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Habitat Bias in Actual and Ideal Transect Lines in Breeding Bird Surveys 1994-1997.

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INDEX

Page No.

LIST OF TABLES

1. EXECUTIVE SUMMARY

1. The BTO/JNCC/RSPB Breeding Bird Survey (BBS) involves volunteers making bird counts in randomly selected Ordnance Survey (OS) 1 km squares using a line transect method. Within each 1 km survey square volunteers are asked to establish two parallel line transects oriented north-south or east-west. The line transects should be 500 m apart and 250 m from the edge of the square. The 2 km of transect are divided into ten 200 m sections and bird and habitat types are recorded in these units.

2. In reality, it is rare for the 'ideal' transect routes to be followed and observers are forced, or may choose, to deviate their routes. Here we assess the degree to which deviation from the 'ideal' route might bias coverage of habitats and hence bird populations.

3. Habitat surveying has been very consistent over the first four years of the BBS whilst coverage has increased by nearly 40% since 1994. Despite frequent deviation from the prescribed line transect routes, observers still surveyed the intended habitat types in nearly 90% of all transect subsections.

4. Where habitat surveyed was not that of the intended 'ideal' transect, the majority of bias was towards broadleaved woodland and away from farmland, possibly reflecting restriction of access by landowners and the proximity of woodland as alternative routes. This bias was consistent across all four years. The cause of this bias may be clarified in future years if the reasons for partial exclusion from proposed transects was reported. A smaller bias away from coastal habitats was probably a function of physical accessibility.

5. Linear and boundary feature bias was apparent in human sites, towards roads, but the situation was not clear in other habitat types since complete information was not available.

6. The biases identified are consistent across years and probably have little effect on the interpretation of BBS results.

2. INTRODUCTION

The Breeding Bird Survey (BBS) began in 1994, taking over the role of the Common Birds Census (CBC) as the main census tool monitoring populations of common British birds. The BBS aims to cover a wide range of regions and habitats, therefore maximising the number of species monitored.

The BBS, supported by the BTO, JNCC and RSPB, is based on surveys of randomly selected 1 km squares of the Ordnance Survey (OS) national grid, by a largely volunteer field workforce. A stratified random sampling regime is employed to select squares to be surveyed in each of 83 regions. In all a total of 1569 squares were surveyed in 1994, rising to 2173 squares in 1997 (Gregory *et al.* 1998).

Within each region, squares to be surveyed are allocated to observers by a regional organiser. Observers make three visits to each square, once to record habitat details and twice to count birds. Ideally, habitat and bird numbers are recorded along two parallel 1 km transect lines (Appendix 1), but in practice it is rarely possible to adhere strictly to the ideal transect routes. Observer choice should not influence transect route choice, but it is inevitable that physical and legal barriers will affect observers' access to some areas, and alter transect routes. Thus it is desirable to quantify the degree to which actual sampling differs from the intended random survey, and whether this deviation introduces any habitat sampling biases.

3. METHODS

Each observer is allocated one or more 1 km Ordnance Survey (OS) grid squares within which both habitat and bird numbers are to be sampled. This is done by means of two 1 km parallel transect lines, evenly spaced across each square, running either north-south or east-west. The ideal transect routes should be 500 m apart and 250 m from the edge of the square, divided into ten 200 m sections within which habitat types and bird numbers are recorded (Appendix 1 - BBS Instructions 1998). In practice, ideal transect routes are rarely completely followed and observers must follow a non-ideal 'actual' route. In these cases, both the ideal route habitat and actual habitat are recorded, and the distance by which the actual route taken deviates from the ideal transect line noted. Habitat type is recorded at a number of levels, the first being broad land use types, and subsequent levels recording more detailed habitat features (Appendix 2).

Since the ideal transect route for each square represents a random sampling of all habitats present (as squares are randomly selected), deviations from the transect line may result in non-random sampling. It is therefore necessary to examine the habitat data collected each year for any bias in favour of, or against any particular habitat type or feature, by comparing the frequency at which each type was actually recorded with that at which it would be expected had the observer been able to follow the ideal transect route. Initially this was done by comparing broad habitat classes, and then at finer levels of habitat type by χ^2 tests for goodness-of-fit between actual (observed) and ideal (expected) habitat frequencies. When bias was found away from a habitat class, χ^2 goodness-of-fit tests were made between actual (observed) habitat frequencies of other types in sections where the under-represented class was expected, and the ideal (expected) other habitat class frequencies calculated from the ideal habitat frequencies encountered in the whole dataset. Frequencies expected in actual and ideal categories were calculated from the χ^2 tables according to the formula (CxR)T: where C = column total of observed values, R = row total of observed values and T = total of all frequencies (n). These expected values were then used to calculate χ^2 values for each case and an overall χ^2 value.

In performing χ^2 tests, it was necessary to assume independence between data points collected on transect sections within an OS square, i.e. observations made by the same observer. Similarly, independence was assumed between data from multiple OS squares sampled by the same observer. The use of χ^2 tests in this way may overestimate the true statistical significance of particular tests, but the analyses were designed to highlight trends rather than provide definitive tests.

