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An investigation of uncertainty in field habitat mapping and the implications for detecting land cover change

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Abstract

Land cover data for landscape ecological studies are frequently obtained by field survey. In the United Kingdom, temporally separated field surveys have been used to identify the locations and magnitudes of recent changes in land cover. However, such map data contain errors which may seriously hinder the identification of land cover change and the extent and locations of rare landscape features. This paper investigates the extent of the differences between two sets of maps derived from field surveys within the Northumberland National Park in 1991 and 1992. The method used in each survey was the 'Phase 1' approach of the Nature Conservancy Council of Great Britain. Differences between maps were greatest for the land cover types with the smallest areas. Overall spatial correspondence between maps was found to be only 44.4%. A maximum of 14.4% of the total area surveyed was found to have undergone genuine land cover change. The remaining discrepancies, equivalent to 41.2% of the total survey area, were attributed primarily to differences of land cover interpretation between surveyors (classification error). Differences in boundary locations (positional error) were also noted, but were found to be a relatively minor source of error. The implications for the detection of land cover change and habitat mapping are discussed.

Introduction

The British landscape has been shaped by hundreds of years of human interference (Ratcliffe 1984). Nonetheless, the decades since the Second World War have witnessed a dramatic acceleration in the rate at which semi-natural vegetation has come under intensive agricultural management with an attendant loss of ecological diversity and conservation interest (Ratcliffe 1984, Fuller 1987, Parry *et al.* 1992). Awareness of the impact of land use change has been heightened by successive surveys of land use and land cover. Early field surveys were undertaken by Stamp (1947) and Coleman (1961). More recently there have been historical analyses of change in sample areas using archival aerial photography, such as the Monitoring Landscape Change project (Hunting Surveys and Consultants Ltd. 1986) and the National Countryside Monitoring Scheme (Nature Conservancy Council 1987). These surveys have served an important role in indicating the types and magnitudes of change which have been occurring.

Acknowledgement of the value of habitat surveys has led to the establishment of a number of field based landscape monitoring projects. Examples in-

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clude the three surveys conducted at six year intervals by the Institute of Terrestrial Ecology (ITE) (Bunce *et al.* 1992; Barr *et al.* 1993), and the monitoring programmes set up within Environmentally Sensitive Areas (Hooper 1992). These recent surveys have incorporated 'quality control' measures, reflecting the recognition of a potentially serious and long-standing problem. Considerable quantities of ecological survey data have accumulated over the last few decades, but there is little information on its reliability. Indeed, ecologists in general have been slow to address questions of data quality and observer error.

The only study known to the authors which attempts to quantify errors in the field mapping of land cover is that of Barr *et al.* (1993), describing results from the most recent ITE survey. In that study, the repeat survey of sample areas revealed a correspondence of 84% (by area). Other studies which recognise the problem of error in land cover mapping in the field, but which do not quantify its extent are those of NCC (1990), Wyatt (1991) and Dargie (1992).

Errors in the recording of the distributions of individual species of plant have been more widely recognised, and severe to emphasise the potential extent of errors in land cover mapping. Several studies deal with inadequacies in presence/absence data recorded in large scale surveys using 2 km (tetrad) or 10 km grid cells as the reporting units (Rich and Woodruff 1992; Prendergast *et al.* 1993). A second group of papers consider the accuracy of plant species lists and abundance estimates obtained from small scale quadrats (typically less than 100 m^2 in area) or transects (Kirby *et al.* 1986; Hooper 1992; Barr *et al.* 1993). Both categories of study indicate that observer bias is an important factor in determining the accuracy of plant species data. Rich and Woodruff (1992) suggest that field surveyors working at the 10 km scale tend to overlook relatively scarce plant species, while accurately recording national rarities and common species. The repeat survey of small quadrats has also indicated an element of human error in recording plant species, and particularly the relative abundances of species (Hooper 1992; Barr *et al.* 1993). The levels of correspondence obtained from these exercises have been reported in differing formats, but figures lying between 60 and 90% agreement appear typical for species lists (with slightly lower figures applying to estimates of abundance). Studies at both large and small scales have also identified differences in season of recording and time spent in the field as determinants of data quality. These factors are likely to be equally important in the survey of land cover, but there is a need for further investigation.

Despite the scarcity of published studies assessing the accuracy with which maps of land cover types can be produced by field surveyors, there have been a number of theoretical studies of error in spatial databases held within Geographical Information Systems (Goodchild and Gopal 1989). Chrisman (1989) identifies two basic types of error which are commonly present within digital map data. First, the misplacement of boundaries between parcels of different land cover types (positional error), and second, the assignment of parcels of land to inappropriate cover types (attribute classification error). Both types of error could be expected to arise in field habitat mapping because of the continuous nature of much variation in semi-natural vegetation, but also because of differences between the perceptions (and abilities) of the surveyors involved. These errors will clearly have the potential to cause problems in studies which aim to identify the magnitude and location of land use changes. Uncertainties in land cover mapping should be of particular concern to conservation bodies which may be interested in monitoring rare or unusual landscape features.

The present paper compares two sets of maps of land cover obtained by field survey of an area of 25 km^2 within the Northumberland National Park, Northern England. The two surveys were undertaken in separate years (1991 and 1992) and were planned independently by different organisations. Each survey used the Phase 1 methodology of the former Nature Conservancy Council (NCC) (NCC 1990) (now replaced by English Nature, Scottish Natural Heritage and the Countryside Commission for Wales). Analyses within a Geographical Information System (GIS) are used to quantify discrepancies between maps which can be attributed to positional and classification errors. The extent to which mapping accuracy is related to the area of a cover type is also investigated. The results are of particular relevance to the application of land cover surveys within conservation bodies in the U.K., because over 70% of the land surface has been mapped using the Phase 1 method (Wyatt 1991).

