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A comparison of breeding bird numbers along canals with and without a close season for fishing

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EXECUTIVE SUMMARY

1 Coarse fish close seasons for fishing apply currently on some canals but not on others. The Environment Agency is considering whether to abolish the statutory coarse fish close season for fishing on canals throughout England and Wales. Information on the value of close seasons to nature conservation is needed to inform this decision. For birds, such data should ideally encompass both the densities and the productivity of waterside breeding species.

2 The British Trust for Ornithology's Waterways Bird Survey (WBS) is an extensive long-running data set on the numbers of breeding birds of linear waters throughout the UK. WBS data from English and Welsh canals were examined to investigate whether differences in breeding bird numbers could be attributed to the presence or absence of a close season. Survey data were available during 1989-97 for 31 canals with a close season and 20 without. Most of the sample canals with a close season were in the Midlands and Thames regions, whereas those without were mainly in the North West.

3 An independent set of bird census data was collected in 1998, using Waterways Breeding Bird Survey (WBBS) transect methodology, along 66 canal stretches of which 32 were subject to a fishing close season. Half the stretches were surveyed by BTO volunteers and the remainder by experienced members of BTO staff. The WBBS data comprised counts of all bird species in up to ten 500-metre sections per stretch. RHS data were collected in parallel by the Institute of Freshwater Ecology and were available for 86% of the 541 WBBS sections.

4 In both the 1989-97 WBS data and the 1998 WBBS results, mean territory densities of waterside bird species often differed between canals with and without a close season. Some were commoner on canals with a close season and others on those without. Such differences appear to stem, however, from the different geographical distributions of the two samples of canals or from other ecological factors not associated with the fishing regime.

5 **Neither WBS nor WBBS data provided evidence that counts of breeding birds differ systematically between canals with and without a close season for coarse angling.**

6 Sites not differing in the numbers of breeding birds could nonetheless differ in their breeding productivity and hence their status as sources or sinks for the population as a whole. This important question was not addressed in the present study. A further programme of new fieldwork would be needed to discover whether and how the breeding success of waterbirds along canals is influenced by fishing and other sources of disturbance.

1 INTRODUCTION

The Environment Agency has a primary statutory duty to maintain, improve and develop fisheries in inland waters in England and Wales, including canals. In doing so it has secondary duties to further the conservation of flora and fauna of special interest, and to take into account any impact of its activities on flora and fauna generally.

Coarse fishing on canals may be subject to a statutory close season from 15 March to 15 June inclusive, during which all coarse angling is prohibited. A statutory coarse fish close season is also in force on all rivers, streams and drains. However, byelaws have dispensed with the close season on some canals; around 30% of the canal network has no close season and is open for coarse angling year-round. For historical reasons the proportions of canals with and without a close season differs between Environment Agency regions. The Agency is currently seeking to resolve the present inconsistencies in canal close seasons, either by introducing a close season on all canals, or by removing the close season thus permitting fishing all year on all English and Welsh canals (except some Sites of Special Scientific Interest (SSSI)).

In formulating its policy on this issue, the Agency has considered the effects of a close season on fisheries. A recent report commissioned by the Agency found no evidence that fish stocks were systematically either higher or lower in canals with a close season (Hendry & Cragg-Hine 1997). The main influence on fish productivity and community structure in canals was identified as the intensity of boat traffic. No evidence was found that fishery performance had declined where the close season had been removed. Expert opinion collated by these authors was that "*angling during the close season is not harmful to fish populations*". They concluded that the evidence from fisheries "*indicated that there would not appear to be justification for maintaining a close season for coarse fish angling on canals*". Its abolition would have socio-economic benefits for the angling community.

Having received this advice, the Agency proposed that "*lifting the close season on the majority of canals is the only rational way forward for fisheries*". The change would apply on all canal stretches where fish stocks were separate from those in any adjoining river systems and where formal conservation status, such as SSSI designation, was lacking. However, having established that removal of the close season would not be detrimental to fisheries, the Agency must consider the impact on recreation and conservation.

The aim of the present report is to examine whether fishing close seasons affect the populations of breeding birds along canals. The literature on the effects of fishing disturbance on birds is very sparse. At reservoirs, shore-anglers, present for long periods, often still but with short bouts of vigorous activity, are regarded as more disturbing to winter wildfowl than other bank users such as birdwatchers, walkers and picnickers, and may drive wildfowl from preferred feeding sites or cause them to depart (Bell & Austin 1985). Wildfowl species vary markedly in their susceptibility to such disturbance, depending on their nervousness and on their preferred sites for feeding (Tuite *et al.* 1984). On rivers, Croonquist & Brooks (1993) have investigated the effect on bird communities of disturbance, as defined as the difference between a forested site and an agricultural and residential one. However, we are not aware of any previous studies that have attempted to evaluate the effects of anglers on the breeding birds of linear waters.

