Researching the Optimality of Hedgerow Statistics for England and Wales from the Countryside Survey

T.H. Sparks[1], D.A. Elston[2] and J.M. Potts[2]

MAFF Project Code BD1009

ITE project number T02083P1

[1] Institute of Terrestrial Ecology
Monks Wood
Abbots Ripton
Huntingdon
Cambridgeshire
PE17 2LS

[2] Biomathematics and Statistics Scotland
Environmental Modelling Unit
MLURI
Craigiebuckler
Aberdeen
AB15 8QH

5th March 1999

EXECUTIVE SUMMARY

1. Countryside Survey measures a multitude of features of the GB countryside based on a stratification of 32 Land Classes. This report focuses just on the hedgerow component, whilst acknowledging that CS has a much wider function.
2. Field boundaries are classified according to their composition, including hedgerow features. In CS1990, 10m long hedge plots were recorded to determine species composition and richness.
3. Total stock estimates and changes in stock between surveys are estimated using standard sample survey techniques. Estimates of species richness have been obtained by pooling data across 1km squares within strata.
4. We found that the stratification by Land Class was not substantially improved upon by other potential strata, but that the numbers of 1km squares visited per strata are inefficiently allocated for the specific purposes of estimating hedgerow stock and change.
5. There is potential benefit in using spatial information in the analyses of hedgerow data. This would include the use of spatially distributed covariates and geostatistical techniques to make fuller use of correlations in the data. Further work is required to establish the best way to use this information.
6. The definition of species richness is arbitrary and estimates of stock are entirely dependent on the definition used. CS1990 plots of 10m are not compatible with current hedgerow regulations requiring 30m samples. CS2000 will provide estimates from 30m plots.
7. There is a positive relationship between species richness and the hedgerow density; this should be taken into account in future analyses.

1. Introduction

1.1 Origins of the Countryside Survey

The Countryside Survey has its origins in the early 1970s with a desire to describe the current state of the British countryside and to obtain a baseline for the assessment of future changes. The Countryside Survey was to be based on field visits of 1km grid squares, to allow collection of more detailed ecological data than could be obtained by remote sensing. Visited squares were to be drawn using a stratified design (Cochran, 1953) so that the results could be extrapolated validly and efficiently to unvisited squares.

Much preliminary work was required to produce a suitable stratification such that variability between squares within strata would be expected to be much less than variability between squares in different strata. This stratification was achieved by measurement of a range of variables in 1km squares located at the intersections of a 15km square grid. Use of a 15km grid ensured all samples were well spread, whilst selected variables were physical in nature to ensure permanence of the classification. The physical variables were used to create 32 Land Classes (Bunce *et al.*, 1996) and these Land Classes form the strata within the Countryside Survey. The Land Classes are not determined from land use, and hence can be treated as semi-permanent.

1.2 Changes made between successive Countryside Surveys

Field visits for the first CS were conducted in 1978, and since then the exercise has been repeated with further visits in 1984, 1990 and 1998. At the time of each repeat, some modifications have been made to the design. These changes have included: re-stratification so that the visited squares now form part of a stratification of all 1km squares in Great Britain; an increase in the number of squares visited so that better estimates could be obtained for the new strata (sampling fractions approximately equal); and, most recently, some divisions of the strata on the basis of principalities. In addition, the variables recorded have changed so that data are available to answer questions of current as well as of historical interest.

1.3 Hedgerow component -what it aims to record and report

The Countryside Survey currently provides estimates of the extent and quality of a wide range of ecological features, including hedgerows. Features measured on hedgerows have included length, shape, and number and composition of woody and herbaceous species present in sample lengths of hedgerows.

1.4 Aim of this review

We will review the suitability of the Countryside Survey as a mechanism for obtaining information about quality and quantity of hedgerows in Great Britain.

2. Description of the hedgerow element of CS

2.1 Definitions

The definition of what comprises a hedgerow is not as straightforward as it may seem. Commendably clear guidelines, in terms of the requirement for continuity, shape and management are provided to all CS2000 field surveyors (Barr, 1998). Unfortunately, recipients of summary results can not all be provided with such detailed descriptions, and there is unavoidably some scope for misconception about what physical features any reported figures will refer to.

2.2 Sample selection

The stratified random sampling approach which underlies the whole of CS is robust and has a long history of application to many types of survey. Definition of strata is such that we might expect variability within strata to be less than variability between strata for a wide range of features, as required. Within the constraints imposed by the 15km grid, squares within strata have been selected at random. In the interests of efficiency, and since this is a survey of *countryside*, squares containing more than 75% urban cover ("urban squares") or greater than 90% sea ("mostly sea squares") were not included in the sampling frame and, when these were occasionally drawn, they were replaced by other squares on the grid. The sampling frame is designated as a population of "rural squares".

Within each visited 1km square, sample lengths of hedgerow (H-plots) were visited for detailed recording of ecological attributes. Although the sample lengths were selected according to a randomisation scheme, not all sections of hedgerow have the same probability of selection. Each section of hedgerow in a 1 km square has a higher probability of being recorded in low density hedgerow squares than high density squares.

Additional information to the main Countryside Survey was obtained from field visits in 1993 which were restricted to those 1km squares which were recorded as containing hedgerows during the 1990 survey (Barr, Gillespie & Howard 1994)

2.3 Estimation of hedgerow stock

Within CS, field boundaries are allocated a code depending on their composition. Potential categories include combinations of banks, fences, grass strips, walls and hedges. For the purpose of this review we concentrate solely on the sum of all categories which included a hedge element, but excluding relict hedges. Urban hedges, woodland hedges and curtilages (property boundaries) are not included. This is the definition of hedges used in summary tables of the Countryside Survey 1990 report (Barr *et al.*, 1993). There will inevitably be some criticism of hedgerow definitions (e.g. Countryside Commission, 1997), but the data are held in such a way as to make different comparisons possible, if required.

A naive estimate of national (or regional) hedgerow stock can be made by calculating the mean hedgerow lengths per square in each Land Class, multiplying these by the corresponding numbers of squares nationally (or regionally), and summing over Land

Class. Standard errors associated with such estimates of stock can been calculated in the normal way as described by Cochran (1953). Sample sizes are small relative to stratum size (all $\leq$ 0.6%) and so the finite population correction can be effectively ignored in calculating standard errors. An example for estimating hedgerow stock from CS1990 is shown in Appendix 1, where GB stock is estimated at 481 thousand km.