Methods

Field surveys

The Phase 1 survey methodology is described in detail elsewhere (NCC 1990). Briefly, the technique requires field surveyors to identify areas of relatively homogenous vegetation and to assign these 'parcels' to land cover types. The cover types are defined primarily on the basis of their plant species composition, but for certain cover types these information are supplemented by soil and land use characteristics (for example, improved grasslands used for recreational activities are classed as amenity grasslands). Hydrological conditions are also important in the definition of wetland and mire land cover types. Flushes, for example, occur on gently sloping ground and are characterised by surface water movement through carpets of bryophytes, together with small sedge and rush species.

The Phase 1 land cover types represent a hierarchical classification of land cover, such that ecologically similar cover types can be aggregated into a reduced set of broader cover types. Detailed descriptions of the Phase 1 land cover types are provided by NCC (1990).

Parcels of land are mapped on to Ordnance Survey (OS) maps in the field using standard colour and alphanumeric codes for each cover type and dominant plant species. The technique also provides for the mapping of boundary types (fences, hedges etc.), but these are not considered in the present paper.

In 1991 a Phase 1 survey of 188 1-km grid squares within the catchment of the River Tyne was conducted as part of the NERC/ESRC Land Use Programme (NELUP) (Cherrill and Lane 1994, in press; Whitby 1992, Cherrill *et al.* 1994; Cherrill *et al.* in press). Selection of the grid squares was stratified using the environmental landscape classification of the Institute of Terrestrial Ecology (Bunce *et al.* 1983). Of the 188 squares, 29 fell wholly or partly within the Northumberland National Park. The survey work involved three surveyors and was carried out between April and October.

In 1992, the Northumberland National Park contracted an independent environmental consultancy to carry out a Phase 1 survey within the boundaries of the Park. The work was then carried out by surveyors employed on fixed-term contracts.

The area surveyed by both groups of surveyors totalled 2578.8 hectares (ha). In each survey, cover types were recorded on 1:10,000 OS maps and field work was preceded by a short training period.

Digitising of field maps

The maps produced in each survey were digitised by a single operator using the ARC/INFO Geographical Information System. Each parcel of land was labelled with a code representing its land cover type.

The codes within the INFO database allowed certain land cover types to be combined, such that a smaller number of broad cover types resulted. The hierarchical nature of the Phase 1 classification of cover types determined the aggregation of cover types, although in some cases relatively dissimilar cover types listed under the same heading were maintained as separate cover types. The final list of aggregated cover types therefore reflected the hierarchical classification and the experience of the authors. Boundaries between parcels sharing the same aggregated land cover type code were dissolved to give maps showing parcels of the aggregated cover types. The maps of the 'original' and 'aggregated' cover types were stored as separate layers within the GIS.

Aspatial analysis

Aspatial analyses utilised the original digital map data for the cover types at the lowest level in the hierarchical Phase 1 classification. Analyses (a) compared the total areas of each cover type recorded in

1991 to their areas recorded in **1992,** and (b) examined changes in area in relation to the area of each cover type in **1991.** The latter analyses addressed the question of whether estimates of the areas of relatively rare cover types were more variable between years than those of more extensive cover types.

Spatial analysis

The **1991** and **1992** field maps were overlaid within ARC/INFO. The results of such an overlay can be presented as a matrix of correspondence in which the $(i,j)^{th}$ cell gives the area of cover type i in one map classed as cover type j in the other. If two maps were in complete agreement there would be one non-zero cell in each row and column. If the cover types were placed in the same order along rows and columns, non-zero cells would lie across the leading diagonal of the matrix. The percentage of land within a matrix which lies within diagonal cells can be used as an index of the extent of agreement between two maps.

The overlay analyses were conducted with and without buffering of polygon boundaries and for both the original maps and the simplified maps showing the aggregated cover types.

Buffering involved identifying land lying within a specified distance of a boundary (Burrough **1986).** Buffering around boundaries was carried out for distances of 5, **10, 15, 20** and **25** m. These buffer zones were successively excluded from the matrix of correspondence. Buffering enabled a comparison of the cover types assigned to the "core areas" of parcels of land, thereby minimising any spatial differences in the location of boundaries in both maps. Comparison of the matrices allowed an assessment of the extent to which positional and classification errors contributed to the apparent differences between maps.

The potential for change

A priori it was possible to identify certain types of land use change which could not have occurred over the twelve month period between surveys. For example, an improved grassland could not revert to an unimproved grassland in this period. In contrast, an unimproved grassland could be ploughed and seeded to produce an improved pasture or arable crop within a single year. **A** matrix of 'potential change' summarising this knowledge was drawn up for the cover types at the lowest level in the Phase 1 hierarchy, but not for the aggregated cover types. The latter task proved too subjective because the individual cover types within the aggregated cover types, although ecologically related, were often dissimilar in their potential to undergo change, or conversely to be the end product of change.

The rows and columns of the matrix represented the cover types recorded in the field in **1991** and **1992** respectively. The $(i,j)^{th}$ cell of each matrix contained a code indicating whether cover type i could or could not change to cover type j between years. The matrix was then circulated to colleagues with experience of land use change within the National Park and modified according to their comments.

The matrix was used to categorise the apparent land use changes in the correspondence matrices derived from **GIS** overlay of the **1991** and **1992** survey maps. In combination with the **GIS** buffering procedure, the matrix allowed an estimate to be made of the overall level of misinterpretation in the two surveys.

Results

Aspatial analyses

Thirty-one cover types were recorded in **1991,** while **35** were recorded in **1992** (Table **1).** In total, 38 cover types were recorded, of which **28** were found in both years. **A** further 43 areal cover types included in the NCC Phase **1** field manual were not recorded in either survey. There was a significant association between the identities of the cover types recorded in the two years (Table **2).**

The total areas of the cover types in **1991** and **1992** were significantly correlated (Spearman Rank Correlation, r_s = **0.65,** P $<$ **0.001,** n = 38), indi-

Table 1. Summary of the areas of each cover type recorded in two years and the areas undergoing apparent change.

