Bird diversity in hedgerows

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BIRD DIVERSITY IN HEDGEROWS

By

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1. INTRODUCTION

1.1 Review in quantitative studies of hedgerow birds

The study of hedgerows and birds has existed for years but few attempts have been made to analyse statistically the relationships between the two (Osborne, 1984). The majority of studies lack adequate statistical analysis of the relationships between bird numbers and hedgerow quantity and quality over a wide spectrum of farm types (O'Connor, 1984). Statistical definitions of the relationships between bird numbers and habitats is important, particularly in applied ecology because it allows predictions to be made about the effects of habitat change on birds (Osborne, 1982,1984).

Farina (1983) gives a good account of the historical development of quantitative methods of habitat description in ornithological studies and a description of the main features of the methods used in different habitats, including hedgerow birds' habitats. A close correlation between bird species diversity and plant species diversity has been demonstrated by many workers studying woodland birds (e.g. MacArthur and MacArthur 1961, MacArthur 1964, 1965, MacArthur et al. 1962, 1966, Recher 1969, Tramer 1969, Wilson 1974) but no attempt has been made to study the relationships between bird species diversity and hedgerow characteristics such as length, width, height, volume and hedgerow plan area and hedgerow shrub species diversity.

1.2 The aim of the study

The aim of this work is to relate these hedgerow characteristics to bird species diversity, bird numbers and the numbers of bird species. It is also intended to make a comparison between bird species,

bird relative abundance, bird distribution and density of bird species at the two study areas.

1.3 The importance of hedges to birds

In addition to the ecological and economical importance of hedgerows, they serve birds in several ways, for example as feeding, nesting, roosting sites, cover from predators and as avian highways for movement and dispersal. For further information of the importance of hedges and its effects on birds, see Parslow (1969), Pollard *et al.* (1974) and the recent quantitative studies of Osborne (1982, 1983, 1984), Arnold (1983) and O'Connor (1984).

2. METHODS

2.1 Study area

The data were collected between early May and late June 1985 on 130 hedges (25 km of hedge) at two sites A and B chosen randomly at different locations in County Durham, North East England. Fig. (1). Site A consisted of a hundred hedges which were examined near Durham City and Site B consisted of thirty hedges studied in Weardale.

2.2 Procedures

Each hedge was visited once, either in the morning or in the evening and the following basic information was recorded :

1) Bird census and
2) Hedge characteristics

2.2.1 Bird Census

To avoid disturbing the birds, the bird census was carried out by watching and counting the number of species and the number of individuals in each hedge before recording the basic data on the hedge. Between 30-40 minutes were spent collecting the basic hedge data and on the bird census, the actual length of time varied according to hedge length and weather conditions. The census was made between 09.00-12.00 and 14.00-18.00 B.S.T. For watching and identification of the bird I used zoom binoculars 7-15 x 35 and the field guide book by Heinzel,Fitter and Parslow (1974). Thirteen common hedgerow bird species were found (Table 1).

Figure 1 : The geographical locations of the two study areas. Site A consisted of 100 hedges examined near Durham City, and site B consisted of 30 hedges studied in Weardale. The solid circles show the sampling locations at both sites A and B.

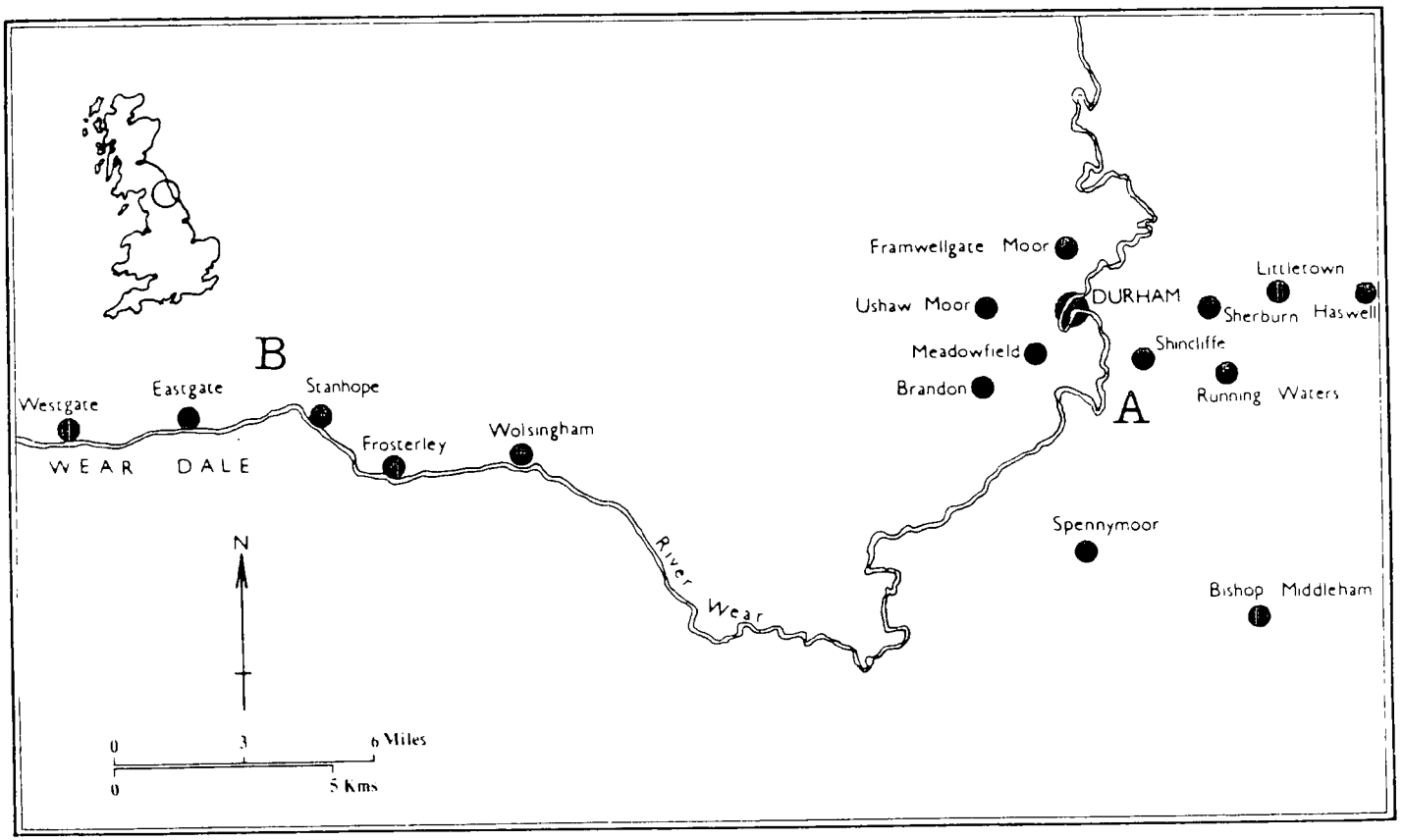
Framwellgate Moor
Littletown
Ushaw Moor
DURHAM
Sherburn
Haswell
Meadowfield
Shincliffe
B
Brandon
Running Waters
A
Westgate
Eastgate
Stanhope
Frosterley
Wolsingham
WEAR DALE
Spennymoor
N
River Wear
Bishop Middleham
0 3 6 Miles
0 5 Kms