4. RESULTS

The number of OS squares where habitat data were reported rose from 1558 of a total 1569 surveyed (99.3%) in 1994, to 2143 of a total of 2173 squares surveyed in 1997 (98.6%) (Table 1). The numbers of squares where the habitat data were complete for both actual and ideal transects remained constant and high at around 97%, whilst the proportion of squares where the transect deviated from the ideal route decreased from 74.5% in 1994 to 67.6% in 1997. However, the proportion of these squares where transect deviation led to sampling of non-intended habitat remained constant at around 40%. Similarly, whilst the total number of 200 m transect sections surveyed increased from 15434 in 1994 to 21159 in 1997, the percentage of sections deviating from the ideal route declined from 59.7% in 1994 to 53.2% in 1997 (Table 2). Although these figures indicate frequent deviations from the ideal transect routes, most deviations do not result in the sampling of a different habitat type. In only 11.1%, 11.2%, 10.1% and 10.9% (in 1994-1997 respectively) of cases did the actual habitat recorded differ from the intended ideal.

The mean distances by which actual transect routes deviated from ideal decreased from 65.81 m in 1994 to 59.28 m in 1997 ($P<0.001$; one-way ANOVA, Tukey pairwise comparison) (Table 3). These mean distances include all transect sections where there was no deviation from the ideal transect route. Mean deviation distance for all years where deviation occurred was 109.57 m, varying between 107.39 m in 1995 and 111.52 m in 1997. Whilst there was no trend apparent in these data there was a significant difference between the highest (1997) and lowest (1995) values ($P<0.05$; one-way ANOVA, Tukey pairwise comparison). When actual recorded habitat differed from ideal habitat, mean deviation distance over all years was 134.37 m (no significant difference between years, one-way ANOVA), whilst that for sections where actual habitat remained that expected despite transect deviation was 103.54 m (no significant difference between years, one-way ANOVA). Deviation distances when actual habitat was not that expected were significantly higher within all years than when actual and ideal habitat were the same ($P<0.001$; t-test).

Comparison of the overall frequency of ideal transect line habitat types with those actually recorded in each section revealed that farmland (level 1 type E) and coastal (level 1 type H) were sampled significantly less than expected, whilst woodland (level 1 type A) and freshwater (level 1 type G) habitats were more frequently encountered in all years (χ^2; $P<0.001$, in 1994-1997) (Table 4).

Consequently, for transect sections where ideal transect route predicted farmland, but deviation resulted in sampling of other habitat types, the frequency of habitat types was compared with the overall frequency of these habitat types expected on the randomly chosen ideal transect routes. In all years, where farmland was expected, woodland and freshwater frequencies were significantly higher than expected, and heathland and bogs significantly less than expected (χ^2; $P<0.001$, in 1994-1997) (Table 5). Furthermore, when the types of woodland found when farmland was expected was examined, it was found that broadleaved woodland was more common and coniferous woodland less common than expected (χ^2; $P<0.001$, in 1994-1997) (Table 6). Examination of the types of freshwater habitats encountered on ideally farmland sections revealed a less clear-cut situation, although the frequencies of river habitats was higher than expected and that of lake and reservoirs lower in all years (χ^2; P<0.001, in 1994-1997) (Table 7).

An analysis of the level 1 habitat type found when coastal habitat was predicted from ideal transect route showed incidences of woodland (type A), scrubland (type B) and heath and bogs (type D) were increased, whilst farmland (type E) was encountered less frequently than expected (χ^2; P<0.001, in 1994-1997)(Table 8).

For those sections where the transect route deviated from ideal but level 1 habitat type agreed with ideal, level 2 habitat types were compared (Table 9). In all but two habitat classes (farmland and coastal) the frequencies with which each level 2 habitat feature was recorded were not significantly different from the ideal frequencies. In farmland sections, however, level 2 type 3 (mixed grass and tilled land) was more frequent than expected in all years (χ^2; P<0.001). In coastal sections, level 2 type 1 (marine shore) was more frequent and level 2 type 5 (open sea) was less frequent than expected, though only in 1995 and 1996 (χ^2; P<0.001). There were no significant differences in 1994 and 1997.

Due to the linear nature of transects, it was also of interest to examine any possible sampling bias towards linear and boundary habitat features. These features were recorded at level 2 in type G (freshwater habitats) (see above) and at level 3 in types C (semi-natural grassland and marsh), E (farmland) and F (human sites). Comparison of level 3 features were made with the ideal transect frequencies (Table 10). In grassland and marsh sections (type C) treeline with no hedge (level 3 type 3) was more frequent in 1994, 1995 and 1997 (χ^2; P<0.05), whilst in farmland sections (type E), treeline with no hedge (level 3 type 3) was significantly more common and other field boundaries (type 4) and groups of trees (type 5) were less common in all years (χ^2; P<0.001, in 1994-1997). It should be noted that in level 1 type C, the majority of level 3 types are boundary features, and all are in level 1 type E, so direct assessment of bias toward or against boundary features was not possible. However, in level 1 type F (human sites) sections, there was a significant bias towards roads (level 3 type 5) in all years (χ^2; P<0.05 in 1994, P<0.001 in 1995-1997), which probably reflects a real sampling bias.

5. DISCUSSION

Habitat sampling within the BBS over the first four years has been remarkably consistent, with proportions of squares reporting full habitat data remaining consistently high despite a 38.5% increase in the number of squares surveyed. Furthermore, despite considerable deviations from the ideal sampling route in all years (~110 m) occurring in around 40% of squares, in only a small proportion of cases (around 11% of sections) did this lead to sampling of birds in 'non-ideal' habitats. This figure does not take into account bias within level 1 habitat classes, and therefore may be an underestimate. Bias at level 2 within habitat classes has been assessed here and found only to occur within farmland and coastal classes.