Phase 1 cover types	area (ha)		changes (% of 1991 areas)			no change (% of 1991 areas)
	1991	1992	net	losses	gains	
1 Semi nat broad lvd wood[1]	45.0	40.6	-9.8	31.1	21.3	68.9
2 Plantation - broad lvd	22.4	14.6	-34.8	95.5	60.7	4.5
3 Plantation - conifer	482.5	474.2	-1.7	11.7	10.0	88.3
4 Semi nat mixed wood	0.5	0.0	-100.0	100.0	0.0	0.0
5 Plantation - mixed	9.7	11.7	20.6	86.6	107.2	13.4
6 Dense scrub	1.7	0.6	-64.7	100.0	35.3	0.0
7 Scattered scrub	0.0	4.6	∞		∞	
8 Scattered trees	23.0	25.0	8.7	93.0	101.7	7.0
9 Felled conifers	30.7	58.8	91.5	0.0	91.5	100.0
10 Unimproved acid grass	546.5	388.9	-28.8	64.5	35.6	35.6
11 SI acid grass[2]	138.8	167.6	20.8	70.5	91.2	29.5
12 Unimproved neutral grass	1.1	2.9	163.6	100.0	263.6	0.0
13 SI neutral grass	33.3	170.9	413.2	46.6	459.8	53.5
14 SI basic grass	0.7	0.0	-100.0	100.0	0.0	0.0
15 Marshy grass	196.0	391.4	99.7	67.9	167.6	32.1
16 Improved grass	234.5	172.0	-26.7	40.3	13.7	59.7
17 Older improved grass	136.6	0.3	-99.8	100.0	0.2	0.0
18 Amenity grass	1.5	0.3	-80.0	80.0	0.0	20.0
19 Bracken	33.1	27.6	-16.6	80.4	63.8	19.6
20 Scattered bracken	0.0	26.6			∞	
21 Ruderal tall herbs	0.8	1.0	25.0	87.5	112.5	12.5
22 Non ruderal tall herbs	0.0	2.4	∞		∞	0.0
23 Dry acid heath	189.4	79.4	-58.1	63.8	5.7	36.2
24 Dry basic heath	0.0	0.8	∞		∞	
25 Wet acid heath	98.5	75.8	-23.1	83.4	60.3	16.7
26 Dry grassheath mosaic	26.5	87.2	229.1	91.7	320.8	8.3
27 Wet grassheath mosaic	8.2	220.1	2584.2	31.7	2615.9	68.3
28 Blanket bog	65.9	33.6	-49.0	80.4	31.4	19.6
29 Wet modified bog	34.4	14.9	-56.7	68.6	11.9	31.4
30 Dry modified bog	131.1	0.0	-100.0	100.0	0.0	0.0
31 Flush	2.1	0.3	-85.7	100.0	14.3	0.0
32 Valley bog	0.0	0.7	∞		∞	
33 Pond	0.0	0.4	∞		∞	
34 River	4.2	4.2	0.0	0.0	0.0	100.0
35 Natural rock	0.0	1.9	∞		∞	
36 Quarry	0.6	0.1	-83.3	100.0	16.7	0.0
37 Arable	38.9	33.6	-13.6	19.8	6.2	80.2
38 Built up	40.6	39.4	-3.0	4.4	1.5	95.6
39 Not recorded	0.3	4.5	1400.0	100.0	1300.0	0.0
Total	2578.8	2578.8	0.0	55.6	55.6	44.4

[1] semi natural broad leaved wood
[2] semi improved acid grass

cating broad similarities between the two surveys. For certain cover types however there were large differences between the estimated areas in the two years. The total area of semi-improved neutral grassland, for example, appeared to increase from 33.3 ha to 170.9 ha. For other cover types, the total

Table 2. Summary of Phase 1 cover types recorded in one or both field surveys. Chi-square = 45.4, d.f. = 1, P < 0.001.

		1992		
		Recorded	Not recorded	Total
1991	Recorded	28	**3**	31
	Not recorded	7	**43**	50
	Total	35	46	81

areas recorded in each year were more concordant (*e.g.* conifer plantation) (Table 1).

Cover types recorded in 1991 only
Three cover types were recorded in 1991 only (Table 1). Of these, semi-natural mixed woodland and semi-improved basic grassland were relatively scarce with total areas of 0.5 ha and 0.7 ha respectively. The third cover type, dry modified bog, had an area of 131.1 ha (Table 1). The mean area of the other 28 cover types recorded in 1991 was 87.4 ha. In terms of their areas in 1991, there was no significant difference between cover types recorded in both years and those recorded in 1991 only (Kruskal-Wallis ANOVA by ranks, H = 1.79, P = 0.18). Sample sizes were small however.

Cover types recorded in 1992 only
Seven cover types were recorded in 1992 only (Table 2). All but one had total areas of less than 5 ha (Table 1). The mean area of the other 28 cover types recorded in 1992 was 90.6 ha. In terms of their areas in 1992, there was a significant difference between cover types recorded in both years and recorded in 1992 only (Kruskal-Wallis ANOVA, H = 4.60, P = 0.03). Cover types recorded in 1992 alone, tended to be relatively rare in that year.

Cover types recorded in both years – not changing in areas
A single cover type, running water, remained unchanged in area between years with a total area of 4.2 ha.

Cover types recorded in both years – declining areas
Of the 28 cover types recorded in both years, 17 declined in area between surveys. The declines in areas of individual cover types, expressed as a percentage of their area in 1991, ranged from –1.7% to –99.8% (Table 1). There was a significant correlation between the percentage change in area and the initial area of a cover type in 1991 (r_s = 0.50, P < 0.05, n = 17). The result indicates that there was a tendency for cover types which were relatively rare in 1991 to undergo a greater decline in total area between years, than cover types which were more extensive in area.

Cover types recorded in both years – increasing areas
Ten of the cover types, which were recorded in both years, increased in area. The increases for individual cover types ranged from 8.7% to 2584.2% of their 1991 areas. The area of wet heath/grass mosaic showed the greatest increase from 8.2 ha to 220.1 ha. There was no significant relationship between the percentage increase and the area of a cover type in 1991 (r_s = –0.07, P > 0.50, n = 10).