Table 1 List of bird species at sites A and B

Blackbird	*Turdus merula*
Yellowhammer	*Emberiza citrinella*
*Greenfinch	*Carduelis chloris*
*Linnet	*Acanthis cannabina*
Chaffinch	*Fringilla coelebs*
Whitethroat	*Sylvia communis*
Robin	*Erithacus rebecula*
Wren	*Troglodytes troglodytes*
Great tit	*Parus major*
Blue tit	*Parus caeruleus*
Songthrush	*Turdus philomelos*
Willow warbler	*Phylloscopus trochilus*
Dunnock	*Prunella modularis*

* Absent from site B.

2.2.2 Hedge characteristics and its measurements

After completing the bird census, I measured the hedge length by pacing along its side and at each five paces (5m. intervals) the hedge shrubs species were recorded. The width and height of the hedge were measured, when I found differences in the height or width of the hedge I have taken the average. The dominant shrubs species, distance from hedge edge to a crop or road (both sides of the hedge), number of occurrences for each hedge shrubs species were recorded. Also other related information were recorded; date, time, place, nature of the fields on each side (grassland, crop or ploughed field) and general comments, e.g. whether the hedge was trimmed or not, were recorded (Table 2).

From these data I have derived:

1. Total number of species and individuals of birds in each hedge. (Appendix 2 for site A and appendix 3 for site B, with the format of the data described in appendix 1)

2. Total number of species and occurrences of hedge shrubs in each hedge (Appendix 2 and 3) and (Table 3) for list of plant species at both sites A and B.

3. The volume and plan area of each hedge.

4. The diversity index of shrubs and birds for each hedge were computed using Margalef's (1951) diversity index ($\alpha = \frac{S-1}{\text{Log}_e N}$)

   Where α is the index of diversity

   S is the number of species

   N is the number of individuals

The other calculations (Multivariate analysis) were performed using the SPSS-X (Statistical package for the social sciences) programme (Nie, 1983, 1984).

Table 2 A full page of field notebook

Hedge number:

Date:

Time:

Location:

Birds:

	Species	Numbers
1.		
2.		
3.		
4.		
5.		
Total :	_____	_____

Hedge shrubs:

	Species	Occurrences
1.		
2.		
3.		
4.		
Total :	_____	_____

Details of hedge:

1. Height:
2. Width:
3. Length:
4. Dominant species:
5. Distance of hedge inside:
6. Distance of hedge outside:

Field on one side:

Field on other side:

Other comments:

Table 3 List of shrub species

Hawthorn	*Crataegus monogyna*
Privet	*Ligustrum vulgare*
Ivy	*Hedera helix*
Horse-chestnut	*Aesculus hippocastanum*
Hazel	*Corylus avellana*
Elder	*Sambucus nigra*
Sycamore	*Acer psendoplatanus*
Holly	*Ilex aquifolium*
Rose	*Rosa villosa*
Ash	*Fraxinus excelsior*
Bramble	*Rubus fruticosa agg.*
Blackthorn	*Prunus spinosa*
Beech	*Fagus sylvatica*
Rowan	*Sorbus aucupana*
Willow	*Salix cinerea-type*
Hornbeam	*Carpinus betulus*
Yew	*Taxus baccata*
Oak	*Quercus rubra*
Gorse	*Ulex europaeus*
White beam	*Sorbus aria agg.*
Elm	*Ulmus procera*
Cherry	*Prunus sp.*
Norway spruce	*Picea alba*

3. RESULTS

3.1 Difference in the hedges at the two study sites

A comparison between the hedges at the two sites A and B showed that they were similar in most of the hedgerow characteristics; height, width, shrub α-diversity and the commonest shrub species (Tables 4, 5, 6 and 7). The sites differed in the length of their hedges and the percentage occurrences of the dominant and non-dominant hedge shrubs. Most of the length of the hedges at site A ranged between 150-250 m (the mean was 216 ± SD85.5) while the length of hedges at site B were mainly between 50-100 m (the mean was 108 ± SD36.9) (Table 8). The difference in the length at both sites was highly significant ($t = 9.9$, $df = 128$, $p < 0.001$). Hawthorn was the dominant shrub species at both sites but different in percentage occurrences of the dominant. At site A, it was dominant in 85% of the hedges and 57% of the hedges in site B (Table 7).

