both visits are given in Table 2 (upper right). They range from 16·3% to 55·7% with a mean of 38·1%. As more species in common would be expected if botanists recorded the same route, the percentage of the combined total of the route in common was also calculated (Table 2, lower left), which ranged from 0% to 23·8% with a mean of 6·8%, surprisingly low figures. The percentage of the route in common was a reasonable predictor of the percentage of species in common between visits (Fig. 5; $r^2 = 0{\cdot}172$, $p=0{\cdot}002$).

EFFECT OF FURTHER RECORDING

The effect of doubling the recording effort on the number of species recorded and on the number of records for each species (an estimate of abundance) was investigated. For each species, the number of records from a random sample of 21 cards was compared with the number of records from all 41 cards (Fig. 6). This shows a linear fit ($r^2 = 0{\cdot}958$, $p<0{\cdot}001$), which suggests that the number of records of each species increases proportionately with the amount of recording, and implies that the

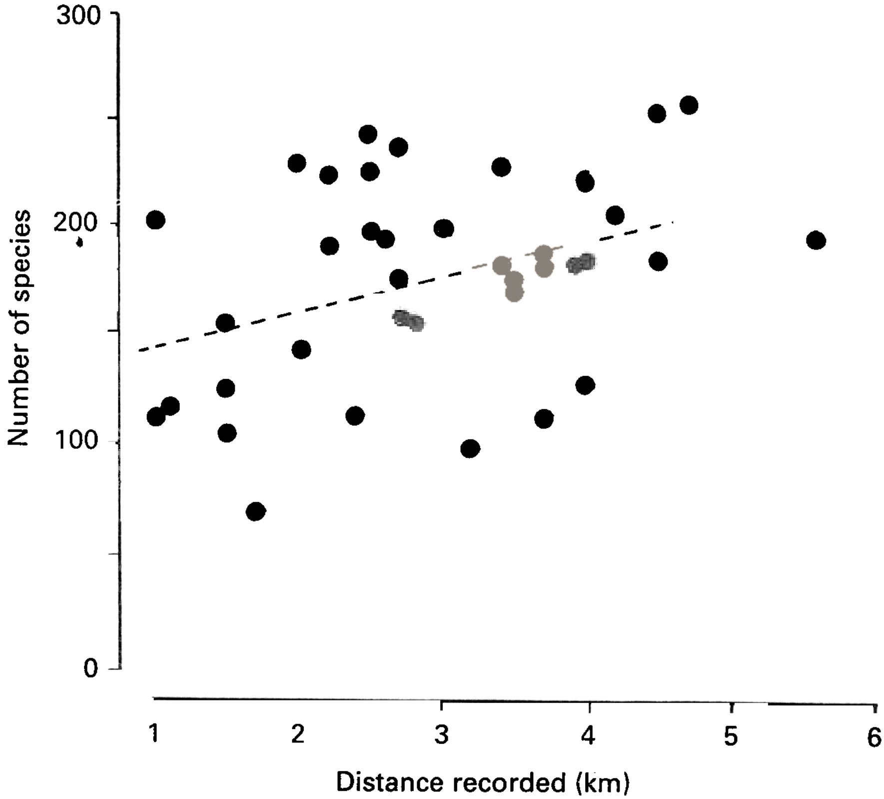

FIGURE 2. Relationship between the number of species recorded and the distance recorded (km) on each card during 41 visits to tetrads at Midhurst, West Sussex. A linear regression line is fitted to indicate the variation in the data.

species are encountered as a random sample from the available pool, and not in any systematic or non-random manner. There is however more variation for rarer species than common species, suggesting that the number of records is a poorer measure of abundance for rarer species than common species.

The data can also be used to see how an increase in recording effort affects the species-abundance distribution. According to Raunkiaer's law (Jaccard 1908; Raunkiaer 1918), there are comparatively many rare (low abundance) species, and possibly comparatively many common (high abundance) species, but relatively few in the middle (medium abundance). As recording (sampling) intensity increases, species "move" from the left of the histogram to the right, whilst maintaining the central dearth of species. This is shown for the random sub-sample and the complete data in Fig. 7. The relationship in Fig. 6 shows that this result is produced when all species are affected equally by the increased recording.