Whether there is a close season might affect:

- the numbers of breeding territories established per unit length of canal, particularly of those bird species that make greatest use of the canal itself or its banks; and

- the nesting productivity of birds alongside the canal, which itself could contribute to effects on breeding densities by altering the rates of recruitment to the breeding population.

However, it is not clear whether a close season would necessarily be expected to benefit bird populations. The answer would depend on the ability of a species to cope with constant moderate levels of disturbance and on its sensitivity to a sudden onset of disturbance, possibly at a high level, in mid June. For some bird species sensitive to disturbance, breeding densities might be higher on canals closed for fishing during spring than on canals where fishing is taking place, but this apparent benefit might be negated by lower breeding productivity owing to disturbance beginning suddenly as the close season ends.

Fishing effort along canals with a close season is greatest in the autumn, whereas on canals without a close season it is concentrated into the period between March and June (Hendry & Cragg-Hine 1997). Fishing disturbance throughout the spring might encourage birds to position their nests in places shielded from its effects, perhaps away from the canal itself, while disturbance beginning in mid June, at the end of a close season, might result in increased breeding failure rates for species nesting or tending broods on or close to the canal banks at that time. At present, however, we can only speculate on such matters, based on what we know of birds' natural history; there is a clear need for specific evidence from carefully designed surveys.

The magnitude of any angling-related difference in breeding bird populations, and thus its detectability, would also depend on the levels of disturbance caused by coarse angling and by other kinds of human activity. Boating, walking, cycling, dog-walking and other activities each impose levels of disturbance that vary markedly between canal stretches.

This report examines whether the densities or community structure of birds holding territory differ systematically between canals with and without a close season, using two independent sets of bird count data. The question of breeding success lay beyond the scope of the present project and requires separate investigation.

2 METHODS

The study had two major components. First, a review was undertaken of historical data collected by the BTO through its Waterways Bird Survey (WBS). Second, data for specially selected samples of canals with ("closed") and without ("open") a close season for fishing were collected by the BTO in the 1998 breeding season, partly by volunteers and partly by BTO staff. This second part of the study was conducted using the transect methods being tested concurrently for a potential new monitoring scheme, the Waterways Breeding Bird Survey (WBBS).

2.1 Review of existing Waterways Bird Survey data

The WBS is an ongoing annual census of breeding birds along rivers and canals carried out by volunteers and organised by the BTO (Taylor 1984, Marchant *et al.* 1990). It began in 1974. Survey stretches are chosen by the volunteers themselves and average between 4 km and 5 km in length. The bird census method used is territory mapping, which produces an estimate of breeding numbers and a map of breeding territories for each species, stretch and year. Observers are asked to make nine visits to their site annually. Only a restricted list of bird species, incorporating all waterside specialists such as grebes, ducks, geese, swans, waders, and reed-bed passerines, is included in the survey.

2.1.1 Samples of WBS stretches available

The WBS archives were searched for canal stretches that could be classified as either "open" or "closed" according to information received from the Environment Agency (A Taylor, pers comm). In respect of changes made to canal fishing seasons, particularly in 1989 and 1990, it emerged that only two WBS canal stretches were without a close season prior to 1989; pre-1989 data therefore provided little comparison between "open" and "closed", and were discarded, while only those stretches providing data for years between 1989 and 1997 were retained. On the advice of the Environment Agency, one further stretch was omitted because its waters were not sufficiently separated from the adjacent river, and another because a close season applied on only part of the length surveyed (A Taylor, pers comm).

In all, 50 stretches were included. Table 1 lists the 31 stretches contributing to this study where a close season was in force, and Table 2 the 20 where there was no close season. One stretch on the Huddersfield Narrow Canal, WBS code 223, had a close season in 1989 but not subsequently, and appears in both tables.

The distribution of the 50 stretches is plotted in Figure 1. Canals with a close season ("closed") were mainly in the Midlands and Thames Agency regions, and those without ("open") were mostly in the North West. This difference, which follows from the regionally biased distribution of canal close seasons generally and is not a feature solely of the WBS sample, adds complications to the analysis because regional differences are to be expected in breeding bird densities (*eg* Gibbons *et al.* 1993), and could confound any differences resulting from differences in fishing seasons.