The percentage occurrences of non-dominant hedge shrub at both sites was different. At site A, the mode was in the range 40-49% (the mean was 41 ± SD19.5) while the percentage of non-dominant hedge shrub at site B had the mode between 60-69% (the mean was 53 ± SD15.3). The difference in the percentage occurrences of non-dominant hedge shrub at both sites was highly significant ($t = 3.5$, $df = 128$, $p < 0.002$)(Table 9).

Table 4 : The frequency distribution of height in 100 hedges examined near Durham (Site A) and 30 hedges at Weardale (Site B)

Frequency of distribution of hedge height (m)	0.1-0.5	0.6-1.0	1.1-1.5	1.6-2.0	2.1-2.5	2.6-3.0	3.1-3.5	3.6-4.0	4.1-4.5	4.6-5.0	Over 5	Mean	SD	SE	t	p
No. of hedges Site (A)	0	11	27	29	4	12	3	6	0	5	3	2.23	1.33	.133	0.62	NS *
No. of hedges Site (B)	0	1	6	14	2	3	3	1	0	0	0	2.11	.78	.142		

df = 128

Table 5 : The frequency distribution of width (m) in 100 hedges examined near Durham (Site A) and 30 hedges at Weardale (Site B)

Frequency of distribution of hedge width	0.1-0.5	0.6-1.0	1.1-1.5	1.6-2.0	2.1-2.5	2.6-3.0	3.1-3.5	3.6-4.0	over 4	Mean	SD	SE	t	p
No. of hedges Site (A)	0	34	28	16	5	6	4	5	2	1.69	.99	.10	0.065	NS
No. of hedges Site (B)	1	5	8	9	3	4	0	0	0	1.7	.72	.13		

df = 128

* NS = not significant

Table 6 : The frequency distribution of shrubs α-diversity in 100 hedges examined near Durham (site A) and 30 hedges at Weardale (site B)

Frequency of distribution of shrubs α-diversity	0.1-0.3	0.4-0.6	0.7-0.9	1.0-1.2	1.3-1.5	1.6-1.8	1.9-2.0	Mean	S D	S E	t	p
No. of hedges Site (A)	9	19	25	23	16	2	1	.92	.44	.04	1.49	N.S
No. of hedges Site (B)	0	6	8	7	5	4	0	1.04	.38	.07		

df = 128

Table 7 : The frequency distribution of dominant shrubs in 100 hedges examined near Durham (site A) and 30 hedges at Weardale (site B)

Shrub species	No. of hedges Site (A)	% of total (Site (A)	No. of hedges Site (B)	% of total (Site (B)
Hawthorn	85	85	17	56.7
Blackthorn	2	2		
Gorse	2	2		
Elder	2	2	3	10.0
Hazel	2	2	2	6.7
Privet	1	1		
Yew	1	1		
Rowan	1	1	1	3.3
Whitebeam	1	1		
Norway spruce	1	1		
Oak	1	1		
Rose	1	1	7	23.3
Total	100	100	30	100

Table 8: The frequency distribution length in 100 hedges examined near Durham (Site A) and 30 hedges at Weardale (Site B)

Frequency of distribution of hedge length (m)	0-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	501-550	Mean	SD	SE	t	p<
No. of hedges Site (A)	0	5	16	33	17	14	10	2	1	1	1	216	85.49	8.55	9.9	0.001
No. of hedges Site (B)	0	18	9	3	0	0	0	0	0	0	0	108	36.85	6.73		

df = 128

Table 9: The frequency distribution of percentage of non-dominant shrubs in 100 hedges examined near Durham (Site A) and 30 hedges at Weardale (Site B)

% of non-dominant shrubs	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	Mean	SD	SE	t	p<
No. of hedges Site (A)	7	11	10	17	22	13	14	6	41	19.45	1.95	3.5	0.002
No. of hedges Site (B)	0	1	2	3	3	8	11	2	53	15.26	2.79		

df = 128

3.2 The relationship between hedgerow characteristics at sites A and B

Table 10 shows the simple correlations between shrub α-diversity and hedge physical characteristics at sites A and B. At site A, shrub α-diversity was significantly correlated with width, height, and shrub species but is not correlated with length and shrub occurrences (number of shrub recorded every 5 m of hedge). At site B, the shrub diversity was significantly correlated with length, number of shrub species and shrub occurrences but is not with width or height. The number of shrub species (Table 11) was significantly correlated with width, height and shrub occurrences at site A. At site B, shrub species was significantly correlated with length and shrub occurrences but is not correlated with width or height. Table 12 gives the simple correlation between height and length and width of hedgerow at sites A and B. The height and width were highly correlated at both sites and height and length were correlated at site B but they were not significant at site A.