Spatial analysis

Unbuffered overlay

Unaggregated cover types. The matrix of correspondence from the overlay analysis of the maps of unaggregated cover types is shown in Table **3.** The cells of the matrix represent areas expressed as tenths of percentages of the total study area. Areas of land which were of the same cover type in both years (lying on the leading diagonal in the matrix) totalled 44.4% percent of the area surveyed, suggesting that 55.6% of the land surface changed from one cover type to another between years. For a given cover type, the off-diagonal row cells represent losses to other cover types from the area recorded in 1991. Conversely, off-diagonal column cells represent gains from other cover types. These losses and gains are summarised in Table 1.

Understanding of the summary of the spatial analyses in Table 1 depends on recognising that the data are expressed as percentages of the areas of the cover types in 1991. Thus, it can be seen that the net changes (derived from the aspatial analyses) represent the differences between the losses and gains. In addition, the percentage of a cover type which remained unchanged between years and the percentage lost (to other cover types) must sum to 100 (*i.e.* the extent of the cover types area in 1991). A figure of 100% in the final column of the table, therefore, does not infer that the absolute area of a cover type remained constant between years; gains from other cover types were possible (as for felled conifers).

Gains and losses, from and to other cover types respectively, were the rule rather than the exception. Only the cover type for running water retained both the same area and the same spatial location between years. Overall, the aspatial analyses appear to underestimate greatly the extent of the change between surveys.

The areas of each cover type remaining unchanged between years, when expressed as a percentage of the cover types' areas in 1991, ranged from 0% to 100% (Table 1). For the 28 cover types recorded in both years the percentage of land remaining unchanged was positively related to their area in 1991 ($r_s = 0.44$, $P < 0.05$, $n = 28$). In other words, extensive cover types appeared to be more stable over time than those with small areas.

Aggregated cover types. The correspondence matrix is shown in Table 4. The cells on the leading diagonal account for 71.0% of the area surveyed. Comparison with the figure of 44.4%, obtained from the overlay of the maps of the unaggregated cover types, suggests that a considerable proportion of the differences in the latter may be due to either confusion between ecologically similar cover types (*i.e.* classification error) or genuine land cover change between years.

Buffered overlay

Unaggregated cover types. The results of the buffered overlay analyses are summarised in Table 5. As the widths of the buffer zones were increased the agreement between maps increased by approximately 2% for each additional 5 m. The results suggest that positional errors (*i.e.* inaccuracies in the location of boundaries) were a relatively minor source of the differences between maps. The correspondence matrices derived from the buffered overlays are not reproduced here because of the relatively small increases in agreement between maps.

Aggregated cover types. The result of buffering the boundaries of the aggregated cover types was similar to that of buffering the unaggregated cover types. An increase in correspondence between surveys of approximately 2% was observed for each 5 m increment in buffer width (Table 5). As was the case for the maps of unaggregated land cover types, the analysis emphasises the importance of apparent attribute classification errors, rather than positional errors.

The potential for change

The matrix categorising transitions between the original unaggregated cover types as either 'possible' or 'impossible' is shown in the Appendix. In Table 6, the correspondence matrices derived from the overlay analyses are summarised in terms of these 'possible' and 'impossible' land use changes. For each overlay analysis, around three-quarters of the differences between surveys could not have occurred in less than 12 months. These apparent changes are therefore likely to be misinterpretations in one or both surveys. The figures for possible changes can be thought of as maximum estimates of the actual land use change.

Overview of results

The analyses highlight a number of important points. First, the greatest discrepancies between surveys were for the cover types with the smallest areas. Second, estimates of land cover change based on aspatial and spatial analyses differ greatly. Those based on the former appear to underestimate the extent of change. Third, the use of line buffered maps in the spatial overlay analyses suggests that map differences due to misplacement of cover type boundaries are a relatively minor source of error. Conversely, the aggregation of ecologically related cover types suggests that a lack of consistency in distinguishing between ecologically simi-

Table 3**.** Correspondence matrix generated from an unbuffered overlay of field survey maps from **1991** and **1992.** Figures are 10 x percentages of the total area surveyed, * = *c* 0.1%.

Cover type in 1991	Cover type in 1992: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 Semi nat broad lvd wood	12	0	1	0	1	0	0	1	0	*	*	0	*	0	1	*	0	0	0	*
2 Plantation - broad lvd	1	*	5	0	*	0	0	0	0	0	*	0	2	0	1	*	0	0	0	0
3 Plantation - conifer	1	4	165	0	2	*	*	1	7	1	*	0	3	0	2	0	0	0	*	*
4 Semi nat mixed wood	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Plantation - mixed	0	0	1	0	1	0	0	0	3	0	*	0	0	0	0	0	0	0	0	0
6 Dense scrub	0	0	0	0	0	0	0	*	0	0	*	0	0	0	0	0	0	0	0	0
7 Scatteredscrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Scattered trees	0	1	*	0	0	0	0	1	0	*	0	0	4	0	*	3	0	0	0	0
9 Felled conifers	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0
10 Unimproved acid grass	1	0	7	0	*	0	0	2	2	75	22	0	3	0	75	*	*	0	3	5
11 SI acid grass	*	0	1	0	0	0	0	1	0	13	16	0	5	0	13	0	0	0	2	1
12 Unimproved neutral grass	0	0	*	0	0	0	0	0	0	0	0	*	0	0	0	*	0	0	0	0
13 SI neutral grass	*	0	*	0	0	0	0	*	0	0	1	0	7	0	3	*	0	0	0	0
14 SI basic grass	0	0	0	0	0	0	0	*	0	0	*	0	*	0	0	0	0	0	0	0
15 Marshygrass	*	0	0	0	0	0	0	*	0	34	2	*	2	0	24	0	0	0	*	*
16 Improvedgrass	*	*	0	0	0	0	1	2	0	*	11	1	16	0	4	54	0	0	*	0
17 Olderimprovedgrass	*	0	*	0	0	0	*	1	0	3	10	0	20	0	11	6	0	0	0	1
18 Amenity grass	*	0	0	0	0	0	0	0	0	0	*	0	0	0	0	*	0	*	0	0
19 Bracken	0	0	0	0	0	0	0	*	0	4	1	0	*	0	2	0	0	0	3	2
20 Scattered bracken	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 Ruderal tall herbs	*	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 Non ruderal tall herbs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 Dry acidheath	0	0	3	0	0	0	0	*	0	2	*	0	1	0	2	0	0	0	1	1
24 Dry basic heath	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 Wetacidheath	0	0	0	0	0	0	0	0	0	3	1	0	0	0	3	0	0	0	2	*
26 Dry grass/heath mosaic	0	0	0	0	0	0	0	0	0	2	0	0	0	0	*	0	0	0	0	0
27 Wet grass/heath mosaic	0	0	0	0	0	0	0	0	0	*	0	0	0	0	*	0	0	0	0	0
28 Blanketbog	0	0	*	0	0	0	0	0	0	4	*	0	0	0	2	0	0	0	*	*
29 Wet modified bog	0	0	0	0	0	0	0	0	0	*	0	0	3	0	5	*	0	0	0	0
30 Dry modified bot	0	0	0	0	0	0	0	0	0	9	1	0	0	0	3	0	0	0	0	0
31 Flush	0	0	0	0	0	0	0	0	0	*	0	0	0	0	*	0	0	0	0	0
32 Valleybog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33 Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34 River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35 Natural rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36 Quarry	0	0	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37 Arable	0	0	0	0	0	*	*	1	0	0	0	0	0	0	0	2	0	0	0	0
38 Built up	*	0	*	0	0	0	0	*	0	0	0	0	0	0	*	*	0	0	0	0
39 Not recorded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	0	0	0
Total	16	6	184	0	5	*	2	10	23	151	65	1	66	0	152	67	*	*	11	10