Rich & Woodruff (1990) corrected for differences in recording effort between the *Atlas of the British flora* and the B.S.B.I. Monitoring Scheme using a simple relationship derived from a crude analysis. The 1992 survey provided an opportunity to examine the relationship more rigorously. The effect of further recording on the number of tetrads in which a species was recorded was examined by calculating, for each species recorded in 1, 2, or 3 tetrads from a random sample of 21 visits in all tetrads, the mean number of tetrads in which they were recorded from 41 visits (that is, from doubled recording effort). It is not possible to estimate the mean number of tetrads recorded for species not originally recorded during the 21 visits since it is not known how many more species

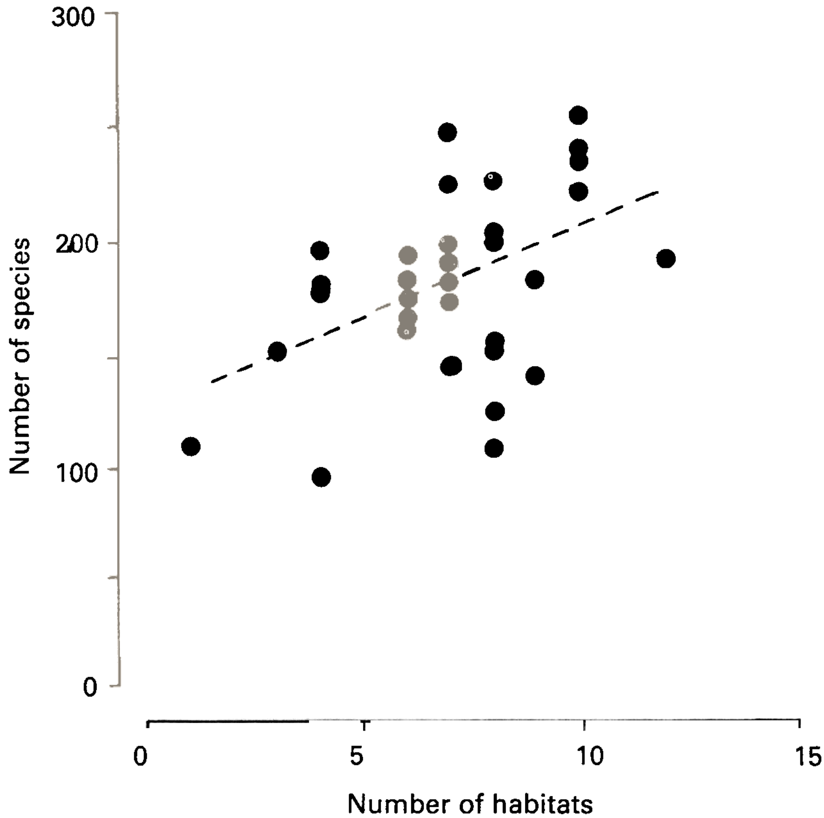

FIGURE 3. Relationship between the number of species recorded and the number of habitats recorded on each card during 41 visits to tetrads at Midhurst, West Sussex. A linear regression line is fitted to indicate the variation in the data.

remain to be discovered. Species already recorded in four tetrads obviously cannot be recorded in more than four tetrads. The results are plotted in Fig. 8, which shows that the number of extra tetrad records tails off as the species become commoner.

DISCUSSION

FACTORS AFFECTING THE NUMBER OF SPECIES RECORDED

The data confirm that, despite efforts to minimise it, the major source of variation was recording by different botanists. Previous work (e.g. Kirby *et al.* 1986; Rich & Woodruff 1990) has already shown that such variation exists even within site surveys, but the scale of the problem exposed here for tetrads was not expected. The actual species recorded may depend on which side of a path is being examined, but the total number of species recorded will depend on the botanist.