Table 13 shows the simple correlations between length and width of hedgerow at sites A and B were not significantly correlated at both sites. The correlation between shrub occurrences and width were not significantly correlated at either sites, also the shrub occurrences were not significantly correlated with height at Site A but were significantly correlated with height at site B (Table 14). Table 15 gives the multiple regression coefficients between shrub α-diversity and height, length and width of hedges at sites A and B. It should be noted that at both sites $r = .48$ and so .23 or 23% (r^2) of the variation in shrub diversity is explained by the three physical characteristics of the hedge.

Table 10 : The simple correlation between shrub α-diversity and hedge physical characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Shrub species	Shrub occurrences
Site A	r	-0.099	0.489	0.388	0.934	-0.053
	p	NS	< 0.001	< 0.001	< 0.001	NS
Site B	r	0.376	0.235	0.086	0.955	0.379
	p	< 0.05	NS	NS	< 0.001	< 0.05

df = 98 for site A and 28 for site B

Tables 11 : The simple correlation between shrub species and the other hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Shrub occurrences
Site A	r	0.074	0.507	0.404	0.722
	p	NS	< 0.001	< 0.001	< 0.001
Site B	r	0.613	0.293	0.233	0.625
	p	< 0.001	NS	NS	< 0.001

Table 12 : The simple correlation between height and length and width of hedgerows at site A and B

		Length	Width
Site A	r	0.074	0.779
	p	NS	< 0.001
Site B	r	0.393	0.774
	p	< 0.05	< 0.001

df = 98 for site A and 28 for site B

Table 13 : The simple correlation between length and width of hedgerows at site A and B

	Site A	Site B
r	-0.037	0.243
p	NS	NS

df = 98 for site A and 28 for site B.

Table 14 : The simple correlation between shrub occurrences and width and height of sites A and B

		Width	Height
Site A	r	0.058	0.118
	p	NS	NS
Site B	r	0.256	0.383
	p	NS	<0.05

df = 98 for site A and 28 for site B.

Table 15 : The stepwise multiple regression analysis between shrub α-diversity as dependent variable and height, length and width of hedgerow at sites A and B

	Site A					Site B					Sig.of difference between slope
Independent variables	Multiple r	Slope	SE of Slope	t	p	Multiple r	Slope	SE of Slope	t	p	
Height		0.022	0.047	0.47	NS		-0.226	0.139	-1.62	NS	NS
Length	0.484	-0.0005	0.0005	-0.98	NS	0.489	0.005	0.002	2.35	<0.027	<0.02*
Width		0.182	0.062	2.92	<0.004		0.256	0.143	1.79	NS	NS
Constant		0.663 ± 0.126					0.595 ± 0.233				

df = 96 for site A and 26 for site B

* t = 2.67

3.3 Bird distribution and abundance at site A and B

The mode of the distribution of the number of birds per hedge was between 4 and 6 birds at site A while at site B it was between 1 - 3 birds. The mean numbers of birds per hedge was 8.3 ± SD5.6 at site A and 5.3 ± SD3.5 at site B (Table 16) and this difference is significant ($t = 3.5$, $df = 128$, $p < 0.002$).

The frequency distribution of numbers of bird species per hedge was 2 - 3 birds at both sites. The mean of the numbers of bird species per hedge was 3.3 ± SD1.64 at site A and 2.5 ± SD1.4 at site B. This difference in the mean is significant ($t = 2.9$, $df = 128$, $p < 0.01$) Table 17). Table 18 gives the frequency distribution of bird α-diversity index in each hedge at both sites but the difference in the means is not significant ($t = 1.02$, $df = 128$).

The relative abundance of each bird species was different at the two sites. For example, at site A, the yellowhammer formed 20.3% of the total bird number (821 birds) and at site B it was 9.7% of the total bird numbers (154 birds). This difference is significant ($\chi^2_1 = 8.91$, $p < 0.01$). The blackbird was 22.1% of total bird numbers at site B and 12.3% of the total bird numbers at site A, again a significant difference ($\chi^2_1 = 9.59$, $p < 0.01$). Table 19).

Table 20 shows the difference in the relative abundance of bird species at both sites. The yellowhammer was the commonest bird at site A and the blackbird was the commonest bird at site B.

The relative abundance of greenfinch, chaffinch, whitethroat, wren and dunnock were not significantly different at the two sites (Tables 19 and 20). The total density of bird species per 1000m of hedge at site B was greater than at site A (47.5 and 38.1 individuals respectively) (Table 21). Again, the yellowhammer had the highest population density at site A (7.7 individuals per 1000 m) and the blackbird had the highest population density at site B (10.5 individuals per 1000 m). The dunnock had the lowest population density (0.3 individual per 1000 m) at both sites. The linnet and greenfinch were present at site A (1.5 and 1.2 individual per 1000 m respectively) while they were absent from site B. The ratio of density of song thrush at sites B and A (3.78) showed that this species was 3.8 times more abundant at site B while the dunnock was over 4 times more abundant at site B than at site A (Table 21).