Table 3. Continued.

		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Total
		Cover type in 1992																			
	1 Semi nat broad lvd wood	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	0	0	*	17
	2 Plantation - broad lvd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
	3 Plantation - conifer	0	0	1	0	*	0	0	0	*	0	0	0	0	0	*	0	0	0	0	187
	4 Semi nat mixed wood	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	*
	5 Plantation - mixed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	6 Dense scrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	7 Scattered scrub	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8 Scattered trees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	9
C	9 Felled conifers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
o	10 Unimproved acid grass	0	1	0	0	3	1	13	*	0	0	0	0	0	0	0	0	0	0	0	212
v	11 SI acid grass	*	0	0	0	0	0	1	0	1	0	0	0	*	0	*	0	0	*	*	54
e	12 Unimproved neutral grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	0	0	*
r	13 SI neutral grass	0	0	0	0	0	0	1	0	0	0	0	0	0	0	*	0	*	0	*	13
	14 SI basic grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*
	15 Marshy grass	0	0	0	0	*	7	6	0	*	0	*	*	*	0	0	0	0	0	0	76
t	16 Improved grass	*	0	0	0	0	*	1	0	0	0	0	0	0	0	0	0	1	0	*	91
y	17 Older improved grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	*	*	0	53
p	18 Amenity grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	0	1
e	19 Bracken	0	*	0	0	*	*	1	*	0	0	*	0	0	0	*	0	0	0	0	13
	20 Scattered bracken	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
i	21 Ruderal tall herbs	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*	*
n	22 Non ruderal tall herbs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23 Dry acid heath	0	0	27	0	4	3	28	1	0	0	0	0	0	0	*	0	0	0	*	73
1	24 Dry basic heath	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*
9	25 Wet acid heath	0	0	3	0	6	12	7	0	0	0	0	*	0	0	*	0	0	0	0	38
9	26 Dry grass/heath mosaic	0	0	0	0	3	1	3	2	0	0	0	0	0	0	0	0	0	0	0	10
1	27 Wet grass/heath mosaic	0	0	0	0	0	*	2	0	0	0	0	0	0	0	0	0	0	0	0	3
	28 Blanket bog	0	0	*	*	2	*	11	5	1	0	0	0	0	0	0	0	0	0	0	26
	29 Wet modified bog	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	13
	30 Dry modified bot	0	0	1	0	10	3	13	4	0	0	0	*	0	0	0	0	0	0	1	51
	31 Flush	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	32 Valley bog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33 Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34 River	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
	35 Natural rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	36 Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*
	37 Arable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	15
	38 Built up	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	*	16
	39 Not recorded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*
	Total	*	1	31	*	23	34	85	13	3	0	*	*	*	2	1	*	13	2	2	000

The row labels "C o v e r t y p e i n 1 9 9 1" run down the left margin.

***Table 4*.** Correspondence matrix generated from an unbuffered overlay of field survey maps from 1991 and 1992 with aggregated Phase 1 cover types. Figures are 10 × percentages, * = < 0.1%.

	Cover type in 1992																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1 **Woodland**	194	*	2	9	10	*	*	0	0	1	*	0	*	0	0	0	1	217
2 **Scrub**	0	0	*	0	*	0	0	0	0	0	0	0	0	0	0	0	0	1
3 **Parkland**	1	0	1	0	5	3	0	0	0	0	0	0	0	0	*	0	0	9
4 **Felled Wood**	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	12
5 **Unsown Grass**	10	0	3	2	295	1	11	*	1	31	1	*	*	*	*	0	*	355
6 **Sown Grass**	1	2	3	0	75	60	1	*	0	1	0	0	*	1	*	0	*	144
7 **Bracken**	0	0	*	0	6	0	5	0	*	1	*	0	*	0	0	0	0	13
8 **Ruderal Herbs**	*	0	0	0	0	0	0	*	0	0	0	0	0	0	0	0	*	*
9 Non ruderal Herbs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 **Heath/Mosaics**	3	0	*	0	15	0	5	0	0	99	3	0	*	0	0	0	*	125
11 **Mires/Flushes**	*	0	0	0	28	*	*	0	0	46	15	0	0	0	0	0	1	91
12 **Open Water**	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
13 **Bare Rock**	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*
14 **Arable**	0	*	1	0	0	2	0	0	0	0	0	0	0	12	0	0	0	15
15 **Built Up**	*	0	*	0	0	*	0	0	0	0	0	0	0	0	15	0	*	16
16 **Amenity Grass**	*	0	0	0	0	*	0	0	0	0	0	0	0	0	*	*	0	1
17 **Unknown**	0	0	0	0	0	*	0	0	0	0	0	0	0	0	0	0	0	*
Total	210	2	10	23	435	67	21	*	1	180	19	2	1	13	15	*	2	1000

Table **5.** Summary of overlay analyses of 1991 and 1992 field survey maps.