One recording episode provided another striking lesson. As Orpine (*Sedum telephium* L.) was thought to occur in only one hedge in the area, T.C.G.R. made a special trip to record the plant, but the hedgerow had been narrowed and fenced, and the plant had gone. A second recorder however had earlier found the plant on a woodland edge 20 m from the original site. Another recorder, overhearing the news, visited the site to see the plant for himself later, but failed to find it. A fourth visit

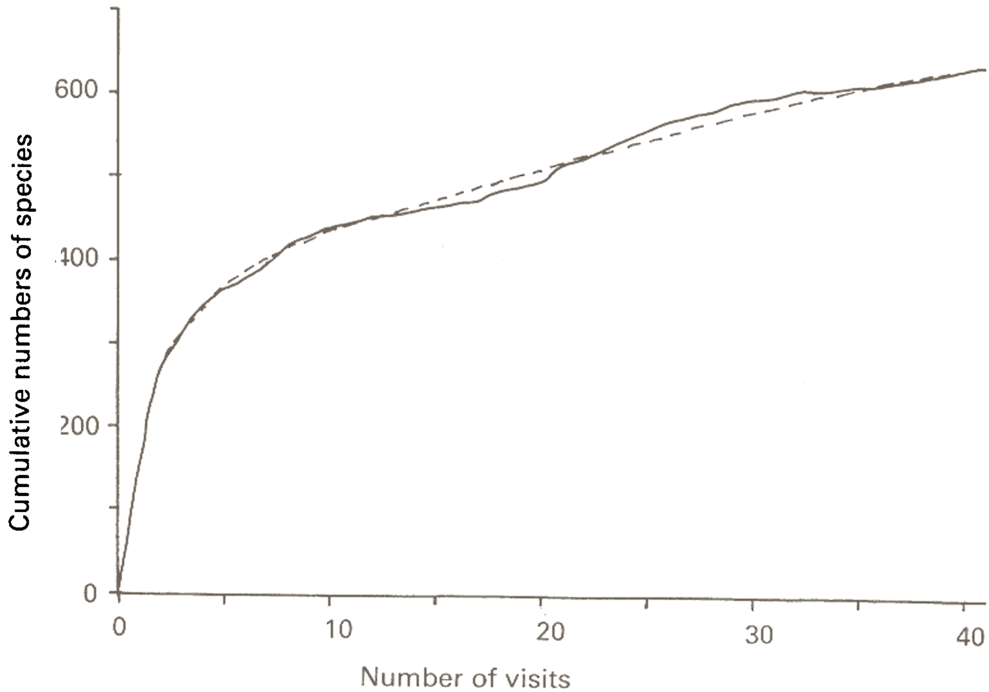

FIGURE 4. Cumulative number of species recorded as cards from additional visits were added (—) from tetrads at Midhurst, West Sussex. A smoothed version of the graph fitted by eye is also shown (- - -).

to double check showed that the plant was indeed present. To have such an obvious species on the edge of a path overlooked on two of the four visits made specially to look for it was very surprising. Failure to find a plant where it had occurred in the past or where it was expected did not mean it was extinct; populations are dynamic, and botanists are not perfect.

Botanists can increase the number of species recorded by training themselves to look for different habitats, remembering to look up at trees, throwing grapnels into ponds, etc. Experience, concentration and a sharp pair of eyes are crucial to good recording, and regularly recording with other botanists can markedly improve the consistency and breadth of knowledge, and impart valuable field-craft skills. The vast majority of species can be recorded routinely by most botanists, but the intrinsic difficulties of recording critical species thoroughly demands that a different approach, such as a systematic sample survey, might be more appropriate.

The relationship between habitats recorded and the number of species corresponds well with the concept of β-diversity, whereby more species are encountered as recorders move into different habitats (Whittaker 1975), and this is the common experience of botanists in the field. There were some difficulties in assessing which habitats had been recorded during the exercise – a few cards had records for plants characteristic of a specific habitat (e.g. ponds), but without that habitat being noted as visited. Also the habitat list on the record card was subsequently found in 1993 to be too simplistic, and even a habitat described as "road verge" would be better listed as a mown verge, unmown verge, disturbed roadside bank, and so forth (data not presented). Consequently, a very detailed list of habitats would need to be listed on the card to collect these data routinely; experience with the Sussex Botanical Recording Society indicates that such lists are usually not filled in but a simple list can be usefully used as an aide-memoire of habitats to record. The length of route recorded is less important than the number of habitats visited, and does not need to be analysed, but the route taken may help indicate other areas to visit or help refind plants in the future.