Habitat bias analyses have indicated that in most cases this 'non-ideal' sampling occurred when the ideal habitat to be surveyed was farmland, resulting in observers surveying woodland sites instead - mainly broadleaved woodland. This probably reflects access problems to arable land, but may to a degree also reflect observer route choice for more personal, aesthetic reasons. Wilson & Gregory (1997) report that the most common reason for squares not being surveyed at all was refusal of access by landowners, and this may have carried through into surveyed squares. The cause of this bias may be clarified in future years if the reasons for partial exclusion from proposed transects was reported. The increase in woodland and freshwater sections perhaps reflects the occurrence of these habitats in predominantly farmland areas, providing adjacent alternative routes where access has been denied. This appears to be a very consistent bias, and short of increasing access to previously uncoverable areas, may not be addressable. The consistent and small (only 11% of 200 m transect sections in total) nature of this sampling error, and the fact that the majority of it is associated with farmland (the commonest British habitat and therefore well sampled) means that it probably has little overall affect on the indices calculated from BBS and on year to year comparisons.

The smaller bias associated with coastal habitats is probably a physical access effect, and the raised incidence of woodland and scrubland, and lowered incidence of farmland probably reflects the nature of adjacent habitats and the national habitat composition.

Linear and boundary type biases were harder to quantify in the BBS data set so far, since in most broad habitat types the full nature of these features is not described. In those habitat types where boundary features are described, the absence of any boundary feature is not always described - notably farmland (in some habitat types they are not described at all) so direct comparisons are not possible. The inclusion of a 'no boundary' category in level 3 of farmland, and boundary feature information for other habitat classes might clarify this. Boundary bias was however clearly shown in human sites - towards roads. This is unsurprising, since roads provide the only or easiest access to many areas.

Overall, the habitat surveying biases identified in the BBS sampling regime are small but consistent from year to year, probably not representing a serious detriment to the bird data collected, and once defined can easily be included in interpretation of bird population statistics. Furthermore, ideal habitat recording has provided a good monitor of the reliability of the surveys year to year and as such should continue.

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Table 1 Habitat data collected during BBS 1994-97. Numbers refer to OS squares where at least one 200m transect section was recorded- apart from Number Surveyed, where at least 4 sections must be recorded.

Year	Number Surveyed	Number reporting habitat data		Number reporting both actual and ideal data		Number where transect deviates from ideal route		Number where actual habitat is not that predicted by ideal transect route	
	n	n	%	n	%	n	%	n	%
94	1569	1558	99.3	1533	97.7	1142	74.5	632	41.2
95	1751	1739	99.3	1687	96.3	1302	77.2	761	45.1
96	1918	1886	98.3	1865	97.2	1214	65.1	689	36.9
97	2173	2143	98.6	2117	97.4	1432	67.6	841	39.7

Table 2 Habitat data collected during BBS 1994-97. Numbers refer to number of 200m transect sections.

Year	Number Surveyed	Number reporting habitat data		Number reporting both actual and ideal data		Number where transect deviates from ideal route		Number where actual habitat is not that predicted by ideal transect route	
	n	n	%	n	%	n	%	n	%
94	15434	15289	99.1	14302	92.7	8537	59.7	1586	11.1
95	17208	17103	99.4	15257	88.7	9875	64.7	1941	11.2
96	18596	18529	99.6	17502	94.1	9036	51.6	1776	10.1
97	21159	21011	99.3	19898	94.0	10577	58.2	2160	10.9

Table 3 Mean deviations distances (m) of sampling transect lines from ideal route in 200m transect sections during BBS 1994-97. Numbers in parentheses are numbers of 200m transect sections. (* = significant difference between mean values determined by Tukey pairwise comparison; One way ANOVA. ns = not significant at P<0.05 level).

Year	Mean distance in all sections	Mean distance in sections where transect deviates from ideal	Mean distance when actual habitat matches ideal	Mean distance when actual habitat does not match	t-test for within year differences between mean distances where actual habitat does and does not match ideal
94	65.81 (14302)*	110.24 (8537)	104.80 (6951)	134.09 (1586)	P<0.001
95	69.51 (15257)*	107.39 (9875)*	101.31 (7934)	132.28 (1941)	P<0.001
96	56.34 (17502)*	109.13 (9036)	103.25 (7260)	133.17 (1776)	P<0.001
97	59.28 (19898)*	111.52 (10577)*	104.86 (8417)	137.51 (2160)	P<0.001
mean of means	62.24	109.59	103.54	134.37	
One way ANOVA for between- year differences	P<0.001	P<0.05	ns	ns	

Table 4 Comparison of the actual frequencies of level 1 habitat types (see Appendix 2) with transect line frequencies recorded in all 200m transects during BBS 1994-97.

1994

HABITAT TYPE	ACTUAL FREQUENCY	IDEAL FREQUENCY	CHI-SQUARED VALUE	
A	1742	1631	7.5543	
B	339	313	2.1597	
C	699	669	1.3453	
D	1219	1170	2.0521	
E	7663	7949	10.2901	
F	2253	2193	1.6416	
G	250	208	8.4808	
H	53	77	7.4805	
I	74	86	1.6744	
J	10	6	2.6667	
TOTAL	14302	14302	45.3455	P<0.001

1995

HABITAT TYPE	ACTUAL FREQUENCY	IDEAL FREQUENCY	CHI-SQUARED VALUE	
A	1840	1696	12.2264	
B	353	318	3.8522	
C	776	712	5.7528	
D	1317	1263	2.3088	
E	8091	8477	17.5765	
F	2427	2356	2.1396	
G	303	244	14.2664	
H	78	101	5.2376	
I	64	84	4.7619	
J	8	6	0.6667	
TOTAL	15257	15257	68.7889	P<0.001

1996

HABITAT TYPE	ACTUAL FREQUENCY	IDEAL FREQUENCY	CHI-SQUARED VALUE	
A	2042	1890	12.2243	
B	409	375	3.0827	
C	831	784	2.8176	
D	1463	1424	1.0681	
E	9358	9750	15.7604	
F	2843	2762	2.3755	
G	401	334	13.4401	
H	80	92	1.5652	
I	75	88	1.9205	
J	0	3	3.000	
TOTAL	17502	17502	57.2544	P<0.001

Table 4 (contd...)