Analysis		% correspondence for:	
		Unaggregated cover types	Aggregated cover types
Unbuffered		44.4	71.0
Buffered	5m	46.2	73.5
	10m	48.1	75.8
	15m	50.0	77.6
	20m	51.8	78.6
	25m	53.4	80.2

Table 6. Summary of overlay analyses of 1991 and 1992 field survey maps of unaggregated cover types, using the classification of apparent changes into 'impossible' and 'possible' types (defined in the Appendix).

Type of change	Unbuffered overlay	Buffered overlay 5m	10m	15m	20m	25m
No change (%)	44.4	46.2	48.1	50.0	51.8	53.4
Possible (%)	14.4	13.5	12.7	12.1	11.6	11.2
Impossible (%)	41.2	40.2	39.2	37.9	36.6	35.4
Total area in overlay	2578.8	2161.6	1844.0	1585.5	1370.7	1189.4

lar cover types may have been an important cause of discrepancies between surveys. Fourth, this interpretation is strengthened by the consideration of the types of land cover changes which could potentially have occurred between the two survey dates. This final analysis suggests that at least three-quarters of the differences between surveys were due to differences of interpretation between the field surveyors. While the initial overlay analyses indicated that 55.6% of land changed from one cover type to another between years, subsequent interpretation suggests that actual land cover change accounted for less than 14.4% of the total area surveyed.

Discussion

The present paper highlights the difficulties associated with identifying the extent of land cover change from temporally separated field surveys. Even when the same methodology is used in successive surveys, large differences in the mapped data can arise from observer error. The current lack of an accepted method of separating this 'noise' from genuine land cover change presents a hindrance in the potential usage of the large quantities of land cover data which have been collected to date. This problem has been exacerbated by the development of a plethora of different (and often incompatible) survey techniques (Wyatt et *al.* 1993), and a long-standing neglect of data quality control.

Positional and classification errors (Chrisman 1989) were apparent in the present study, with the latter being an order of magnitude greater. The nature of these results was not unexpected, yet the extent of the apparent differences in interpretation of the Phase 1 cover type definitions between surveys was a surprise. All surveyors were recruited on the basis of their past experience and botanical expertise, were issued with the standard field manual describing the vegetation types to be mapped (NCC 1990), and undertook preliminary group training to ensure consistency of approach within each survey. Despite these precautions the data suggest that differences in interpretation of the Phase 1 manual existed between the two surveys. The simple step of aggregating ecologically similar land cover types led to a 27% reduction in the area of discrepancy between surveys (Table 5).

Sources of discrepancy between surveys can be illustrated explicitly by reference to map data from