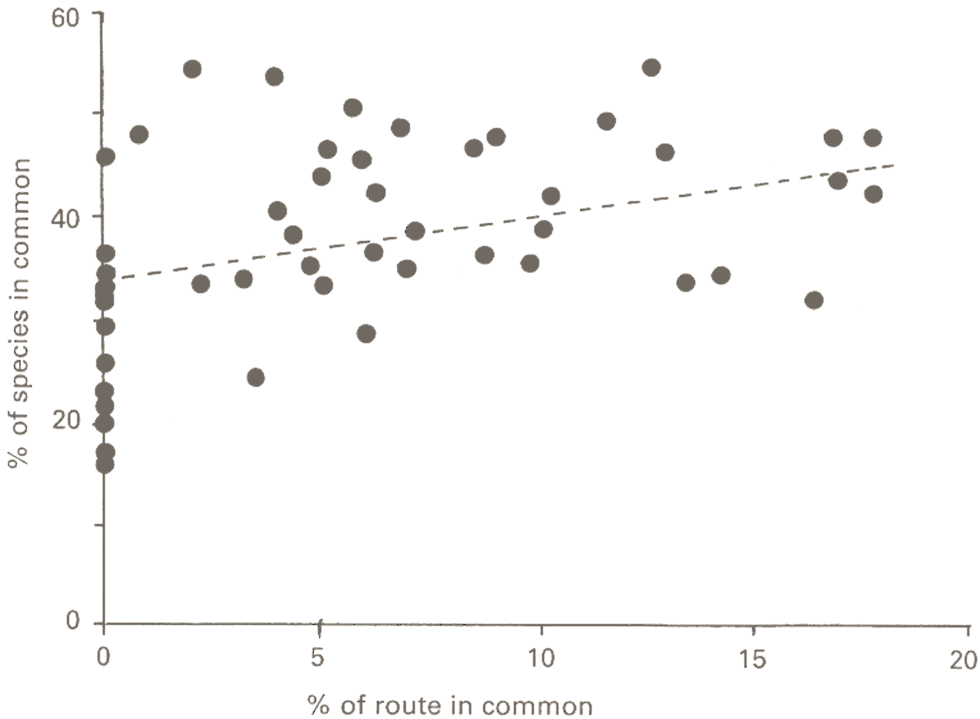

FIGURE 5. Relationship between percentage of route in common and number of species in common for recording visits to tetrad K at Midhurst, West Sussex. A linear regression line is fitted to indicate the variation in the data.

RELATIONSHIP BETWEEN RECORDING TRIPS

The fact that new species were being found in each tetrad after nine to eleven visits and in the four tetrads combined after 41 visits suggests that it is impractical to try to record each tetrad or area comprehensively. The number of species recorded obviously increases with more visits, but most tetrad flora projects are unlikely to achieve even the mean of eight visits required to obtain 90% of the species recorded in each tetrad here. Additional visits at different times of year are also required to record spring and autumn species (Kirby *et al.* 1986), as are visits during different years to account for species-turnover and variations from year to year.

TABLE 2. PERCENTAGES OF SPECIES IN COMMON (UPPER RIGHT) AND ROUTE IN COMMON (LOWER LEFT) FOR 11 RECORDING VISITS TO TETRAD K AT MIDHURST, WEST SUSSEX