1997

HABITAT TYPE	ACTUAL FREQUENCY	IDEAL FREQUENCY	CHI-SQUARED VALUE	
A	2322	2139	15.6564	
B	497	445	6.0764	
C	899	855	2.2643	
D	1567	1525	1.1567	
E	10861	11324	18.9305	
F	3171	3051	4.7198	
G	438	379	9.1847	
H	77	101	5.7030	
I	57	75	4.3200	
J	9	4	6.2500	
TOTAL	19898	19898	74.2618	P<0.001

Table 5 Comparison of actual level 1 habitat type frequencies with overall ideal frequencies for 200m transect sections where farmland (level 1 type E) was predicted by ideal transect route but not encountered for 1994-1997

1994

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	288	224.994	63.0056	17.644	1254	1317.01	-63.0056	3.0142	1542	
B	60	42.606	17.3941	7.101	232	249.39	-17.3941	1.2132	292	
C	44	60.553	-16.5530	4.525	371	345.45	16.5530	0.7730	415	
D	17	75.582	-58.5818	45.405	501	442.42	58.5818	7.7570	518	
F	306	317.064	-11.0641	0.386	1867	1855.94	11.0641	0.0660	2173	
G	67	37.353	29.6468	23.530	189	218.65	-29.6468	4.0199	256	
H	0	17.363	-17.3634	17.363	119	101.64	17.3634	2.9663	119	
I	3	8.609	-5.6087	3.654	56	50.39	5.6087	0.6243	59	
J	0	0.875	-0.8755	0.875	6	5.12	0.8755	0.1496	6	
Column Totals	785	785.000	0.0000	120.485	4595	4595.00	-0.0000	20.5834	5380	χ^2= 141.0684 P = <0.001

1995

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	351	282.568	68.4320	16.5728	1330	1398.43	-68.4320	3.3487	1681	
B	61	54.463	6.5372	0.7847	263	269.54	-6.5372	0.1585	324	
C	57	63.204	-6.2038	0.6089	319	312.80	6.2038	0.1230	376	
D	23	73.121	-50.1214	34.3559	412	361.88	50.1214	6.9420	435	
F	380	406.790	-26.7903	1.7643	2040	2013.21	26.7903	0.3565	2420	
G	84	50.092	33.9076	22.9522	214	247.91	-33.9076	4.6377	298	
H	0	16.810	-16.8095	16.8095	100	83.19	16.8095	3.3965	100	
I	5	12.775	-7.7752	4.7321	71	63.22	7.7752	0.9562	76	
J	0	1.177	-1.1767	1.1767	7	5.82	1.1767	0.2378	7	
Column Totals	961	961.000	0.0000	99.7572	4756	4756.00	-0.0000	20.1570	5717	χ^2 = 119.9142 P = <0.001

Table 5 (contd...)

1996

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	359	281.080	77.9199	21.601	1314	1391.92	-77.9199	4.3620	1673	
B	64	54.603	9.3969	1.617	261	270.40	-9.3969	0.3266	325	
C	58	70.228	-12.2280	2.129	360	347.77	-12.2280	0.4299	418	
D	18	79.301	-61.3005	47.386	454	392.70	61.3005	9.5690	472	
F	383	414.648	-31.6477	2.415	2085	2053.35	31.6477	0.4878	2468	
G	94	51.915	42.0850	34.116	215	257.09	-42.0850	6.8894	309	
H	1	17.305	-16.3050	15.363	102	85.70	16.3050	3.1023	103	
I	3	10.249	-7.2486	5.127	58	50.75	7.2486	1.0353	61	
J	0	0.672	-0.6720	0.672	4	3.33	0.6720	0.1357	4	
Column Totals	980	980.000	0.0000	130.427	4853	4853.00	0.0000	26.3380	5833	$\chi^2 = 156.7650$ P = <0.001

1997

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	419	347.15	71.8508	14.871	1486	1557.85	-71.8508	3.3139	1905	
B	84	66.88	17.1214	4.383	283	300.12	-17.1214	0.9767	367	
C	56	80.73	-24.7281	7.575	387	362.27	24.7281	1.6879	443	
D	16	72.89	-56.8922	44.404	384	327.11	56.8922	9.8950	400	
F	482	499.86	-17.8584	0.638	2261	2243.14	17.8594	0.1422	2743	
G	101	67.43	33.5747	16.719	269	302.57	-33.5747	3.7256	370	
H	5	18.77	-13.7697	10.102	98	84.23	13.7697	2.2510	103	
I	2	10.39	-8.3871	6.772	55	46.61	8.3871	1.5091	57	
J	0	0.91	-0.9112	0.911	5	4.09	0.9112	0.2030	5	
Column Totals	1165	1165.00	-0.0000	106.375	5228	5228.00	0.0000	23.7044	6393	$\chi^2 = 130.0794$ P = <0.001

Table 6 Comparison of actual level 2 habitat type frequencies with overall ideal frequencies for 200m transect sections where farmland (level 1, type E) was predicted by ideal transect route, and woodland (level 1, type A) was encountered for 1994-1997.