However the above method leads to inefficient estimation of hedgerow stock because the hedge lengths in the sampled squares and the stratum sizes (numbers of squares) are not adjusted for the amount of sea within them. This will most affect those Land Classes with a major component of sea in them, i.e. western coastal land classes. CS has thus adopted an alternative approach to calculating hedgerow stock. Hedgerow stock estimates are obtained as the length of hedge per unit area of land (i.e. ratio estimates dividing the total length of hedgerow in each 1km square by the non-sea element in that square). Arithmetic means and corresponding standard errors are formed within each stratum. Calculation of areas within each land class (rather than number of squares) is done by adding the area of "rural squares" to the land element of "mostly sea" squares to the rural element of "urban" squares and adjusting for a discrepancy between mapped sea boundary and surveyed sea boundary. Weighted means are then formed to give national or regional totals, together with corresponding standard errors. The weight for each stratum is defined according to that stratum's area of countryside in the target region. Stratum means, and the regional totals derived from them, are assumed to follow normal distributions. Variances of regional totals are assumed to be sufficiently well known that confidence intervals can be derived from standard normal distributions. An example showing calculations with this method is given in Appendix 2, whose estimates (GB = 463 thousand km) agree with the published CS1990 results apart from some minor rounding errors. Estimates based on areas, but not correcting for sea in sampled squares, are virtually the same at this scale and level of accuracy.

2.4 Estimation of change

Estimates of change are formed in the same way as stock estimates, only now the variable analysed is the difference in stock estimates for each square between the two relevant surveys. Two methods of estimating change have been considered; one using just those squares appearing in both surveys, and one using all data. The former is simplest to use and, given the degree of overlap between the 1984 and 1990 surveys, suffers from little loss of efficiency. The calculations ignoring 1km squares which appeared in just one survey are given in Appendix 3.

2.5 Estimation of species-richness

Within CS1990 two 10m hedge plots (H-plots) per sample square were sampled where possible. The numbers of all species, including woody species (as defined in Appendix 4), were recorded in each plot. In CS2000, the potential number of plots for determining woody species richness (now of length 30m) has been extended to ten. In the past, estimates of species richness have been formed by pooling data across 1km squares within strata. Thus estimates of species-richness treat the targeted sections of hedgerow as the sampling unit. CS data are stored in such a way that a different suite of species to that used here could be used to identify woody species richness.

2.6 Presentation of results

Results for hedgerow stock are based in integer thousand km units. This seems eminently sensible to prevent undue accuracy being allotted to stock estimates. Published results deal with areas no smaller that the principality level. Given that the sampling scheme is designed for national estimates this would also appear to be a sensible caution. When calculating estimates for the separate principalities of GB, stratum means for the whole of the GB have been used. This is an unusual approach in sampling, but is a result of poor representation of some strata in individual principalities, the larger sample from the GB leading to estimates for principalities with increased precision. A recent paper (Howard *et al.*, 1998) justifies this approach. For CS2000 greater representation of some land classes in Scotland and Wales is being undertaken.

In presenting estimates of change, separate figures have been presented for loss of existing hedgerows and for plantings of new hedgerows. This seems sensible, given that different factors will be governing these processes, and that the biodiversity value of old and new hedgerows may differ. Finally, this division is sensible statistically, since it makes little sense to present hedgerows planted over a period as a proportion of the stock at the start of that period.

3 Assessment of existing approach

3.1 Survey structure

The stratification used is sensible given the multi-purpose function of CS. The penalties for having too few strata are greater than those for having too many; hence the choice of 32 strata, which may seem a lot, is a good one. However, whilst it is simple to envisage the make-up of hedgerow stock being related to the stratification used, it is rather harder to envisage change in hedgerow stock being related to the definitions of the strata. Such changes are more likely to relate to short-term, socio-economic pressures than to the long-term, environmental and physical variables used to define the strata. There is therefore some merit in looking to other ways of stratifying the 1km squares to see whether there are any clear improvements over the existing stratification scheme.

Alternative stratification schemes will only be valid if the extent of the strata is known for GB and the regions. Alternatives schemes considered were:

- County
- SSSI present
- AONB present
- ESA present
- Bioclimatic zone
- DETR region (England only)
- Countryside character (England only)
- Natural area (England only)

3.2 Methods of analysis

Whilst a stratified design ensures a good spatial spread of sampled areas, the associated analysis does not necessarily make full use of the information in the collected data. Hence we investigated the potential of geostatistical techniques for analysing CS hedgerow lengths and changes in length. These techniques use the relationship between separation of 1km squares and their correlation to extract full information from the data. They are particularly powerful if used in conjunction with other covariates whose values are available for all 1km squares in Great Britain. We investigate the potential suitability as covariates of the following 17 land cover categories derived from satellite imagery.

- Urban
- Suburban
- Tilled land
- Managed grassland
- Rough grass
- Bracken
- Heath grass
- Open shrub heath
- Dense shrub heath
- Bog
- Deciduous woodland
- Coniferous woodland
- Inland bare
- Saltmarsh
- Coastal bare
- Inland water
- Sea/estuary

In addition, km data are available on

- Slope
- Altitude

Furthermore, it is clear that the results of any analysis of species richness will be dependent on the definition of species richness used, and on the use of any relationship that may exist between species richness and hedgerow length. We investigate the effect of definition of species richness, and possible relationship between species richness and hedgerow length.

4. Results

4.1 Alternative stratification schemes

The standard error of the estimate of total hedge length was compared for different stratification schemes. A comparison was also made with the standard error that would be obtained if the same number of squares was sampled in total but sample sizes for each stratum were chosen optimally. For the 1990 survey a comparison was made between stratification on the basis of Land Class and Bioclimatic Zone for the whole of Great Britain (Table 1), and between stratification on the basis of Land Class, Bioclimatic Zone and DETR Region for England only (Table 2). There were only 381 squares that were sampled in both 1984 and 1990. In looking at the change in hedgerow length, the number of sampled squares in some strata was too small to allow estimates to be obtained for England only and the whole of Great Britain was therefore stratified on the basis of DETR region by adding Wales as a region, and the whole of Scotland and the Isle of Man as another region (Table 3). However, a subdivision of Scotland into separate regions might be more appropriate. For this exercise, no adjustment was made for the area of sea in each sampled square and the number of km squares in each stratum was used in place of the total land area. This was forced upon us because the total area of countryside in each stratum was not available to us.