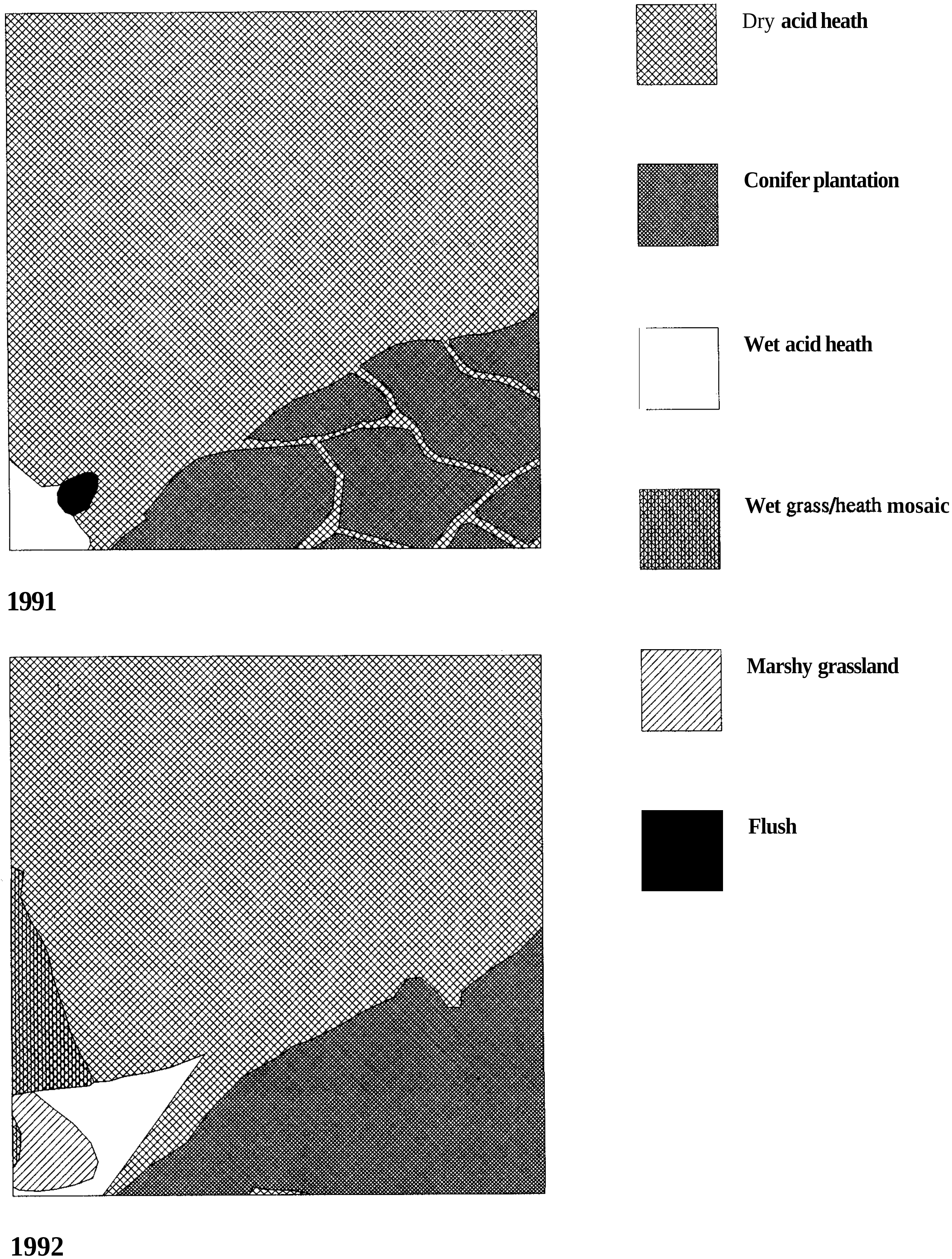

Fig. 1. Land cover recorded within an example 1-km gridsquare (British Ordnance Survey Grid Reference NY9694) in 1991 and 1992.

an individual 1-km grid square. The 1-km grid square in Fig. 1 was selected because the two maps illustrate the principle types and sources of apparent error. The major blocks of land cover within Fig. 1; namely dry acid heath and coniferous plantation, were recognised in both field surveys. Nonetheless, their shared boundary, although a sharp transition between dissimilar cover types, was not drawn in precisely the same location in each survey. This is an example of a positional error. However, the two surveys also differed in the resolution applied to mapping the conifer plantations and dry heath. In 1991, the field surveyor mapped the forest rides as a continuation of the dry heath on the open moorland, but in 1992 the forest was mapped as a continuous block. Whilst some degree of error associated with locating boundaries is inevitable, the differences in the treatment of forest rides could have been avoided by standardisation of approaches used in the two surveys. This example illustrates the importance of the scale of observation in mapping, and in particular as a potential source of classification errors (Chrisman 1989).

Examples of more complex discrepancies between surveys are provided by the vegetation in the South West corner of the example square (Fig. 1). Although both surveys recognised this area as being distinctly wetter than the adjacent dry heath, there were marked differences in the spatial locations of an area of wet heath and in the identity of the associated cover types. In part these differences may reflect difficulties in identifying artificial boundaries along gradients of continuously varying semi-natural vegetation. However, they also appear to illustrate fundamental differences in the way the surveyors perceived the vegetation.

The lack of consistency in the application of the Phase 1 methodology is worrying; not least because by 1991 70% of the land surface of Great Britain had been mapped using this approach (Wyatt 1991). One of the aims of these extensive surveys has been to provide a baseline against which future land cover changes can be quantified (NCC 1990). Great care will evidently need to be exercised if this potential is to be realised. This is especially true for cover types with small areas. The magnitudes of discrepancies between surveys were inversely related to the areas of the cover types concerned. This finding is of particular relevance for conservation bodies who may wish to monitor components of the British landscape which are rare or have small areas (*e.g.* ponds, rock outcrops). The results should also be of concern to those who use field surveys to provide 'ground-truth' in the interpretation of remotely sensed land cover data (see Curran and Williamson 1985, Cherrill *et al.* 1994, Cherrill *et al.* in press).

To be fair to the Phase 1 methodology, it must be pointed out that the subjectve nature of habitat mapping will also apply to other field survey techniques. Documentary evidence, however, is lacking, perhaps due to an understandable (but misplaced) reluctance to publicise information which appears to undermine the value of expensive survey work. A second reason for the lack of data on this subject is that quality control has been neglected. It is likely that many (if not most) studies have been conducted without provision for estimation of observer error. This applies to both surveys included in the present paper – where comparison of the two surveys became possible only after the chance overlap of sampling effort. The land cover survey conducted by the Institute of Terrestrial Ecology incorported the resurvey of sample squares, but has the same disadvantage as that reported here; namely that the two surveys were conducted in different years (Barr *et al.* 1993). In these circumstances, it is proposed that GIS buffering techniques, the aggregation of related cover types, and the application of commonsense can greatly increase understanding in the comparison of data from successive surveys. In the long-term, however, these steps should be seen only as additional tools in the interpretation of surveys for which adequate quality control safeguards have been incorporated at the outset. Clearly, resurvey exercises should run concurrently with the main sampling programme.

Quality control measures may include rigorous group training of field surveyors, refresher courses during extended surveys, the use of aerial photographs as an aid to locating complex boundaries, the pairing of field surveyors and the regular mixing of surveyors between pairs (NCC 1990, Wyatt 1991, Dargie 1992, Hooper 1992, Barr *et al.* 1993). It is interesting to speculate that the relatively high figure of 84% correspondence achieved in the ITE resurvey exercise may be attributed to their inclusion of these measures. Indeed, in light of the results of the present study, these precautions would appear essential. However, just as the extent of mapping errors remains a largely hidden problem, the efficacy of individual quality control measures remains largely untested (Dargie 1992). This is an area requiring considerably greater attention than has been the case to date; not least because introduction of each additional quality control measure inevitably increases financial costs. Of course, the ultimate consideration is that a poorly executed survey will be of little use in the subsequent detection of land cover change. One solution may be to focus resources on the monitoring of land cover change in small carefully selected sample areas, as exemplified by Barr *et al.* (1993). However, even where accuracies of 80–90% are achieved within individual surveys, the problem of distinguishing subsequent land cover change from observer error is likely to remain a significant issue.

The problems identified in the present paper will be exacerbated where the land cover data in successive surveys have been obtained using different methodologies and differing classifications of land cover. Such retrospective analyses are not desirable, but often become necessary when practical decision-making demands utilisation and integration of all available data. Clearly, estimates of land cover change derived from temporally separated field surveys should be treated with extreme caution, and particularly so where the land cover definitions used in each have been defined by organisations with differing objectives. Current research initiatives in integrating contrasting land cover data sets, detecting land cover change and the estimation of errors in land cover surveys are described by Bunce *et al.* (1992), Wyatt *et al.* (1994), Cherrill (in press), Cherrill *et al.* (in press) and McClean *et al.* (in press). It is hoped that the present paper will raise awareness of the issues involved.