1994

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	174	125.486	48.5143	18.7562	497	545.51	-48.5143	4.3145	671	
2	29	97.621	-68.6208	48.2357	493	424.38	68.6208	11.0958	522	
3	79	60.405	18.5948	5.7241	244	262.59	-18.5948	1.3167	323	
4	6	2.992	3.0078	3.0235	10	13.01	-3.0078	0.6955	16	
5	0	0.748	-0.7481	0.7481	4	3.25	0.7481	0.1721	4	
6	0	0.748	-0.7481	0.7481	4	3.25	0.7481	0.1721	4	
Column Totals	288	288.00	0.0000	77.2356	1252	1252.00	0.0000	17.7667	1540	$\chi^2 = 95.0023$ P = <0.001

1995

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	202	158.347	43.6526	12.0340	555	598.65	-43.6526	3.1831	757	
2	39	104.380	-65.3796	40.9514	460	394.62	65.3796	10.8319	499	
3	98	81.788	16.2116	3.2133	293	309.21	-16.2116	0.8500	391	
4	10	4.184	5.8164	8.0867	10	15.82	-5.8164	2.1390	20	
5	0	1.046	-1.0459	1.0459	5	3.95	1.0459	0.2766	5	
6	2	1.255	0.7449	0.4422	4	4.74	-0.7449	0.1170	6	
Column Totals	351	351.000	0.0000	65.7735	1327	1327.00	-0.0000	17.3975	1678	$\chi^2 = 83.171$ P = <0.001

Table 6 (contd...)

1996

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	202	161.153	40.8470	10.3534	549	589.85	-40.8470	2.8287	751	
2	42	106.005	-64.0048	38.6455	452	388.00	64.0048	10.5584	494	
3	107	85.405	21.5953	5.4606	291	312.60	-21.5953	1.4919	398	
4	6	4.506	1.4937	0.4951	15	16.49	-1.4937	0.1353	21	
5	1	1.073	-0.0729	0.0050	4	3.93	0.0729	0.0014	5	
6	1	0.858	0.1417	0.0234	3	3.14	-0.1417	0.0064	4	
Column Totals	359	359.000	-0.0000	54.9830	1314	1314.00	0.0000	15.0220	1673	$\chi^2 = 70.005$ P = <0.001

1997

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	234	185.953	48.0467	12.4144	611	659.05	-48.0467	3.5028	845	
2	59	127.857	-68.8566	37.0824	522	453.14	68.8566	10.4630	581	
3	113	97.268	15.7321	2.5445	329	344.73	-15.7321	0.7179	442	
4	11	5.942	5.0583	4.3062	16	21.06	-5.0583	1.2150	27	
5	1	1.100	-0.1003	0.0091	4	3.90	0.1003	0.0026	5	
6	1	0.880	0.1197	0.0163	3	3.12	-0.1197	0.0046	4	
Column Totals	419	419.000	0.0000	56.3730	1485	1485.00	0.0000	15.9059	1904	$\chi^2 = 72.2789$ P = <0.001

Table 7 Comparison of actual level 2 habitat type frequencies with overall ideal frequencies for 200m transect sections where farmland (level 1, type E) was predicted by ideal transect route, and freshwater (level 1, type G) was encountered for 1994-1997.

1994

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	0	2.3555	-2.3555	2.3555	9	6.645	2.3555	0.8350	9	
2	1	6.5430	-5.5430	4.6958	24	18.457	5.5430	1.6647	25	
3	1	11.7773	-10.7773	9.8623	44	33.223	10.7773	3.4961	45	
4	0	4.1875	-4.1875	4.1875	16	11.813	4.1875	1.4845	16	
5	1	5.2344	-4.234	3.4254	19	14.766	4.2344	1.2143	20	
6	12	8.3750	3.6250	1.5690	20	23.625	-3.6250	0.5562	32	
7	40	22.5078	17.4922	13.5942	46	63.492	-17.4922	4.8191	86	
8	1	0.5234	0.4766	0.4339	1	1.477	-0.4766	0.1538	2	
9	3	2.3555	0.6445	0.1764	6	6.645	-0.6445	0.0625	9	
10	8	3.1406	4.8594	7.5187	4	8.859	-4.8594	2.6654	12	
Column Totals	67	67.0000	0.0000	47.8187	189	189.000	0.0000	16.9516	256	$\chi^2 = 64.8386$ P = <0.001

1995

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	2	3.1007	-1.1007	0.3907	9	7.899	1.1007	0.1534	11	
2	2	6.7651	-4.7651	3.3564	22	17.235	4.7651	1.3175	24	
3	4	13.8121	-9.8121	6.9705	45	35.188	9.8121	2.7361	49	
4	0	4.7919	-4.7919	-4.7919	17	12.208	4.7919	1.8810	17	
5	5	6.7651	-1.7651	0.4605	19	17.235	1.7651	0.1808	24	
6	11	9.3020	1.6980	0.3099	22	23.698	-1.6980	0.1217	33	
7	45	31.8523	13.1477	5.4269	68	81.148	-13.1477	2.1302	113	
8	1	0.5638	0.4362	0.3376	1	1.436	-0.4362	0.1325	2	
9	6	3.1007	2.8993	2.7111	5	7.899	-2.8993	1.0642	11	
10	8	3.9463	4.0537	4.1640	6	10.054	-4.0537	1.6345	14	
Column Totals	84	84.000	0.0000	28.9196	214	214.000	0.0000	11.3516	298	$\chi^2 = 40.2712$ P = <0.001

Table 7 (contd...)