The results suggest that choice of stratifying factor is unimportant, but that the sample sizes for each stratum are far from optimal for producing statistics on hedges alone. Equivalent figures were produced for a stratification by county, although the small sample sizes meant that some rather arbitrary groupings were required. This provided a stratification with over 60 strata, but there was little to be gained from this increase.

Table 1
Estimated hedgerow length in Great Britain from the 1990 survey

Stratification	Total length ('000 km)	Standard error	Standard error for optimal sample sizes
Land Class	481	25	19
Bioclimatic zone	481	25	21

Table 2
Estimated hedgerow length in England from the 1990 survey, using only 1km squares in England.

Stratification	Total length ('000 km)	Standard error	Standard error for optimal sample sizes
Land Class	413	20	13
Bioclimatic zone	410	21	14
DETR region	421	22	15

Table 3
Estimated difference in hedgerow length in Great Britain between the 1990 and 1984 surveys

Stratification	Total decrease in length ('000 km)	Standard error	Standard error for optimal sample sizes
Land Class	135	15	10
Bioclimatic zone	132	14	11
DETR Region (+W, Sc/IoM)	137	16	13

4.2 Optimal sample allocations for hedgerow statistics

There is evidently some scope for improving precision by changing the proportions of sampled squares in the different land classes, i.e. by increased sampling in more variable strata. Tables 4 and 5 give the actual proportion of sampled squares in Great Britain in each Land Class together with the optimal proportions for hedgerow stock and hedgerow change respectively. These estimates will change from data set to data set, e.g. will differ between CS1990 and CS2000, so need to be treated with caution. There is a high correlation between the optimal proportions in the two cases. Note however that it would not be possible to achieve exactly these proportions in practice because of the need to have a minimum number of squares in each stratum.

Table 4

Optimal sampling of ITE Land Classes for estimating hedgerow length in 1990.

Land Class	Actual percentage of sampled squares	Optimal percentage of sampled squares
1	5.5	11.8
2	4.7	7.8
3	5.9	5.7
4	2.0	6.2
5	1.2	1.7
6	4.5	11.0
7	2.6	1.4
8	2.8	0.8
9	4.1	8.0
10	4.3	8.7
11	4.3	3.6
12	2.0	1.4
13	3.3	5.4
14	1.2	0.1
15	1.8	3.3
16	2.2	1.4
17	5.5	6.0
18	2.6	4.8
19	1.4	0
20	0.8	0
21	3.7	0
22	4.9	0.1
23	3.3	0
24	3.0	0
25	4.7	4.4
26	3.0	2.6
27	3.0	2.7
28	2.8	0.9
29	2.2	0
30	2.8	0
31	2.2	0.2
32	2.0	0.04

Table 5
Optimal sampling of ITE Land Classes for estimating hedgerow change 1984-1990.

Land Class	Actual percentage of sampled squares	Optimal percentage of sampled squares
1	3.7	6.6
2	3.2	9.2
3	4.2	7.2
4	1.6	4.1
5	1.1	0.8
6	3.4	13.9
7	3.4	1.1
8	3.2	4.2
9	4.2	4.6
10	4.5	14.1
11	5.0	4.1
12	2.4	1.0
13	3.7	3.4
14	1.6	0.2
15	1.8	5.3
16	2.6	0.7
17	4.2	6.6
18	2.4	2.1
19	1.1	0
20	1.1	0.1
21	4.2	0
22	4.2	0.2
23	3.7	0
24	3.2	0
25	4.7	2.9
26	3.7	1.7
27	3.2	1.9
28	3.2	4.0
29	2.9	0
30	3.7	0
31	2.9	0.03
32	2.6	0.03

4.3 Use of spatially distributed covariates.

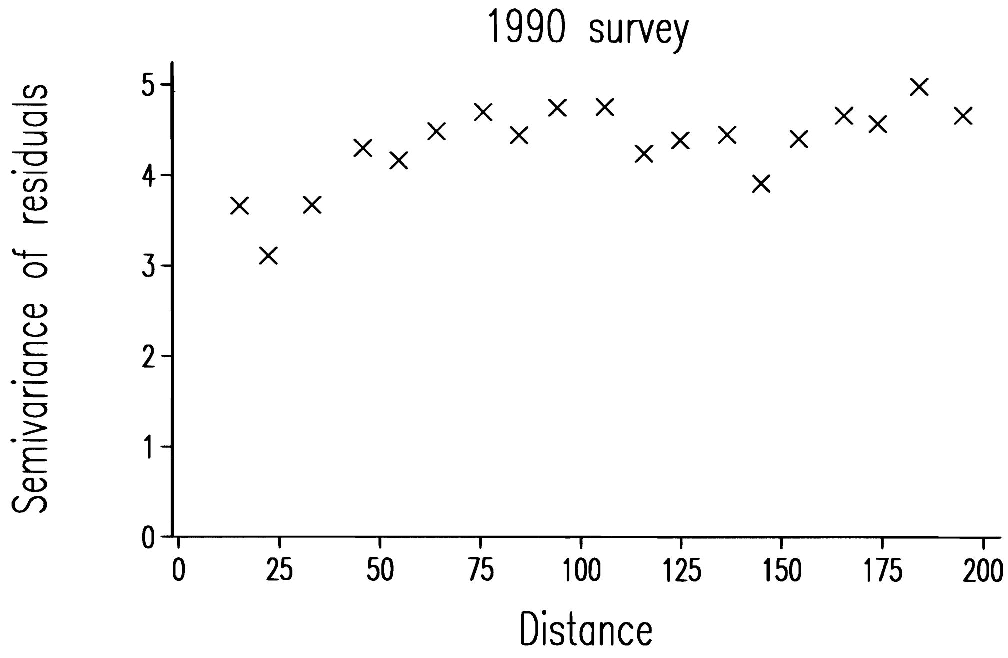
An alternative approach to estimation is to use knowledge about the correlation between hedgerows and covariates whose values are known for all 1km squares in Great Britain. There is a range of possible land cover covariates which are available from satellite survey, and although we only have the covariate values at sampled 1km squares, it allows us to assess their potential. Table 6 shows the correlation between raw and Land Cover corrected data for both hedgerow length and change. In the raw data there is evidence that some covariates, notably northing and managed grass+tilled, may be useful in estimation of hedgerow stock. However, correlations with change data and with the residuals after fitting Land Class effects are very much smaller suggesting that many of the differences in environmental variables are already accounted for by Land Class differences. The Land Class corrected correlation coefficient between length and managed grass (r=0.19) may justify further investigation, as this land cover type is traditionally associated with hedgerows.