Table 16 : The frequency distribution of bird numbers in 100 hedges censused near Durham (site A) and 30 hedges at Weardale (site B)

Frequency of bird Numbers	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	Mean	S D	S E	t	p<
No. of hedges Site A	16	26	24	16	9	2	3	2	2	8.3	5.6	0.56	3.5	0.002
No. of hedges Site B	10	9	7	1	2	1	0	0	0	5.3	3.5	0.64		

df = 128

Table 17 : The frequency distribution of numbers of bird species in 100 hedges censused near Durham (site A) and 30 hedges at Weardale (site B)

Frequency of bird species	0-1	2-3	4-5	6-7	Mean	S D	S E	t	p<
No. of hedges at site A	12	47	33	8	3.3	1.64	0.164	2.9	0.01
No. of hedges at site B	3	23	4	0	2.5	1.14	0.21		

df = 128

Table 18 : The frequency distribution of bird α-diversity in 100 hedges examined near Durham (site A) and 30 hedges at Weardale (site B)

Frequency distribution of bird α-diversity	0.1-0.3	0.4-0.6	0.7-0.9	1.0-1.2	1.3-1.5	1.6-1.8	1.9-2.1	Mean	S D	S E	t	p
No. of hedges at site A	12	8	20	18	22	16	6	1.09	0.55	0.06	1.02	NS
No. of hedges at site B	3	3	11	4	6	1	2	0.98	0.53	0.09		

df = 128

Table 19 : A comparison of bird species relative abundance at site A and B

Bird species *	Bird Nos. Site A	Bird % Site A	Bird Nos. Site B	Bird % Site B	χ^2 with Yates Corr.	p
Yellowhammer	167	20.3	15	9.7	8.91	<0.01
Chaffinch	134	16.3	27	17.5	0.06	N S
Blue tit	123	15.0	10	6.5	7.23	<0.01
Blackbird	101	12.3	34	22.1	9.59	<0.001
Whitethroat	64	7.8	7	4.6	1.58	N S
Robin	40	4.9	15	9.7	4.89	<0.05
Willow Warbler	33	4.0	13	8.4	4.70	<0.05
Wren	32	3.9	7	4.6	0.02	N S
Linnet	32	3.9	0	0.0	5.04	<0.05
Dunnock	27	3.3	1	0.7	2.36	N S
Great tit	25	3.1	14	9.1	10.92	<0.01
Greenfinch	24	2.9	0	0.0	3.48	N S
Song thrush	19	2.3	11	7.1	8.58	<0.01
Total	821	100	154	100		

* For the scientific name of birds see Table 1.

Table 20 : The differences in the relative abundance of birds at site A and B

Significantly more common at site A	Significantly more common at site B	No significant difference between A and B
Yellowhammer	Blackbird	Greenfinch
Blue tit	Great tit	Chaffinch
Robin	Willow warbler	Whitethroat
Linnet		Wren
Songthrush		Dunnock

Table 21 : The density of bird species per 1000 m of hedge at site A (21568 m) and site B (3241 m) and the ratios of bird species at both sites

Bird species	Site A	Site B	Ratio : $\frac{B}{A}$
Yellowhammer	7.7	4.6	0.59
Chaffinch	6.2	8.3	1.34
Blue tit	5.7	3.1	0.54
Blackbird	4.7	10.5	2.23
Whitethroat	2.9	2.2	0.76
Robin	1.9	4.6	2.42
Willow warbler	1.5	4.0	2.67
Wren	1.5	2.2	1.47
Linnet	1.5	0	0
Dunnock	1.3	0.3	0.23
Great tit	1.2	4.3	3.58
Greenfinch	1.1	0	0
Song thrush	0.9	3.4	3.78
Total bird density	38.1	47.5	1.25

3.4 Birds and hedgerow characteristics at sites A and B

Tables 22, 23 and 24 give the simple correlation between birds and hedgerow characteristics at both sites. These were examined to show which of the independent variables correlated with bird diversity, number of bird species and number of individuals of bird. Table 22 gives the simple correlation coefficients between bird α-diversity index and the hedgerow characteristics at the two study areas. Most of the independent variables at site A were significant. At site B, all of the hedgerow characteristics were significant. The height of hedges at site B was highly correlated with bird diversity ($r = +0.739$, $df = 28$, $p < 0.001$).

The number of bird species was positively correlated with all independent variables at both sites (Table 23). At site B, the correlation coefficients between number of bird species and independent variables were greater than at site A. The length was more highly correlated with bird species at site B ($r = +0.673$, $df = 28$, $p < 0.001$) than at site A ($r = +0.275$, $df = 98$, $p < 0.01$). Table 24 gives the correlation coefficients between bird numbers and hedgerow characteristics. At site A, the correlation between bird numbers and hedgerow characteristics were positively correlated but the shrub α-diversity and the number of shrub species were not significant. The length was significant at site B while the other independent variables were not significant. The length was highly correlated with bird numbers at sites B and A ($r = +0.481$, $df = 28$, p 0.01; $r = +0.362$, $df = 98$, $p < 0.001$ respectively).

Table 25 gives the simple correlations between numbers of blackbird and hedgerow characteristics at site A and B. The blackbird numbers were correlated with length of hedgerow at site B ($r = +0.282$, $df = 28$, $p < 0.01$) but not significantly related to any of the other independent variables at either site. The dunnock numbers were correlated with height, shrub α-diversity and number of shrub species at site B, but not significantly with all the other independent variables at both sites (Table 26).

Table 22 : The simple correlation between bird α-diversity index and the hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Sh.α-D.I*	Shrub species
Site A	Value of r	0.205	0.301	0.213	0.301	0.320
	Value of p	NS	< 0.01	NS	< 0.01	<0.01
Site B	Value of r	0.622	0.597	0.739	0.359	0.514
	Value of p	< 0.001	< 0.001	< 0.001	< 0.05	<0.01

df = 98 for site A and 28 for site B.

* Sh.α-D.I is the shrub α-diversity index.