Visit				4	5	6		8	9	10	11
1	–	54·9	40·6	36·4	23·3	42·2	47·8	42·7	44·1	45·6	48·1
2	12·7	–	38·3	36·4	23·4	38·6	48·7	46·5	45·5	48·0	50·6
3	4·1	4·4	–	33·7	17·6	35·6	33·3	33·8	32·9	35·1	34·2
4	8·8	0	2·3	–	16·3	42·5	31·8	38·9	34·8	32·4	35·4
5	0	0	0	0		25·8	20·0	21·8	28·8	25·8	24·5
6	10·3	7·2	9·8	6·3	0	–	29·5	32·2	36·6	33·5	34·6
7	9·1	6·9	5·1	0	0	0	–	48·1	45·7	55·7	46·9
8	17·8	13·0	13·5	10·1	0	16·4	17·8	–	44·0	46·6	48·4
9	5·1	6·0	0	0	6·1	6·3	0	17·0		54·3	49·4
10	0	0·9	7·0	0	23·8	0	22·5	5·2	2·1	–	53·5
11	16·9	5·8	3·2	4·8	3·5	14·3	8·5	23·4	11·6	4·0	–

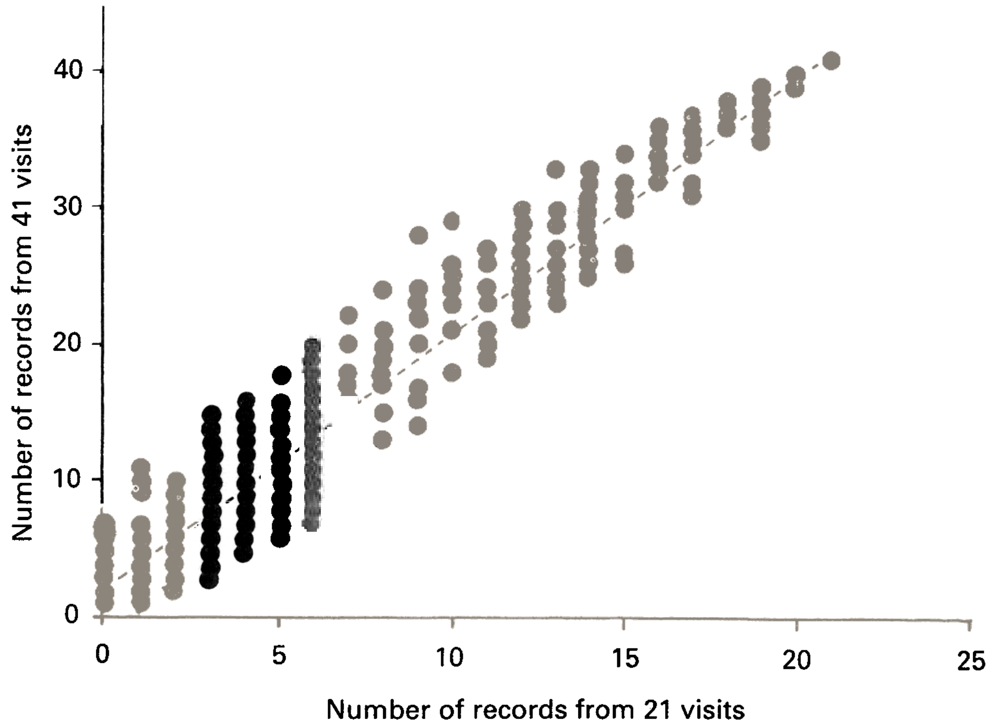

FIGURE 6. Relationship between the numbers of records obtained from a random selection of 21 visits and from all 41 visits (an approximate doubling of recording effort) from tetrads at Midhurst, West Sussex. The regression line (– – –) implies the species are encountered as a random sample from the available pool, and not in any systematic or non-random manner.

The average number of species in common between visits (38%) was lower than the figures of 52% reported by Rich & Woodruff (1990) or of 47% by Woodell (1975) for crudely equivalent surveys. As virtually all cards added species, further visits are to be encouraged to improve the species lists, but it is not possible to say how many visits are required as the actual number of species present is not known, and a general rule for south-east England will not apply in north-west Scotland. The percentage of the route in common was so low (6·8%) that there is little need to direct botanists to different areas at least initially, though a final check that all habitats have been recorded would clearly be of value. This means botanists can be largely left to get on with the recording themselves without detailed directions from a central co-ordinator.