1996

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	1	2.4337	-1.4337	0.8446	7	5.566	1.4337	0.3693	8	
2	8	10.9515	-2.9515	0.7954	28	25.049	2.9515	0.3478	36	
3	5	17.6440	-12.6440	9.0609	53	40.356	12.6440	3.9615	58	
4	1	3.6505	-2.6505	1.9244	11	8.350	2.6505	0.8414	12	
5	7	8.2136	-1.2136	0.1793	20	18.786	1.2136	0.0784	27	
6	11	10.6472	0.3528	0.0117	24	24.353	-0.3528	0.0051	35	
7	44	31.9417	12.0583	4.5521	61	73.058	-12.0583	1.9902	105	
8	1	0.6084	0.3916	0.2520	1	1.392	-0.3916	0.1102	2	
9	6	3.6505	2.3495	1.5122	6	8.350	-2.3495	0.6611	12	
10	10	4.2589	5.7411	7.7391	4	9.741	-5.7411	3.3836	14	
Column Totals	94	94.0000	0.0000	26.8718	215	215.000	0.0000	11.7486	309	$\chi^2 = 38.6204$ P = <0.001

1997

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
1	1	1.642	-0.6423	0.2512	5	4.358	0.6423	0.0947	6	
2	5	9.854	-4.8537	2.3908	31	26.146	4.8537	0.9010	36	
3	5	17.244	-12.2439	8.6937	58	45.756	12.2439	3.2764	63	
4	0	3.285	-3.2846	3.2846	12	8.715	3.2846	1.2378	12	
5	6	11.222	-5.2222	2.4301	35	29.778	5.2222	0.9158	41	
6	18	11.770	6.2304	3.2981	25	31.320	-6.2304	1.2429	43	
7	47	36.404	10.5962	3.0843	86	96.596	-10.5962	1.1624	133	
8	1	0.547	0.4526	0.3742	1	1.453	-0.4526	0.1410	2	
9	18	9.033	8.9675	8.9029	15	23.967	-8.9675	3.3552	33	
Column Totals	101	101.000	0.0000	32.7098	268	268.000	0.0000	12.3272	369	$\chi^2 = 45.037$ P = <0.001

Table 8 Comparison of actual level 1 habitat type frequencies with overall ideal frequencies for 200m transect sections where coastal (level 1, type H) was predicted by ideal transect route but not encountered. 1994-1997.

1994

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	11	3.7935	7.2065	13.690	1254	1261.21	-7.2065	0.04118	1265	
B	8	0.7197	7.2803	73.645	232	239.28	-7.2803	0.22151	240	
C	1	1.1155	-0.1155	0.012	371	370.88	0.1155	0.00004	372	
D	6	1.5204	4.4796	13.199	501	505.48	-4.4796	0.03970	507	
E	3	18.4905	-15.4905	12.977	6163	6147.51	15.4905	0.03903	6166	
F	0	5.5987	-5.5987	5.599	1867	1861.40	5.5987	0.01684	1867	
G	1	0.5698	0.4302	0.325	189	189.43	-0.4302	0.00098	190	
I	0	0.1679	-0.1679	0.168	56	55.83	0.1679	0.00051	56	
J	2	0.0240	1.9760	162.758	6	7.98	-1.9760	0.48954	8	
Column Totals	32	32.000	0.0000	282.373	10639	10639.00	0.0000	0.84932	10671	χ^2 =283.222 P = <0.001

1995

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	14	3.7356	10.2644	28.204	1330	1340.26	-10.2644	0.07861	1344	
B	3	0.7393	2.2607	6.912	263	265.26	-2.2607	0.01927	266	
C	2	0.8922	1.1078	1.375	319	320.11	-1.1078	0.00383	321	
D	6	1.1618	4.8382	20.148	412	416.84	-4.8382	0.05616	418	
E	2	18.9754	-16.9752	15.186	6825	6808.02	16.9754	0.04233	6827	
F	3	5.6785	-2.6785	1.263	2040	2037.32	2.6785	0.00352	2043	
G	1	0.5976	0.4024	0.271	214	214.40	-4024	0.00076	215	
I	0	0.1973	-0.1973	0.197	71	70.80	0.1973	0.00055	71	
J	1	0.9778	0.9778	42.995	7	7.98	-0.9778	0.11984	8	
Column Totals	32	32.0000	0.0000	116.552	11481	11481.00	0.0000	0.32486	11513	χ^2 = 116.877 P = <0.001

Table 8 (contd...)

1996

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	14	5.3502	8.6498	13.9841	1314	1322.65	-8.6498	0.05657	1328	
B	4	1.0676	2.9324	8.0541	261	263.93	-2.9324	0.03258	265	
C	3	1.4625	1.5375	1.6165	360	361.54	-1.5375	0.00654	363	
D	6	1.8532	4.1468	9.2786	454	458.15	-4.1468	0.03753	460	
E	4	27.6859	-23.6859	20.2368	6868	6844.31	23.6859	0.08197	6872	
F	15	8.4605	6.5395	5.5047	2085	2091.54	-6.5395	0.02045	2100	
G	1	0.8702	0.1298	0.0194	215	215.13	-0.1298	0.00008	216	
I	0	0.2337	-0.2337	0.2337	58	57.77	0.2337	0.00095	58	
J	0	0.0161	-0.0161	0.0161	4	3.98	0.0161	0.00007	4	
Column Totals	47	47.0000	0.0000	58.5209	11619	11619.00	0.0000	0.23672	11666	χ^2 =58.758 P = <0.001