Table 23 : The simple correlation between number of bird species and the hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Sh.α-D.I.	Shrub species
Site A	Value of r	0.275	0.344	0.278	0.292	0.326
	Value of p	< 0.01	< 0.001	< 0.01	< 0.01	< 0.001
Site B	Value of r	0.673	0.469	0.619	0.494	0.652
	Value of p	< 0.001	< 0.01	< 0.001	< 0.01	< 0.001

df = 98 for site A and 28 for site B

Table 24 : The simple correlation between bird numbers and hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Shα-D.I.	Shrub species
Site A	Value r	0.362	0.289	0.289	0.171	0.235
	Value of p	< 0.001	< 0.01	< 0.01	NS	NS
Site B	Value of r	0.481	0.193	0.089	0.223	0.338
	Value of p	< 0.01	NS	NS	NS	NS

df = 98 for site A and 28 for site B.

Table 25 : The simple correlation between blackbird and hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Shrub α-diversity	Shrub species
	r	0.193	-0.116	-0.127	-0.012	0.027
	p	NS	NS	NS	NS	NS
	r	0.282	-0.139	0.092	-0.227	-0.214
	p	<0.01	NS	NS	NS	NS

df = 98 for site A and 28 for site B

Table 26 : The simple correlation between dunnock and hedgerow characteristics at sites A and B

Hedge characteristics		Length	Width	Height	Sh.α-D.I.	Shrub species
Site A	r	0.146	-0.155	-0.087	0.055	0.080
	p	NS	NS	NS	NS	NS
Site B	r	0.215	0.340	0.457	0.357	0.414
	p	NS	NS	<0.01	<0.05	<0.02

df = 98 for site A and 28 for site B.

3.5 Multiple regression analysis

Regression analysis is appropriate because it can be used for prediction and statistical control and therefore is an important subject in statistics and an invaluable tool (Sokel 1969). Multiple regression is mathematically an extention of linear regression to include more than one independent variable in the final equation. In this investigation bird numbers, bird diversity and bird species are used as dependent variables on characteristics of hedge (length, width, height shrub α-diversity, volume and hedge plane area) as independent variables. The multiple regression coefficient measures the proportion of variation in the dependent variables explained by all the independent variables including in the regression equation (Bailey 1981, Rands 1982). The multiple regression coefficient has been used in this study for two purposes : firstly, to find which hedge characteristics relate to bird numbers, bird diversity and bird species and to measure the expected change in dependent variable for unit change in the independent variables. The second purpose is to examine whether there is a difference between the study areas. Tables 27, 28 and 29 give the stepwise multiple regression analysis for bird numbers, bird diversity and bird species as dependent variables and the characteristics of hedge as independent variables at sites A and B. Bird numbers and bird diversity were correlated with length and width at sites A and B. Neither site had significant differences between their multiple regression coefficients (Tables 27 and 28). The other independent variables (height, shrub α-diversity, volume and hedge plan area) did not enter the programme. Bird species were

correlated with length, height and shrub α-diversity at both sites except height was not significant at site A. Again, sites A and B did not have significant differences between their multiple regression coefficients (Table 29). The width, volume and hedge plan area did not enter the programme.

Table 27 : The stepwise multiple regression analysis between bird numbers as dependent variable and characteristics of hedge (length, width, height, shrub α-diversity index, volume and plan area of hedge) as independent variables at site A and B

Independent variables	Site A					Site B					Sig. of difference between slope
	r	Slope	SE of slope	t	p	r	Slope	SE of slope	t	p	
Length	0.362	0.023	0.005	4.17	<0.0001	0.481	0.044	0.017	2.67	<0.013	NS
Width	0.472	1.590	0.471	3.38	<0.0011	0.488	0.393	0.844	0.47	NS	NS
Height *	-	-	-	-	-	-	-	-	-	-	-
Sh.α-D.I*	-	-	-	-	-	-	-	-	-	-	-
Volume *	-	-	-	-	-	-	-	-	-	-	-
Area *	-	-	-	-	-	-	-	-	-	-	-
Constant	0.5847 ± 1.525					-0.2979 ± 2.084					

df = 97 For site A and 27 for site B.

* A dash indicates that the variable to which it refers did not enter the programme

Table 28 : The stepwise multiple regression analysis between bird α-diversity index as dependent variable and characteristics of hedge (length, width, height, shrub α-diversity, volume and plan area of hedge) as independent variables at sites A and B

	Site A					Site B					Sig. of difference between slope
Independent variables	r	Slope	SE of Slope	t	p	r	Slope	SE of Slope	t	p	
Length	0.370	0.0014	0.0006	2.29	<0.02	0.773	0.0073	0.0018	4.02	<0.001	N S
Width	0.300	0.171	0.0522	3.27	<0.002	0.597	0.346	0.092	3.76	<0.001	N S
Height *	-	-	-	-	-	-	-	-	-	-	-
Sh.α-D.I.*	-	-	-	-	-	-	-	-	-	-	-
Volume *	-	-	-	-	-	-	-	-	-	-	-
Area *	-	-	-	-	-	-	-	-	-	-	-
Constant		0.50153 ± 0.1690					-0.3901 ± 0.2271				

df = 97 for site A and 27 for site B

* A dash indicates that the variable to which it refers did not enter the programme.