EFFECT OF FURTHER RECORDING

Doubling the recording effort resulted in a proportional increase in the number of records, and the species were recorded in a random manner from the available pool. This indicates that if comprehensive coverage cannot be obtained, then data from a standardised survey can provide comparative data representative of the flora. A standard survey should be based on standard recording effort; some county Flora projects set a target number of species to get even coverage, but this may result in poor areas being relatively well-recorded and richer areas being poorly recorded unless a high target is set. Also if standard surveys are carried out with known (and documented) recording effort, then it should be possible to correct the results relative to each other to assess change even if the amount of effort varied between surveys. The analysis of numbers of tetrads recorded for each species in 21 and 41 visits indicates that the model used to correct the *Atlas of the British flora*/B.S.B.I. Monitoring Scheme data (Rich & Woodruff 1990) was acceptable.

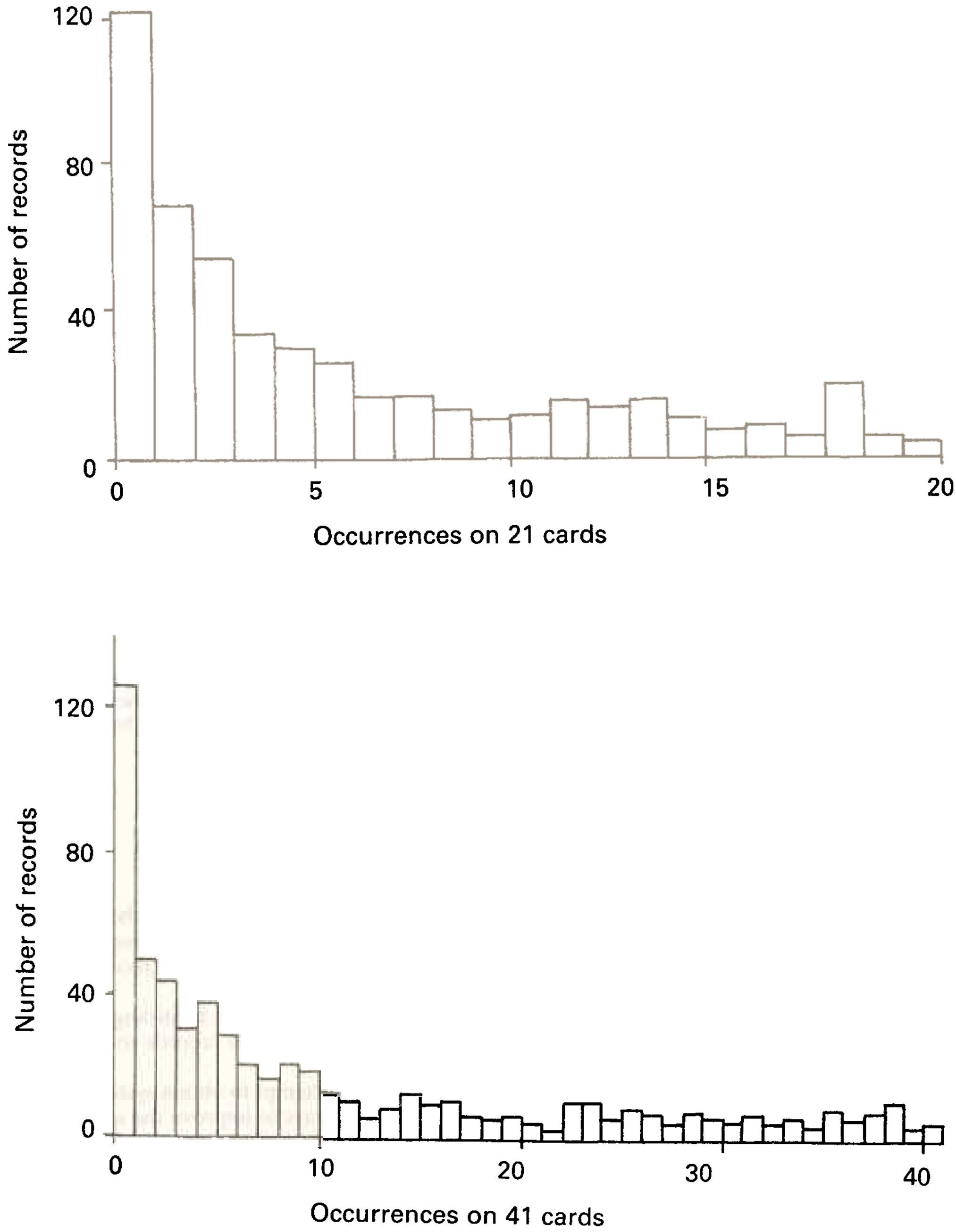