Table 6 Correlations between hedgerow length and change (1984-1990) and environmental data in the raw data (first two columns) and in residuals after eliminating Land Class effects (final two columns). Variables are ordered by the magnitude of the correlation with hedgerow length raw data (first column)

	raw data		after removing LC effects	
	length	change	length	change
Northing	-0.53	0.30	-0.07	0.00
Managed grass+tilled	0.44	-0.11	0.17	0.05
Managed grass	0.35	-0.12	0.19	0.01
Open shrub	-0.33	0.15	-0.04	-0.03
Easting	0.23	-0.10	0.00	0.02
Tilled	0.23	-0.03	0.04	0.06
Bog	-0.22	0.10	-0.06	0.01
Mean slope	-0.20	0.00	-0.03	-0.06
Dense shrub	-0.20	0.08	-0.08	0.01
Mean altitude	-0.18	0.01	0.00	-0.08
Heath grass	-0.17	-0.06	-0.03	-0.15
Sea/estuary	-0.15	0.06	-0.07	0.04
Suburban	0.15	-0.06	-0.08	0.01
Coniferous	-0.14	0.07	-0.06	0.04
Coastal	-0.13	0.08	-0.06	0.05
Inland bare	-0.07	0.10	-0.03	0.08
Deciduous	0.06	-0.13	-0.14	0.00
Urban	0.06	-0.02	-0.02	0.01
Inland water	-0.05	0.02	-0.02	0.00
Salt marsh	-0.05	0.04	-0.03	0.04
Bracken	-0.04	-0.15	-0.01	-0.13
Rough grass	-0.04	0.05	-0.06	0.06

4.4 Geostatistical Techniques

Within each Land Class, if hedgerow length is more highly correlated in squares that are close together than in those that are further apart, then there is scope for improving estimates of hedgerow length through the use of geostatistical techniques. Figure 1 shows the variograms for the 1990 survey data and for the difference between the 1990 and 1984 surveys. Each point on the variogram shows an estimate of one half of the mean squared difference in residuals for pairs of points separated by a particular distance. The tendency for the semivariance to increase with separation suggests that 1km squares that are closer together are more highly correlated than 1km squares that



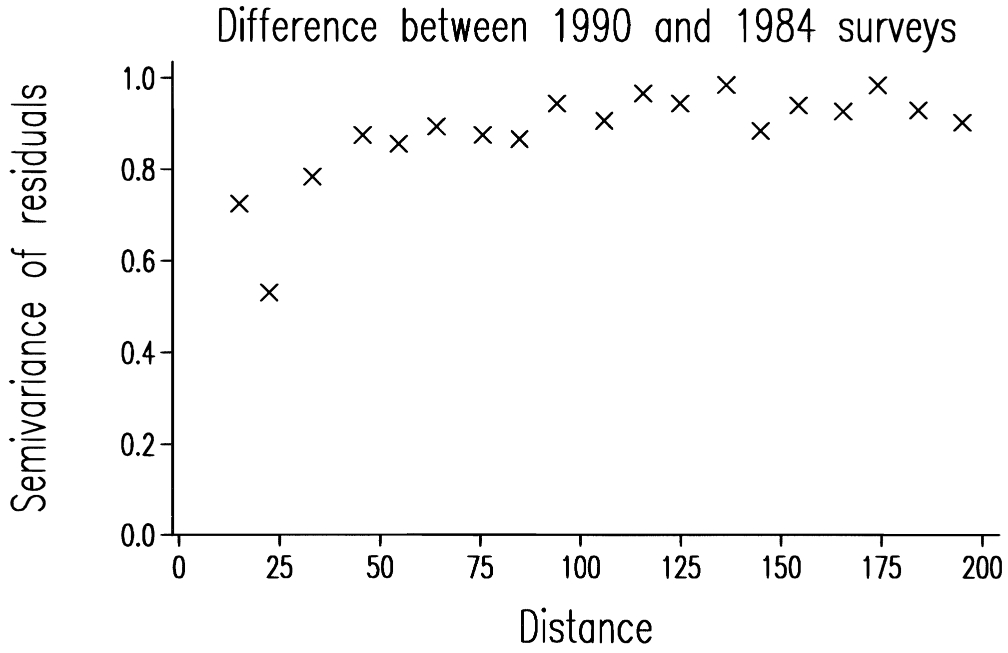


Figure 1. Variograms of the residuals (after subtracting the mean value for each Land Class) for the 1990 survey and for the difference between the 1990 and 1984 surveys.

are further apart. Such spatial correlation is likely to be greatest between squares that are very close together. Hence, for geostatistical techniques to be fully effective, it must be possible to estimate the correlation at small spatial scales. However, at present, the minimum distance between any pair of squares is 6km and there are only five pairs of squares that are less than 10km apart.

These variograms suggest that such methods could potentially lead to improved estimation. Further evidence to support this is provided by the fact that regressing total hedge length in the sampled squares on the easting and northing within each Land Class provides a better fit than regressing the data on Land Class alone.

4.5 Analysis of species richness

The choice of threshold for classifying hedges as being species-rich clearly has a huge effect on the estimates of species-rich length. This can be seen from Appendix 5, where the current practice of pooling H-plots across 1km squares within strata has been adopted. Nationally, about half of H-plots contain at least 3 woody species, whilst one quarter contain at least 5 species. Note also that, regardless of definition, the percentage of hedgerow that is classified as species-rich is estimated to be much lower in Scotland than in England or Wales. This due to a strong latitudinal trend (Figure 2).