1997

Habitat Type	Observed Frequency	Expected Frequency	Difference	Chi-Squared	Observed Frequency All	Expected Frequency All	Difference All	Chi-squared All	Row Totals	
A	14	6.0535	7.9465	10.432	1486	1493.95	-7.9465	0.04227	1500	
B	5	1.1623	3.8377	12.672	283	286.84	-3.8377	0.05135	288	
C	3	1.5739	1.4261	1.292	387	388.43	-1.4261	0.00524	390	
D	6	1.5739	4.4261	12.447	384	388.43	-4.4261	0.05044	390	
E	8	32.1156	-24.1156	18.108	7950	7925.88	24.1156	0.07337	7958	
F	14	9.1811	4.8189	2.529	2261	2265.82	-4.8189	0.01025	2275	
G	1	1.0896	-0.0896	0.007	269	268.91	0.0896	0.00003	270	
I	0	0.2220	-0.2220	0.222	55	54.78	0.2220	0.00090	55	
J	2	0.0282	1.9718	137.624	5	6.97	-1.9718	0.55765	7	
Column Totals	53	53.000	0.0000	195.334	13080	13080.00	0.0000	0.79149	13133	χ^2 = 196.125 P = <0.001

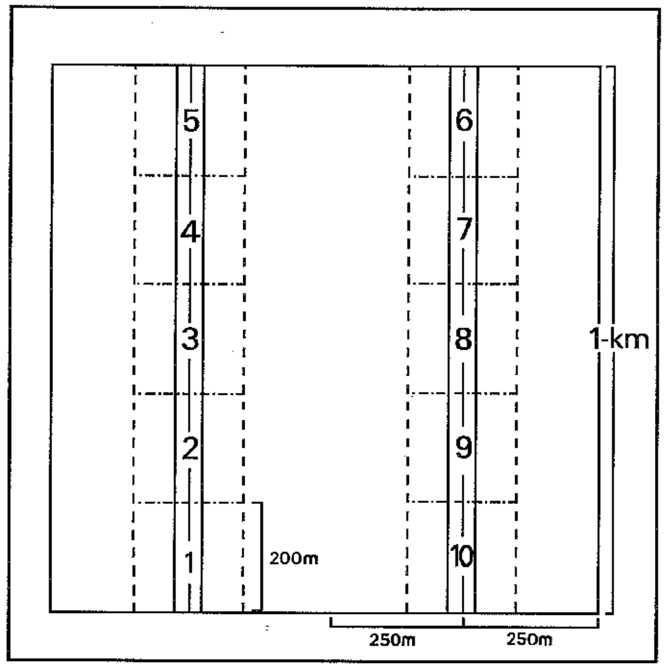
Table 9 Summary of χ^2 goodness-of-fit tests for habitat feature bias in BBS level 1 habitat classes. Tests were not performed on type J habitat class because of the low number of cases. Numbers in inverted commas refer to BBS level 2 habitat classes + = over-representation in actual frequency, - = under representation in actual frequency. (ns = not significant at P<0.05 level).

Year	A	B	C	D	E	F	G	H	I	J
94	ns	ns	ns	ns	+'3' P<0.001	ns	ns	ns	ns	-
95	ns	ns	ns	ns	+'3' P<0.001	ns	ns	+'1' -'5' P<0.001	ns	-
96	ns	ns	ns	ns	+'3' P<0.001	ns	ns	+'1' -'5' P<0.001	ns	-
97	ns	ns	ns	ns	+'3' P<0.001	ns	ns	ns	ns	-

Table 10 Summary of χ^2 goodness-of-fit tests for habitat boundary feature bias in BBS level 1 habitat classes. C (Grasslands & Marsh), E (Farmland) and F (Human Sites) 1994-1997. Comparisons made between ideal and actual frequencies of boundary features in habitat level 3. Numbers in inverted commas refer to BBS level 2 habitat classes + = over-representation in actual frequency, - = under representation in actual frequency. (ns = not significant at P<0.05 level).

Year	Habitat C	Habitat E	Habitat F
94	+'3' P<0.05	+'3' -'4' -'5' P<0.001	+'5' P<0.05
95	+'3' P<0.05	+'3' -'4' -'5' P<0.001	+'5' P<0.001
96	ns	+'3' -'4' -'5' P<0.001	+'5' P<0.001
97	+'3' P<0.05	+'3' -'4' -'5' P<0.001	+'5' P<0.001

Appendix 1 **Data recording ideal transect line used during BBS habitat and bird surveys. Large square represents the OS unit square. Ideal 1km transects comprise two 500m parallel routes, 500m apart, subdivided into ten 200m sections. Habitat, together with actual route taken (and deviation distance if the observer does not follow the ideal route) are recorded for each section). (BBS Instructions 1998).**