FIGURE 7. Histograms showing the number of records ("abundances") obtained from tetrad records from Midhurst, West Sussex: Upper histogram, random sub-sample of 21 cards; Lower histogram, all 41 cards. The change in the number of records in each class shows that as recording (sampling) intensity increases, species "move" from the left of the histogram to the right, whilst maintaining the central dearth of species (Raunkiaer's law).

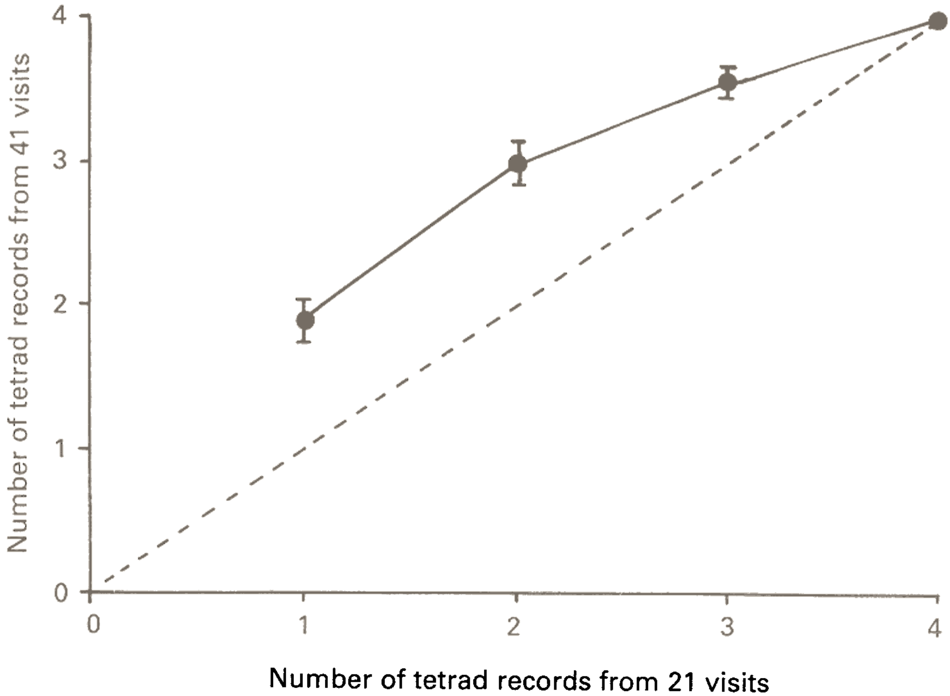

FIGURE 8. Number of tetrad records (mean ± twice the standard error) from 21 visits plotted against number of tetrad records from 41 visits to tetrads at Midhurst, West Sussex. It is not possible to estimate the mean number of tetrads recorded for species not originally recorded during the 21 visits since it is not known how many more species remain to be discovered. A 1:1 relationship is also shown (– – –).

CONCLUSIONS AND RECOMMENDATIONS

Overall, the results demonstrate that if care has been taken to obtain even coverage the numbers of records should be a reliable indication of the frequency of a species. If coverage is not comprehensive or not systematic, significant variations will be introduced by the recorders which will affect the dot maps.

It is also worth reiterating that data on the recording such as time spent recording, number of visits, etc. should be routinely collected and presented with the species records to aid in their interpretation (Rich & Woodruff 1990).