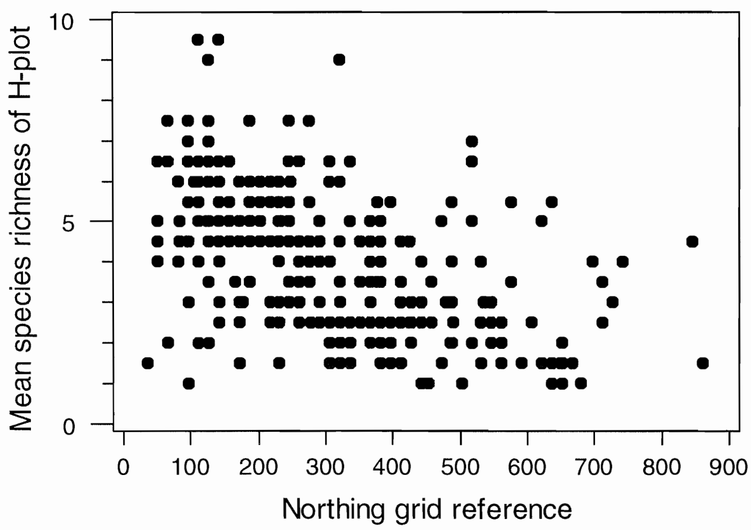


Figure 2. Mean numbers of woody species in relation to latitude.

The pooling of H-plots between squares within strata is only valid if there is no relationship between species-richness and hedgerow length. If such a relationship exists, then hedgerows in areas of low density are more likely to be sampled than in areas of high density, leading to a biased sample. Figure 3 demonstrates that there is a positive relationship between hedgerow length and number of woody species in the H-plots. The correlation ignoring strata, r=0.42, is highly significant (p<0.001), whilst the correlation within strata (r=0.31) still confirms this relationship. Estimates of species-rich hedgerow length, derived from multiplying the proportion of H-plots defined as species rich in each 1km square (i.e. either 0, 50 or 100%) by hedge length recorded for that square, are given in Appendix 6. These can be used to estimate the percentage of hedgerows that are species rich; for example half of GB hedgerows would be estimated to have at least 5 species per 10m length. The apparent conflict between this value and the one presented in Appendix 5 is due to the relationship between species-richness and hedgerow length. Improvements to the precision of estimates of species richness will result from increased recording of hedge plots in CS2000, but the presence of bias will depend on the methodology adopted. The 10m plots recorded in CS1990 are not directly compatible with the 30m lengths used in hedgerow regulations. The relationship between plot length and richness is not a linear one (probably a log relationship) and is not understood in sufficient detail to convert the CS1990 data to 30m equivalents.

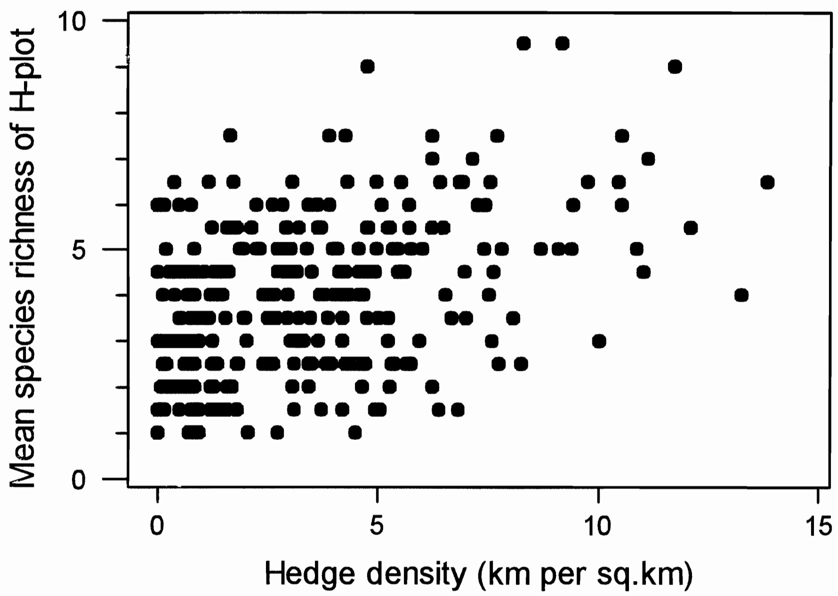


Figure 3. Mean numbers of woody species in relation to hedge density.

5. Recommendations, discussion and suggestions for further research

5.1 Use of ITE Land Classes

The 32 Land Classes currently used to define the stratification of the Countryside Survey were not markedly improved on by any other stratification scheme that we tried, nor do we consider that any substantial improvement through this route is likely. However, the sample allocation scheme currently in use is inefficient for estimating hedgerow stock and change. Whether or not this observation can be used in practice depends on the cost of surveying 1km squares for hedgerows alone, or on the loss to other aspects of the Countryside Survey of reducing the number of squares in strata that are being over-sampled with respect to hedgerows.

5.2 Use of spatial covariates and geostatistical techniques

The greatest potential improvement in precision of estimates associated with hedgerow length is likely to come from the use of spatially distributed covariates in combination with the use of geostatistical techniques. The former method could be adopted within the current, classical, sampling framework by the use of a regression estimator, although the estimation of separate regressions within each of the 32 strata is unlikely to be the most efficient approach. Alternatively, the use of smoothing splines or other semi-parametric approaches appears attractive, although it would require sufficient computing power to store fitted values for all the 1km squares in Great Britain. Whilst the use of geostatistical techniques would appear to capitalise most fully on the spatial information, this option is currently infeasible due the lack of good estimates of correlations between 1km squares less than 10 km apart. Such estimates could only be obtained by recording data from hedgerows in 1km squares separated by considerably less than the 15km distance between the grid lines for the current sampling scheme.

5.3 Analysis of species richness data

The choice of threshold for determining species richness is both arbitrary and important. This can only be seen by example, and so there is a strong case for using more than one figure. Regardless of this, future analyses should use the relationship between species richness and hedgerow length (density) to avoid bias. Data from CS2000 using a larger number of 30m plots is compatible with hedgerow regulations, and likely to be more valuable than the data reported here.

6. References

Barr, C.J., Bunce, R.G.H., Clarke, R.T., Fuller, R.M., Furse, M.T., Gillespie, M.K., Groom, G.B., Hallam, C.J., Hornung, M., Howard, D.C. & Ness, M.J. 1993. *Countryside Survey 1990. Main Report.* Department of Environment, London.