Table 29 : The stepwise multiple regression analysis between bird species as dependent variable and characteristics of hedge (length, width, height, shrub α-diversity, volume and plan area of hedge) as independent variables at site A and B

	Site A					Site B					Sig. of difference between slope
Independent variables	Multiple r	Slope	SE of Slope	t	p	Multiple r	Slope	SE of Slope	t	p	
Length		0.00553	0.0018	3.13	<0.02		0.001178	0.0039	2.96	<0.007	NS
Sh. α-D.I.	0.4462	0.9749	0.3748	2.60	<0.01	0.828	0.93568	0.3559	2.63	<0.014	NS
Height		0.19187	0.12270	1.564	NS		0.64491	0.1751	3.68	<0.001	NS
Width*	-	-	-	-	-	-	-	-	-	-	-
Volume*	-	-	-	-	-	-	-	-	-	-	-
Area *	-	-	-	-	-	-	-	-	-	-	-

Constant 0.7403 ± 0.5457 -1.0763 ± 0.5009

df = 96 for site A and 26 for site B

* A dash indicates that the variable to which it refers did not enter the programme

4. DISCUSSION

4.1 The pattern of distribution of hedgerow characteristics

In general, both sites A and B were similar in pattern of the frequency distribution of the recorded hedgerow characteristics such as width, height, the commonest shrub species (hawthorn) and shrub α-diversity. The two sites differed in the percentage occurrences of dominant and non-dominant hedge shrub. For example, hawthorn was the dominant shrub species at sites A and B but differed in percentage occurrences of the dominant. The dominance of hawthorn is not surprising because it is the most frequent plant used for hedging in Britain (Pollard *et al*. 1974).

4.2 The simple correlations between hedgerow characteristics at site A and B

Tables 10 - 14 give the simple correlation between hedgerow characteristics. The height and width of the hedge were highly correlated at both sites A and B ($r = +0.779$, $df = 98$, $p < 0.001$; $r = +0.774$, $df = 28$, $p < 0,001$ respectively (Table 12). This is probably due to the management of the hedgerow where the farmers control the height and width of the hedges at specific periods of time by trimming.

4.3 Bird distribution

Although sites A and B had no differences in the main hedgerow characteristics, the pattern of the distribution of bird species and individuals of bird were highly significantly different between the sites (Tables 16 and 17). This difference may be due to the difference in length of hedges at the sites.

But this finding is contrary to the view of Osborne (1983) who found that the length of hedgerow gave a poor correlation with species number compared with the other variables. This difference might be due to surrounding habitat, for example ditches, trees and hedgerow management. These surrounding variables were not considered in detail in this study. Arnold (1983) found that blackbirds were influenced by the amount of cover in the ditches whilst song thrushes were not. The same author found that the tree species were the major factors determining the abundance of the wren and great tit. Parslow (1969) found poorer breeding success for a number of species in hedges trimmed to 1.2 m compared with that of nests in higher, untrimmed hedges.

The frequency distribution of bird diversity was not significantly different at both sites but the species composition did differ.

4.4 Bird relative abundance

Reference to Table 19 shows that the relative abundance of each bird species was different at both sites. For example, yellowhammer formed 20.3% of all birds recorded at site A and 9.7% at site B and the blackbird abundance was 22.1% of the total bird numbers at site B and 12.3% at site A. Generally speaking, the yellowhammer was the commonest bird at site A and the blackbird was the commonest bird at site B (Table 20). The song thrush was 3.8 times more abundant at site B than at site A while the dunnock was over 4 times more abundant at site B than at site A (Table 21).

4.5 Bird density

At site B the total density of birds per 1000 m. of hedge was greater than at site A (47.5 and 38.1 individuals respectively). This may be due to the surrounding area which was very poor in vegetation cover because many of the farmland boundaries were stone walls which forced all the birds to concentrate in the remaining hedges which occurred at site B. The blackbird had the highest population density at site B (10.5 individuals per 1000 m). This is probably because the hedges of site B are near farms (including buildings, roads, gardens and houses). The dunnock had the lowest population density of the bird species which were present at both sites. The linnet and greenfinch were present at site A but were absent from site B (Table 21).

4.6 The relationships between the bird and hedgerow characteristics

A close correlation between bird species diversity and foliage height was found by MacArthur (1961) and this was followed by many similar reports (For review see Nilson 1979, Osborn 1984). But no attempt has been made to study the relationship between bird species diversity and the hedgerow characteristics; length, width, height, hedge volume, hedgerow plan area and hedgerow shrub species diversity. Simple correlations have been used to show how many of these independent variables correlated with bird diversity, bird species and bird numbers at both study areas. The number of bird species at both sites was correlated with all hedgerow characteristics except that shrub occurrences were not significant at site A (Table 23).

The prediction equation of bird species diversity at site B is

$(-0.390 \pm 0.2271) + (0.346 \pm 0.092) \times \text{width} + (0.0073 \pm 0.02) \times \text{length}$.

The number of bird species were correlated with length, height and shrub diversity at both sites (except height was not significant at site A). Both sites did not have significant differences in the multiple correlation coefficients. A prediction of the number of bird species can be calculated by using the general multiple regression equation (Table 29).

Table 15 gives the multiple regression coefficient between shrub α-diversity as dependent variable and height, length and width of hedges as independent variables at sites A and B. Both sites have significant differences between their multiple regression coefficient of length. This is because both sites were different in their length of hedges. The prediction equation of shrub α-diversity can be calculated by using the general multiple linear regression equation.