It is therefore recommended that future atlas projects should attempt to obtain systematic, even coverage so that data can be used for other purposes. The best ways to improve the quality of the basic data within the constraints imposed by using volunteers (critical species may require a different approach) are as follows:

1. improve the recording ability of the botanists, by training in identification skills and field-craft, and through contact with other botanists;
2. encourage recorders to visit many different areas rather than concentrate on one area;
3. try to achieve even coverage by recording for the same number of hours or having the same number of visits in each tetrad;
4. visit as many habitats as possible in each square, note which habitats have been recorded and try to ensure all are visited during the course of the work; and
5. ensure adequate seasonal coverage (e.g. Rich & Woodruff 1992).

ACKNOWLEDGMENTS

We are particularly grateful to those members of the Sussex Botanical Recording Society and the Botanical Society of the British Isles who collected the data, to Pat Donovan and Francis Rose for providing unpublished records, and to Judy Rich and Evelyn Jones for an excellent cream tea for the recorders on Saturday afternoon. Michael Braithwaite provided useful comments on the manuscript.

REFERENCES

BRIGGS, M. (1990). *Sussex plant atlas. Selected supplement*. Booth Museum of Natural History, Brighton.
DONY, J. G. (1963). The expectation of plant records from prescribed areas. *Watsonia* **5**: 377–385.
DONY, J. G. (1976). Species area relationship in Bedfordshire. *Bedfordshire naturalist* **30**: 61–62.
ELLIS, R. G. (1986). Tetrads. *B.S.B.I. news* **43**: 9.
GOOD, R. (1948). *A geographical handbook of the Dorset flora*. Dorset Natural History and Archaeological Society, Dorchester.
GRAHAM, G. G. & PRIMAVESI, A. L. (1993). *Roses of Great Britain and Ireland*. B.S.B.I., London.
HALL, P. C. (1980). *Sussex plant atlas*. Booth Museum of Natural History, Brighton.
JACCARD, P. (1908). Nouvelles recherches sur la distribution florales. *Bulletin de la Société Vaudoise des sciences naturelles* **44**: 223–270.
KIRBY, K. J., BINES, T., BURN, A., MACKINTOSH, J., PITKIN, P. & SMITH, I. (1986). Seasonal and observer differences in vascular plant records from British woodlands. *Journal of ecology* **74**: 123–131.
LE DUC, M. G., HILL, M. O. & SPARKS, T. H. (1992). A method for predicting the probability of species occurrence using data from systematic surveys. *Watsonia* **19**: 97–105.
NATURE CONSERVANCY COUNCIL (1989). *Guidelines for the selection of biological S.S.S.I.s*. Nature Conservancy Council, Peterborough.
OSBORNE, P. E. & TIGAR, B. J. (1992). Interpreting bird atlas data using logistic models: an example for Lesotho, Southern Africa. *Journal of applied ecology* **29**: 55–62.
PERRING, F. H. & WALTERS, S. M. eds. (1962). *Atlas of the British flora*. Thomas Nelson & Sons, London.
PHILP, E. G. (1982). *Atlas of the Kent flora*. Kent Field Club, Maidstone.
RAUNKIAER, C. (1918). Recherchés statistiques sur les formations vegetales. *Biologiske meddelelser* **1**: 1–80.
RAY, J. (1689). *Synopsis methodica stirpium Britannicarum* (1973 reprint). Ray Society, London.
RICH, T. C. G. & WOODRUFF, E. R. (1990). *The B.S.B.I. Monitoring Scheme 1987–88*. Chief Scientist's Directorate report no. 1265. Nature Conservancy Council, Peterborough.
RICH, T. C. G. & WOODRUFF, E. R. (1992). Recording bias in botanical surveys. *Watsonia* **19**: 73–95.
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 Wildlife Trust, Shrewsbury.
WATSON, H. C. (1883). *Topographical botany*. Bernard Quaritch, London.
WHITTAKER, R. H. (1975). *Communities and ecosystems*. Macmillan, New York.
WOODELL, S. J. (1975). Five years of a county Flora project. *Watsonia* **10**: 265–272.

(*Accepted December 1995*)