Barr, C.J. 1998. *Countryside Survey 2000 Field Handbook.* ITE internal report.

Barr, C.J. 1998. *The Sampling Strategy for Countryside Survey 2000.* ITE report to DETR under Contract CR0212.

Barr, C., Gillespie, M. and Howard, D. 1994. *Hedgerow Survey 1993 (Stock and change estimates of hedgerow length in England and Wales, 1990-1993).* ITE Report to Department of the Environment.

Bunce, R.G.H., Barr, C.J., Clarke, R.T., Howard, D.C. & Lane, A.M.J. (1996). Land classification for strategic ecological survey. *Journal of Environmental Management*, **47**, 37-60.

Cochran, W.G. 1953. *Sampling Techniques.* Wiley, New York.

Countryside Commission (1997). *Agricultural landscapes: a third look.* Countryside Commission, Northampton.

Howard, D.C., Barr, C.J. & Scott, W.A. (1998). The validity of using Countryside Survey sample data from Great Britain to estimate land cover in Scotland. *Journal of Environmental Management*, **52**, 131-146.

Appendix 1. Estimate of hedgerow stock based on lengths per grid square (CS1990 data). (E=England, Sc=Scotland, W=Wales, GB= Great Britain)

Land	Sample	Number of grid squares					Km per square			estimated lengths '000 km			
Class	size	E	Sc	W	GB		mean	SD		E	Sc	W	GB
1	28	13103	0	1056	14159		4.96	3.54		65	0	5	70
2	24	14459	0	4	14463		2.71	2.29		39	0	0	39
3	30	15360	0	92	15452		3.24	1.56		50	0	0	50
4	10	8954	0	58	9012		2.33	2.92		21	0	0	21
5	6	2480	12	1385	3877		3.34	1.81		8	0	5	13
6	23	7595	10	2735	10340		5.66	4.51		43	0	15	59
7	13	1438	262	832	2532		1.37	2.34		2	0	1	3
8	14	3316	258	838	4412		0.58	0.73		2	0	0	3
9	21	11027	53	701	11781		3.29	2.89		36	0	2	39
10	22	13641	129	135	13905		3.49	2.65		48	0	0	49
11	22	8895	0	0	8895		3.71	1.72		33	0	0	33
12	10	3542	1	0	3543		1.95	1.69		7	0	0	7
13	17	4800	1802	661	7263		2.69	3.16		13	5	2	20
14	6	603	301	29	933		0.44	0.51		0	0	0	0
15	9	1397	336	2462	4195		3.97	3.33		6	1	10	17
16	11	2451	315	323	3089		2.87	1.96		7	1	1	9
17	28	3935	63	9001	12999		1.28	1.95		5	0	12	17
18	13	2221	3571	940	6732		1.06	3.04		2	4	1	7
19	7	3193	2186	42	5421		0.00	0.00		0	0	0	0
20	4	1235	1028	245	2508		0.00	0.00		0	0	0	0
21	19	9	9708	0	9717		0.00	0.00		0	0	0	0
22	25	3294	9252	3	12549		0.01	0.03		0	0	0	0
23	17	842	6068	41	6951		0.00	0.00		0	0	0	0
24	15	197	7010	0	7207		0.00	0.00		0	0	0	0
25	24	2011	8541	0	10552		0.91	1.77		2	8	0	10
26	15	1192	5683	1	6876		1.27	1.63		2	7	0	9
27	15	1499	5382	0	6881		0.92	1.64		1	5	0	6
28	14	962	6502	0	7464		0.14	0.49		0	1	0	1
29	11	0	5465	0	5465		0.00	0.00		0	0	0	0
30	14	0	4254	0	4254		0.00	0.00		0	0	0	0
31	11	0	3016	0	3016		0.07	0.24		0	0	0	0
32	10	0	3779	0	3779		0.01	0.05		0	0	0	0
Total	**508**	**133651**	**84987**	**21584**	**240222**					**392**	**34**	**55**	**481**
SE										**20**	**6**	**5**	**25**

Appendix 2. Estimate of hedgerow stock, correcting for sea, based on lengths per km^2 (CS1990 data). (E=England, Sc=Scotland, W=Wales, GB= Great Britain)

Land class	Sample size	Areas km^2					per km^2			estimated lengths '000 km			
		E	Sc	W	GB		mean	SD		E	Sc	W	GB
1	28	12478	0	1050	13528		4.96	3.54		62	0	5	67
2	24	14068	0	4	14072		2.71	2.29		38	0	0	38
3	30	15340	0	81	15421		3.24	1.56		50	0	0	50
4	10	7982	0	54	8036		2.33	2.92		19	0	0	19
5	6	2391	8	1328	3726		3.34	1.81		8	0	4	12
6	23	7489	7	2672	10168		5.66	4.51		42	0	15	58
7	13	744	141	467	1352		1.65	2.73		1	0	1	2
8	14	2063	107	501	2671		0.63	0.83		1	0	0	2
9	21	10340	24	699	11064		3.29	2.89		34	0	2	36
10	22	13274	83	134	13492		3.52	2.62		47	0	0	47
11	22	8721	0	0	8721		3.71	1.72		32	0	0	32
12	10	3427	0	0	3427		1.95	1.69		7	0	0	7
13	17	4270	1737	635	6642		2.69	3.16		11	5	2	18
14	6	422	211	24	658		0.46	0.52		0	0	0	0
15	9	1286	328	2432	4046		3.97	3.33		5	1	10	16
16	11	2424	308	322	3053		2.88	1.96		7	1	1	9
17	28	3935	63	9001	12999		1.28	1.95		5	0	12	17
18	13	2181	3571	929	6681		1.06	3.04		2	4	1	7
19	7	3193	2186	42	5421		0.00	0.00		0	0	0	0
20	4	1235	1028	245	2508		0.00	0.00		0	0	0	0
21	19	9	9707	0	9716		0.00	0.00		0	0	0	0
22	25	3294	9252	3	12549		0.01	0.03		0	0	0	0
23	17	842	6068	41	6951		0.00	0.00		0	0	0	0
24	15	197	7009	0	7206		0.00	0.00		0	0	0	0
25	24	2011	8496	0	10507		0.91	1.77		2	8	0	10
26	15	997	5253	0	6250		1.27	1.63		1	7	0	8
27	15	1449	5305	0	6754		0.92	1.64		1	5	0	6
28	14	957	6390	0	7347		0.14	0.49		0	1	0	1
29	11	0	2453	0	2453		0.00	0.00		0	0	0	0
30	14	0	3475	0	3475		0.00	0.00		0	0	0	0
31	11	0	1750	0	1750		0.08	0.27		0	0	0	0
32	10	0	3685	0	3685		0.01	0.05		0	0	0	0
Total	**508**	**127019**	**78644**	**20664**	**226327**					**377**	**32**	**54**	**463**
SE										**19**	**6**	**5**	**24**

Appendix 3. Estimate of changes in hedgerow length, based on differences (1990-1984) in lengths per km^2 using 1km squares visited at both times.