The numbers of blackbirds were correlated with length ($r = +0.282$, $df = 98$, $p < 0.01$) at site A but not correlated with the other independent variables at either sites (Table 25). Arnold (1983) found that the blackbird and dunnock numbers correlated with height. In this study the blackbird numbers were not related to hedge height at either site (Table 25). The dunnock numbers were highly correlated with hedge height at site B ($r = +0.457$, $df = 28$, $p < 0.01$) but not significantly so at site A.

4.7 Multiple regression analysis

The multiple regression has been used to find which multiples of independent variables (hedgerow characteristics) related to dependent variables (bird species, bird numbers and bird diversity) and to measure the expected change in dependent variables. Also to examine differences between the two study areas. Bird numbers and bird species diversity were correlated with length and width at sites A and B. Both sites did have significant differences in their multiple regressions. From Tables 27 and 28 one can compute the predicted number of birds and bird species diversity for any given unit of length and width of any hedge at either site using the general multiple regression equation ($y = a + b_1.x_1 + b_2.x_2 \cdots\cdots$) so, the prediction equation of bird numbers at site A is

$$(0.585 \pm 1.53) = (0.023 \pm 0.005) \times \text{length} + (1.6 \pm 0.47) \times \text{width}.$$

The prediction equation of bird numbers at site B is

$$(-0.298 \pm 2.084) + (0.046 \pm 0.02) \times \text{length} + (0.393 \pm 0.844) \times \text{width}.$$

The prediction equation of bird species diversity at site A is

$$(0.502 \pm 0.17) + (0.171 \pm 0.0522) \times \text{width} + (0.0014 \pm 0.0006) \times \text{length}$$

SUMMARY

1. The aim of this study was to relate hedgerow characteristics to bird diversity, bird numbers and the number of bird species.

2. The study was carried out at two sites A and B. Site A consisted of hundred hedges which were examined near Durham City and site B consisted of thirty hedges studied in Weardale.

3. Thirteen species of the commonest hedgerow birds were recorded at both sites. The yellow hammer was the commonest bird at site A and the blackbird was the commonest bird at site B.

4. Twenty three shrub species were recorded at both sites. The hawthorn was the dominant shrub species at both sites.

5. α- diversity index was computed for the bird and shrub species for the two study areas using Marglef's diversity index. The other calculations were performed using the SPSS-X programme.

6. Site A and B were similar in most of the hedgerow characteristics.

7. The sites differed in the length of their hedges and percentage occurrences of the dominant and non-dominant hedge shrubs.

8. The difference in length at both sites was highly significant ($t = 9.9$, $df = 128$, $p < 0.001$).

9. The difference in the percentage occurrences of non-dominant hedge shrub at both sites was highly significant ($t = 3.5$, $df = 128$, $p < 0.002$).

10. The length was more highly correlated with bird species at site B ($r = +0.7$, $df = =8$, $p < 0.001$) than at site A ($r = +0.3$, $df = 98$, $p < 0.01$).

11. The height and width of hedge were highly correlated at both sites A and B ($r = +0.8$, $df = 98$, $p < 0.001$; $r = +0.8$, $df = 28$, $p < 0.001$ respectively).

12. The frequency distribution of bird diversity was not significantly different at both sites but the species composition did differ.

13. At site B the total density of birds per 1000 m of hedge was greater than at site A (48 and 38 individuals respectively).

14. The multiple regression coefficient has been used in this study for two purposes. Firstly, to find which hedge characteristics relate to birds and measure the expected change in dependent variable for unit change in the independent variables. The second purpose is to examine whether there is a difference between the study areas.

15. Bird numbers and bird diversity were correlated with length and width at sites A and B. Neither site had significant difference between their multiple regression coefficients.

16. The prediction equation of bird numbers, bird species and bird diversity were calculated using the general multiple linear regression equation ($y = a + b_1.x_1 + b_2.x_2 \ldots\ldots$).

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APPENDIX 1 FORMAT OF ORIGINAL DATA FOR SITES A AND B

Columns	Variable
1 - 3	Number of hedge
4 - 6	Length of hedge
7 - 9	Width of hedge
10 - 12	Height of hedge
13 - 14	Bird numbers
15	Bird species
16 - 18	Shrub occurrences
19	Shrub species
20 - 23	Bird α-diversity index
24 - 27	Shrub α-diversity index
28	Blackbird numbers
29	Robin numbers
30	Blue tit numbers
31	Great tit numbers
32	Dunnock numbers
33	Whitethroat numbers
34	Yellowhammer numbers
36	Songthrush numbers
37	Chaffinch numbers
38	Linnet numbers
39	Wren numbers
40	Greenfinch numbers

Columns	Variable
41 - 43	Hawthorn occurrences
44 - 45	Privet occurrences
46 - 47	Ivy occurrences
48 - 49	Horse-chestnut occurrences
50 - 51	Hazel occurrences
52 - 53	Elder occurrences
54 - 55	Sycamore occurrences
56 - 57	Holly occurrences
58 - 59	Rose occurrences
60 - 61	Ash occurrences
62 - 63	Bramble occurrences
64 - 65	Blackthorn occurrences
66 - 67	Beech occurrences
68 - 69	Rowan occurrences
70 - 71	Willow occurrences
72 - 73	Hornbeam occurrences
74 - 75	Yew occurrences
76 - 77	Oak occurrences
78 - 79	Gorse occurrences
80 - 81	Whitebeam occurrences
82 - 83	Elm occurrences
84 - 85	Cherry occurrences
86 - 87	Norway spruce occurrences

APPENDIX 2.

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APPENDIX 2 (Cont.)

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APPENDIX 3.

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