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Appendix

Matrix summarising potential changes between cover types from 1991 to 1992. 1 = possible land use change; 2 = impossible and use change; 3 = no change.

Cover type in 1991	Cover type in 1992: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 Semi nat broad lvd wood	3	1	1	1	1	2	2	1	2	2	2	2	2	2	2	1	2	1	1	1
2 Plantation - broad lvd	2	3	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	1	1
3 Plantation - conifer	2	1	3	2	1	2	2	1	1	2	2	2	2	2	2	1	2	1	1	1
4 Semi nat mixed wood	1	1	1	3	1	2	2	1	2	2	2	2	2	2	2	1	2	1	1	1
5 Plantation - mixed	2	1	1	2	3	2	2	1	2	2	2	2	2	2	2	1	2	1	1	1
6 Dense scrub	2	1	1	2	1	3	1	1	2	2	2	2	2	2	2	1	2	1	2	1
7 Scattered scrub	2	1	1	2	1	2	3	1	2	1	1	1	1	1	1	1	1	1	1	1
8 Scattered trees	2	1	1	2	1	2	2	3	2	1	1	1	1	1	1	1	1	1	1	1
9 Felled conifers	2	1	1	2	1	2	2	1	3	2	2	2	2	2	2	1	2	1	1	1
10 Unimproved acid grass	2	1	1	2	1	2	2	1	2	3	1	2	2	2	2	1	2	1	2	1
11 SI acid grass	2	1	1	2	1	2	2	1	2	1	3	2	2	2	2	1	2	1	2	1
12 Unimproved neutral grass	2	1	1	2	1	2	2	1	2	2	2	3	1	2	2	1	2	1	2	1
13 SI neutral grass	2	1	1	2	1	2	2	1	2	2	2	1	3	2	2	1	2	1	2	1
14 SI basic grass	2	1	1	2	1	2	2	1	2	2	2	2	2	3	2	1	2	1	2	1
15 Marshy grass	2	1	1	2	1	2	2	1	2	2	2	2	2	2	3	1	2	1	2	1
16 Improved grass	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	3	1	1	2	2
17 Older improved grass	2	1	1	2	1	2	2	1	2	2	1	2	1	1	2	1	3	1	2	2
18 Amenity grass	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	1	3	2	2
19 Bracken	2	1	1	2	1	2	2	1	2	1	1	1	1	1	2	1	2	1	3	1
20 Scattered bracken	2	1	1	2	1	2	2	1	2	1	1	1	1	1	2	1	2	1	1	3
21 Ruderal tall herbs	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	1	1	2	1
22 Non ruderal tall herbs	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
23 Dry acid heath	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
24 Dry basic heath	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
25 Wet acid heath	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
26 Dry grass/heath mosaic	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
27 Wet grass/heath mosaic	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
28 Blanketbog	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
29 Wet modified bog	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
30 Dry modified bot	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	1	2	1	2	1
31 Flush	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	2
32 Valleybog	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
33 Pond	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	2
34 River	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
35 Naturalrock	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
36 Quarry	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
37 Arable	2	1	1	2	1	2	2	1	2	2	2	2	2	2	2	1	2	1	2	2
38 Built up	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
39 Notrecorded	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix

Continued.

Cover type in 1991	Cover type in 1992: 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
1 Semi nat broad lvd wood	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
2 Plantation - broad lvd	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
3 Plantation - conifer	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
4 Semi nat mixed wood	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
5 Plantation - mixed	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
6 Dense scrub	1	1	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
7 Scatteredscrub	1	1	1	1	1	1	1	2	1	1	2	2	1	2	2	1	1	1	1
8 Scattered trees	1	1	1	1	1	1	1	2	1	1	2	2	1	2	2	1	1	1	1
9 Felled conifers	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
10 Unimproved acid grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
11 SI acid grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
12 Unimproved neutral grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
13 SI neutral grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
14 SI basic grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
15 Marshy grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
16 Improved grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
17 Older improved grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
18 Amenity grass	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
19 Bracken	1	2	1	1	1	1	1	2	1	1	2	2	1	2	2	1	1	1	1
20 Scattered bracken	1	2	1	1	1	1	1	2	1	1	2	2	1	2	2	1	1	1	1
21 Ruderal tall herbs	3	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
22 Non ruderal tall herbs	1	3	2	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
23 Dry acid heath	1	2	3	2	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
24 Dry basic heath	1	2	2	3	2	2	2	2	2	2	2	2	1	2	2	1	1	1	1
25 Wetacidheath	1	2	2	2	3	2	2	2	2	2	2	2	1	2	2	1	1	1	1
26 Dry grass/heath mosaic	1	2	2	2	2	3	2	2	2	2	2	2	1	2	2	1	1	1	1
27 Wet grass/heath mosaic	1	2	2	2	2	2	3	2	2	2	2	2	1	2	2	1	1	1	1
28 Blanketbog	2	2	2	2	2	2	2	3	2	2	2	2	1	2	2	1	1	1	1
29 Wet modified bog	2	2	2	2	2	2	2	2	3	2	2	2	1	2	2	1	1	1	1
30 Dry modified bot	2	2	2	2	2	2	2	2	2	3	2	2	1	2	2	1	1	1	1
31 Flush	2	2	2	2	2	2	2	2	2	2	3	2	1	2	2	1	1	1	1
32 Valley bog	2	2	2	2	2	2	2	2	2	2	2	3	1	2	2	1	1	1	1
33 Pond	1	2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	1	1	1
34 River	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	1
35 Naturalrock	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	1	2	1	1
36 Quarry	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	3	2	1	1
37 Arable	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	3	1	1
38 Built up	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	3	1
39 Notrecorded	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3