Land Class	Sample size	Number of grid squares	1990			1984			Difference		
			Km per square		Estimated length '000 km	Km per square		Estimated length '000 km	Km per square		Estimated length '000 km
			Mean	SD		Mean	SD		Mean	SD	
1	14	14159	4.81	4.02	68	5.76	4.43	82	-0.95	0.95	-13
2	12	14463	2.15	1.62	31	2.56	2.61	37	-0.41	1.28	-6
3	16	15452	3.29	1.37	51	4.48	1.98	69	-1.20	0.95	-18
4	6	9012	0.83	0.84	7	1.25	1.55	11	-0.42	0.93	-4
5	4	3877	2.73	1.84	11	2.89	1.44	11	-0.16	0.41	-1
6	13	10340	4.23	4.56	44	6.39	3.66	66	-2.16	2.73	-22
7	13	2532	1.37	2.34	3	1.94	2.77	5	-0.56	0.86	-1
8	12	4412	0.67	0.75	3	1.33	2.21	6	-0.65	1.92	-3
9	16	11781	3.23	3.07	38	3.89	3.16	46	-0.66	0.79	-8
10	17	13905	3.36	2.31	47	4.27	2.52	59	-0.91	2.06	-13
11	19	8895	3.69	1.84	33	4.45	2.04	40	-0.76	0.94	-7
12	9	3543	1.79	1.71	6	2.16	2.00	8	-0.37	0.55	-1
13	14	7263	2.83	3.28	21	3.26	3.95	24	-0.43	0.96	-3
14	6	933	0.44	0.51	0	0.97	0.88	1	-0.54	0.54	-1
15	7	4195	3.54	2.03	15	5.87	3.14	25	-2.33	2.55	-10
16	10	3089	2.77	2.04	9	3.09	2.30	10	-0.32	0.45	-1
17	16	12999	1.87	2.35	24	2.53	3.13	33	-0.66	1.03	-9
18	9	6732	1.32	3.64	9	1.64	4.19	11	-0.31	0.63	-2
19	4	5421	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
20	4	2508	0.00	0.00	0	0.09	0.11	0	-0.09	0.11	0
21	16	9717	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
22	16	12549	0.01	0.04	0	0.01	0.02	0	0.00	0.03	0
23	14	6951	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
24	12	7207	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
25	18	10552	0.95	1.89	10	1.30	2.32	14	-0.35	0.56	-4
26	14	6876	1.27	1.69	9	1.66	2.02	11	-0.38	0.51	-3
27	12	6881	1.15	1.77	8	1.55	2.07	11	-0.40	0.55	-3
28	12	7464	0.16	0.53	1	0.58	1.32	4	-0.42	1.08	-3
29	11	5465	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
30	14	4254	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
31	11	3016	0.07	0.24	0	0.07	0.22	0	0.01	0.02	0
32	10	3779	0.01	0.05	0	0.01	0.03	0	0.01	0.02	0
Total	**381**	**240222**			**448**			**583**			**-135**
SE					**30**			**34**			**15**

Appendix 4. H plot species defined as woody for the purpose of defining species richness.

Abies alba
Abies sp
Acer campestre
Acer platanoides
Acer pseudoplatanus
Aesculus hippocastanum
Alnus glutinosa
Betula pendula
Betula pubescens
Betula spp.
Buddleja davidii
Buxus sempervirens
Carpinus betulus
Castanea sativa
Chamaecyparis lawsoniana
Clematis vitalba
Cornus mas
Cornus sanguinea
Cornus sp
Cornus suecica
Corylus avellana
Cotoneaster horizontalis
Cotoneaster microphyllus
Crataegus laevigata
Crataegus laevigata X monogyna
Crataegus monogyna
Cupressus sp
Cytisus scoparius
Daphne laureola
Daphne mezereum
Euonymus europaeus
Fagus sylvatica
Frangula alnus
Fraxinus excelsior
Fuchsia magellanica
Hedera helix
Hippophae rhamnoides
Humulus lupulus
Ilex aquifolium
Juniperus communis
Laburnum anagyroides
Larix spp.
Ligustrum ovalifolium
Ligustrum sp
Ligustrum vulgare
Malus domestica
Malus sylvestris
Picea abies
Picea sitchensis
Picea sp
Pinus contorta
Pinus muricata
Pinus nigra
Pinus pinaster
Pinus sp
Pinus sylvestris
Populus nigra
Populus sp
Populus tremula
Prunus avium
Prunus domestica
Prunus laurocerasus
Prunus padus
Prunus sp
Prunus spinosa
Pseudotsuga menziesii
Pseudotsuga spp.
Pyrus cultivar
Quercus borealis
Quercus cerris
Quercus ilex
Quercus petraea
Quercus robur
Quercus spp.
Rhamnus cathartica
Rhododendron ponticum
Rhododendron spp.
Ribes nigrum/rubrum
Ribes rubrum
Ribes sp
Ribes uva-crispa
Rosa arvensis
Rosa canina
Rosa pimpinellifolia
Rosa spp.
Rosa tomentosa
Rubus caesius
Rubus chamaemorus
Rubus fruticosus
Rubus idaeus
Rubus saxatilis
Rubus spectabilis
Ruscus aculeatus
Salix alba
Salix atrocinerea
Salix aurita
Salix caprea
Salix cinerea
Salix fragilis
Salix herbacea
Salix lapponum
Salix myrsinifolia
Salix pentandra
Salix phylicifolia
Salix repens
Salix reticulata
Salix spp.
Salix triandra
Salix viminalis
Salix x smithiana
Sambucus nigra
Sambucus racemosa
Sequoiadendron giganteum
Sorbus aria
Sorbus aucuparia
Sorbus intermedia
Sorbus sp
Sorbus torminalis
Symphoricarpus albus
Symphoricarpus sp
Tamarix spp.
Taxus baccata
Tilia cordata
Tilia hybrids
Tilia platyphyllos
Tilia sp
Tsuga heterophylla
Ulex europaeus
Ulex gallii
Ulex minor
Ulex minor/gallii
Ulmus carpinifolia
Ulmus glabra
Ulmus minor
Ulmus procera
Ulmus sp
Viburnum lantana
Viburnum opulus