Appendix 2 BBS Habitat Coding Scheme

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
A WOODLAND	1 Broadleaved	1 Mixed-aged or semi-natural	1 Dense shrub layer
	2 Coniferous	2 Coppice with standards	2 Moderate shrub layer
	3 Mixed (10% of each)	3 Coppice without standards	3 Sparse shrub layer
	4 Broadleaved water-logged	4 Mature plantation (taller than 10m, with closed canopy)	4 Dense field layer
	5 Coniferous water-logged	5 Young plantation (5-10m, open canopy)	5 Moderate field layer
	6 Mixed water-logged	6 Parkland (scattered trees and grassy areas)	6 Sparse field layer
		7 High-medium disturbance from people	7 Grazed (moderate to heavy)
		8 Low disturbance	8 Lightly grazed
			9 Dead wood present
			10 Dead wood absent
B SCRUBLAND (or young woodland <5m tall)	1 Regenerating natural or semi-natural woodland	1 Broadleaved	1 Predominantly tall (3-5m)
	2 Downland (chalk)	2 Coniferous	2 Predominantly low (1-3m)
	3 Heath scrub	3 Mixed (10% of each)	3 Dense shrub layer
	4 Young coppice	4 Broadleaved swamp scrub	4 Moderate shrub layer
	5 New plantation	5 Coniferous swamp scrub	5 Sparse shrub layer
	6 Clear-felled woodland, with or without new saplings	6 Mixed swamp scrub	6 Extensive bracken
	7 Other	7 High-medium disturbance from people	7 Dense field layer
		8 Low disturbance	8 Moderate field layer
			9 Sparse field layer
			10 Grazed (moderate to heavy)
C SEMI-NATURAL GRASSLAND /MARSH	1 Chalk downland	1 Hedgerow with trees	1 Ungrazed
	2 Grass moor (unenclosed)	2 Hedgerow without trees	2 Cattle
	3 Grass moor mixed with heather (unenclosed)	3 Tree-line without hedge	3 Sheep
	4 Machair	4 Other field boundary (wall, ditch, etc.)	4 Horses
	5 Other dry grassland	5 Isolated group of 1-10 trees	5 Rabbits
	6 Water-meadow/ grazing marsh	6 No field boundary	6 Deer
	7 Reed swamp	7 Montane	7 Other grazers
	8 Other open marsh	8 High-medium disturbance from people	8 Extensive bracken
	9 Saltmarsh	9 Low disturbance	9 Hay
D HEATHLAND AND BOGS	1 Dry heath	1 Montane	1 Ungrazed
	2 Wet heath	2 Raised bog	2 Cattle
	3 Mixed heath	3 Valley/ basin bog	3 Sheep
	4 Bog	4 Blanket bog	4 Horses
	5 Breckland	5 Heath mixed with rough grass	5 Rabbits
	6 Drained bog	6 Heath without grass	6 Deer
		7 Heath with extensive bracken	7 Other grazers
		8 Undetermined bog	8 Ploughed
		9 Isolated group of 1-10 trees	9 Burned
		10 High-medium disturbance from people	10 Planted with saplings lessthan0.5m tall
		11 Low disturbance	
E FARMLAND	1 Improved grassland	1 Hedgerow with trees	1 Ungrazed
	2 Unimproved grassland	2 Hedgerow without trees	2 Cattle
	3 Mixed grass/ tilled land	3 Tree-line without hedge	3 Sheep
	4 Tilled land	4 Other field boundary (wall, ditch, etc.)	4 Horses
	5 Orchard	5 Isolated group of trees	5 Other stock
	6 Other farming	6 Farmyard (active)	6 Bare earth/plough
			7 Autumn cereal
			8 Spring cereal
			9 Root crops (specify)
			10 Other crops (specify)
			11 Oil seed rape
			12 Other brassicas (specify)
			13 Stubble (clean)
			14 Stubble (weedy)
			15 Unsown/Fallow
F HUMAN SITES	1 Urban	1 Building	1 Industrial
	2 Suburban	2 Gardens	2 Residential
	3 Rural	3 Municipal parks/ mown grass/ golf courses/ recreational areas	3 Well-wooded
		4 Sewage works "urban"	4 Not well-wooded
		5 Near road (within 50m)	5 Area of large gardens
		6 Near active railway line (within 50m)	6 Area of medium gardens
		7 Other	7 Area of small gardens
		8 Rubbish tip	8 Many shrubs
			9 Few shrubs
			10 Disused
G WATER BODIES (freshwater)	1 Pond (less than 50m²)	1 Undisturbed/ disused	1 Eutrophic (green water)
	2 Small water-body (50-450m²)	2 Water sports (sailing etc)	2 Oligotrophic (clear water, few weeds)
	3 Lake/unlined reservoir	3 Angling (coarse or game)	3 Dystrophic (black water)
	4 Lined reservoir	4 Coarse angling	4 Marl (clear water, large water-weeds)
	5 Gravel pit, sand pit, etc	5 Game fishing	5 Slow-medium running
	6 Stream (less than 3m wide)	6 Industrial activity	6 Fast-running
	7 River (more than 3m wide)	7 Sewage processing 'rural'	7 Dredged
	8 Ditch with water (less than 2m wide)	8 Other disturbance	8 Undredged
	9 Small canal (2-5m wide)	9 Small island	9 Banks cleared
	10 Large canal (more than 5m wide)		10 Banks vegetated
H COASTAL	1 Marine - open shore	1 Mud or silt	1 Cliff vertical/ steeply sloping
	2 Marine shore - inlet/cove/ loch	2 Sand	2 Dune
	3 Estuarine	3 Shingle	3 Flat/gently sloping
	4 Brackish lagoon	4 Rocky	4 Small island
	5 Open sea	5 Fully vegetated	5 Spit
		6 Sparse/medium vegetation	6 Dune slack
		7 Inter-tidal	7 Sloping ground
		8 Below low-water mark	8 Undisturbed
			9 Disturbed
			7 Sloping ground
			8 Undisturbed
			9 Disturbed
I INLAND ROCK	1 Cliff	1 Active	1 Bare rock
	2 Scree/boulder slope	2 Disused	2 Low vegetation present (mosses, liverworts, etc)
	3 Limestone pavement	3 Montane	3 Grasses present
	4 Other rock outcrop	4 Non-montane	4 Scrub present
	5 Quarry	5 High disturbance from climbers/ walkers etc.	
	6 Mine/spoil/ slag heap	6 Medium disturbance	
	7 Cave	7 Low disturbance	
J MISCELLANEOUS			

* *Shrub layer* comprises woody plants less than 5m tall. *Field layer* comprises herbaceous, non-woody plants.