Appendix 5. The percentage of H-plots in each land class that can be defined as species rich, where species richness can be defined as from at least 3 species to at least 8 species per H-plot. Estimates for principalities and GB are given at the bottom of the table. Data are from CS1990

			percentage of H-plots with at least					
Land class	Number of sample squares	number with H plots	3 species	4 species	5 species	6 species	7 species	8 species
1	28	28	89	80	55	38	23	7
2	24	23	78	63	50	30	22	11
3	30	29	81	66	36	22	7	5
4	10	9	67	50	44	28	6	6
5	6	6	100	83	83	50	25	8
6	23	22	93	84	68	45	32	23
7	13	6	67	58	33	17	0	0
8	14	7	71	43	29	21	7	0
9	21	21	52	21	14	10	7	5
10	22	21	74	52	29	19	7	0
11	22	21	76	50	33	17	5	0
12	10	10	70	50	20	15	10	5
13	17	9	78	50	39	22	11	6
14	6	4	38	0	0	0	0	0
15	9	9	94	83	78	39	33	17
16	11	11	59	32	18	9	5	5
17	28	14	79	50	39	18	4	4
18	13	5	70	40	20	20	0	0
19	7	0	*	*	*	*	*	*
20	4	0	*	*	*	*	*	*
21	19	0	*	*	*	*	*	*
22	25	0	*	*	*	*	*	*
23	17	0	*	*	*	*	*	*
24	15	0	*	*	*	*	*	*
25	24	10	20	15	5	0	0	0
26	15	8	56	38	25	13	6	0
27	15	8	56	38	6	0	0	0
28	14	2	50	25	25	25	25	0
29	11	0	*	*	*	*	*	*
30	14	0	*	*	*	*	*	*
31	11	0	*	*	*	*	*	*
32	10	0	*	*	*	*	*	*
Total	**508**	**283**						
	England	**mean**	**69.7**	**51.9**	**35.9**	**22.4**	**11.3**	**5.4**
		se	**2.1**	**2.4**	**2.2**	**1.9**	**1.4**	**1.0**
	Scotland	**mean**	**19.1**	**12.0**	**6.8**	**4.4**	**2.8**	**0.2**
		se	**4.4**	**2.7**	**2.3**	**2.1**	**2.0**	**0.1**
	Wales	**mean**	**80.5**	**59.4**	**47.6**	**26.5**	**13.1**	**7.6**
		se	**3.3**	**4.8**	**3.8**	**3.6**	**2.4**	**2.1**
	GB	**mean**	**52.8**	**38.4**	**26.7**	**16.4**	**8.4**	**3.7**
		se	**2.2**	**1.9**	**1.7**	**1.5**	**1.2**	**0.6**

Appendix 6. Mean species rich hedge lengths (km per km^2) estimated from H-plots and estimates ('000 km) for the principalities and GB. Species richness defined as from at least 3 to at least 8 species per 10m length.

		At least 3	At least 4	At least 5	At least 6	At least 7	At least 8
1		4.48	4.05	3.17	2.40	1.71	0.60
2		2.43	1.92	1.66	1.02	0.71	0.35
3		2.78	2.24	1.34	0.89	0.33	0.24
4		2.16	1.94	1.48	1.04	0.09	0.09
5		3.34	3.02	3.02	1.70	0.72	0.01
6		5.66	5.33	4.71	3.33	2.36	1.88
7		1.42	1.19	0.78	0.31	0.00	0.00
8		0.43	0.29	0.23	0.21	0.02	0.00
9		1.93	0.92	0.85	0.44	0.42	0.32
10		2.87	1.93	1.03	0.87	0.37	0.00
11		2.78	1.90	1.29	0.69	0.21	0.00
12		1.47	1.19	0.55	0.40	0.11	0.04
13		2.23	1.38	1.08	0.71	0.36	0.21
14		0.06	0.00	0.00	0.00	0.00	0.00
15		3.37	3.00	2.77	1.65	1.56	0.88
16		1.74	1.04	0.81	0.49	0.27	0.27
17		1.11	0.83	0.62	0.29	0.08	0.08
18		1.03	0.59	0.50	0.50	0.00	0.00
19		0.00	0.00	0.00	0.00	0.00	0.00
20		0.00	0.00	0.00	0.00	0.00	0.00
21		0.00	0.00	0.00	0.00	0.00	0.00
22		0.00	0.00	0.00	0.00	0.00	0.00
23		0.00	0.00	0.00	0.00	0.00	0.00
24		0.00	0.00	0.00	0.00	0.00	0.00
25		0.18	0.10	0.01	0.00	0.00	0.00
26		0.59	0.46	0.27	0.21	0.17	0.00
27		0.32	0.19	0.09	0.00	0.00	0.00
28		0.13	0.07	0.07	0.07	0.07	0.00
29		0.00	0.00	0.00	0.00	0.00	0.00
30		0.00	0.00	0.00	0.00	0.00	0.00
31		0.00	0.00	0.00	0.00	0.00	0.00
32		0.00	0.00	0.00	0.00	0.00	0.00
'000 km							
England	**mean**	**316**	**250**	**189**	**128**	**73**	**37**
	se	**20**	**19**	**17**	**14**	**10**	**7**
Scotland	**mean**	**17**	**11**	**8**	**5**	**3**	**0.8**
	se	**4**	**3**	**2**	**2**	**1**	**0.4**
Wales	**mean**	**48**	**41**	**35**	**22**	**14**	**9**
	se	**5**	**4**	**4**	**3**	**3**	**2**
GB	**mean**	**381**	**302**	**231**	**156**	**89**	**47**
	se	**23**	**21**	**19**	**17**	**12**	**9**