Table 1. **Waterways Bird Surveys 1989-97 along canals with a close season for fishing ("closed").**

EA region	Canal	WBS code	Length (km)	Altitude (m)	Grid references	Years & no. of surveys
Midlands	Birmingham & Fazeley	234	5.1	81	SP186938 - 202988	1989-93 (5)
Midlands	Chesterfield	253	16.0	25	SK596791 - 695815	1989-92 (3)
Southern	Chichester	354	4.0	8	SU858036 - 842013	1989-97 (9)
Midlands	Coombe Hill	64	4.3	9	SO886272 - 849265	1989-97 (5)
Midlands	Droitwich	345	4.0	38	SO888630 - 860600	1989-90 (2)
Midlands	Erewash	439	5.4	55	SK454471 - 469431	1994-97 (4)
Midlands	Gloucester & Sharpness	432	3.7	10	SO746085 - 737050	1993 (1)
Anglian	Grand Union	427	3.7	107	SP695916 - 664927	1993-96 (4)
Anglian	Grand Union	380	5.5	100	SP720902 - 727878	1991-97 (7)
Anglian	Grand Union	358	5.4	76	SP908270 - 883309	1989-95 (6)
Anglian	Grand Union	430	3.7	83	SP915230 - 929202	1993-97 (5)
Midlands	Grand Union	377	4.6	110	SP138821 - 181804	1991-97 (7)
Thames	Grand Union	188 †	5.4 5.5	103	SP892141 - 923140	1989-97 (4)
Thames	Grand Union	267	4.8	38	TQ043904 - 053856	1989-97 (9)
Thames	Grand Union	176	4.9	43	TQ062940 - 043903	1989-97 (9)
Thames	Grand Union	280	4.7	31	TQ141843 - 180837	1989-97 (9)

Midlands	Grantham	367	3.4	29	SK639367 - 608368	1990-97	(7)
Midlands	Grantham	346	4.9	46	SK676307 - 711292	1989-97	(9)
North East	Huddersfield Narrow	223*	4.7	187	SE039119 - 078139	1989	(1)
South West	Kennet & Avon	355	3.0	30	ST770662 - 752642	1989-97	(8)
Midlands	Oxford	341	3.8	16	SP443793 - 481779	1989-90	(2)
North West	Shropshire Union	359	5.5	91	SJ685343 - 672392	1990-94	(5)
Midlands	Shropshire Union	371	5.0	99	SJ869115 - 845157	1991-97	(7)
Midlands	Stafford & Worcs	374	3.2	44	SO853825 - 842804	1991-97	(7)
Midlands	Stafford & Worcs	473	4.0	87	SO860973 - 867937	1997	(1)
Midlands	Stafford & Worcs	465	5.5	46	SO862849 - 856809	1996-97	(2)
Midlands	Stafford & Worcs	464	4.5	58	SO862887 - 864855	1996-97	(2)
Midlands	Stafford & Worcs	334 ††	7.0 3.3	73	SJ973214 - 995226	1989-97	(9)
Midlands	Stratford on Avon	450	3.5	97	SP187711 - 188677	1994-97	(4)
Welsh	Swansea	471	4.5	40	SN752065 - 722041	1994-96	(2)
Thames	Wey Navigation	425	3.1	18	TQ050578 - 056604	1993-97	(5)

Notes:

* Site 223, which had a closed season in 1989 but not subsequently, appears also in Table 2.

† At site 188, 5.5 km were surveyed in 1989-90 and 5.4 km in 1996-97.

†† At site 334, 7.0 km were surveyed in 1989 and 3.3 km in 1990-97.

Table 2. **Waterways Bird Surveys 1989-97 along canals without a close season for fishing ("open").**

EA region	Canal	WBS code	Length (km)	Altitude (m)	Grid references	Years & no. of surveys
South West	Exeter	320	4.6	2	SX940894 - 963861	1989-97 (9)
South West	Grand Western	451	5.0	93	SS973122 - 999137	1996-97 (2)
North West	Huddersfield Narrow	462	5.0	140	SD992046 - 974007	1995-97 (3)
North East	Huddersfield Narrow	223*	4.7	187	SE039119 - 078139	1990-91 (2)
North West	Lancaster	401	4.3	19	SD487452 - 482483	1991-97 (7)
North West	Lancaster	423	7.0	50	SD521854 - 530804	1990-97 (8)
North West	Leeds & Liverpool	235	6.5	15	SD375052 - 376102	1989-90 (2)
North West	Leeds & Liverpool	457	6.5	19	SD443121 - 494104	1995-97 (3)
North West	Leeds & Liverpool	237	6.3	5	SD460203 - 461149	1989-97 (6)
North West	Leeds & Liverpool	364 †	3.0 5.5	20	SD523092 - 507099	1990-97 (7)
North West	Leeds & Liverpool	352	3.0	21	SD494104 - 524093	1989-97 (9)
North East	Leeds & Liverpool	444	4.5	48	SE223365 - 259356	1994 (1)
North West	Llangollen Branch, Shr U	474	4.7	60	SJ626553 - 611508	1997 (1)
North West	Macclesfield	368	4.0	135	SJ933779 - 937817	1990-97 (8)
North West	Macclesfield	480	3.0	160	SJ952856 - 961884	1997 (1)
North West	Peak Forest	479	3.5	160	SJ961884 - 976856	1997 (1)

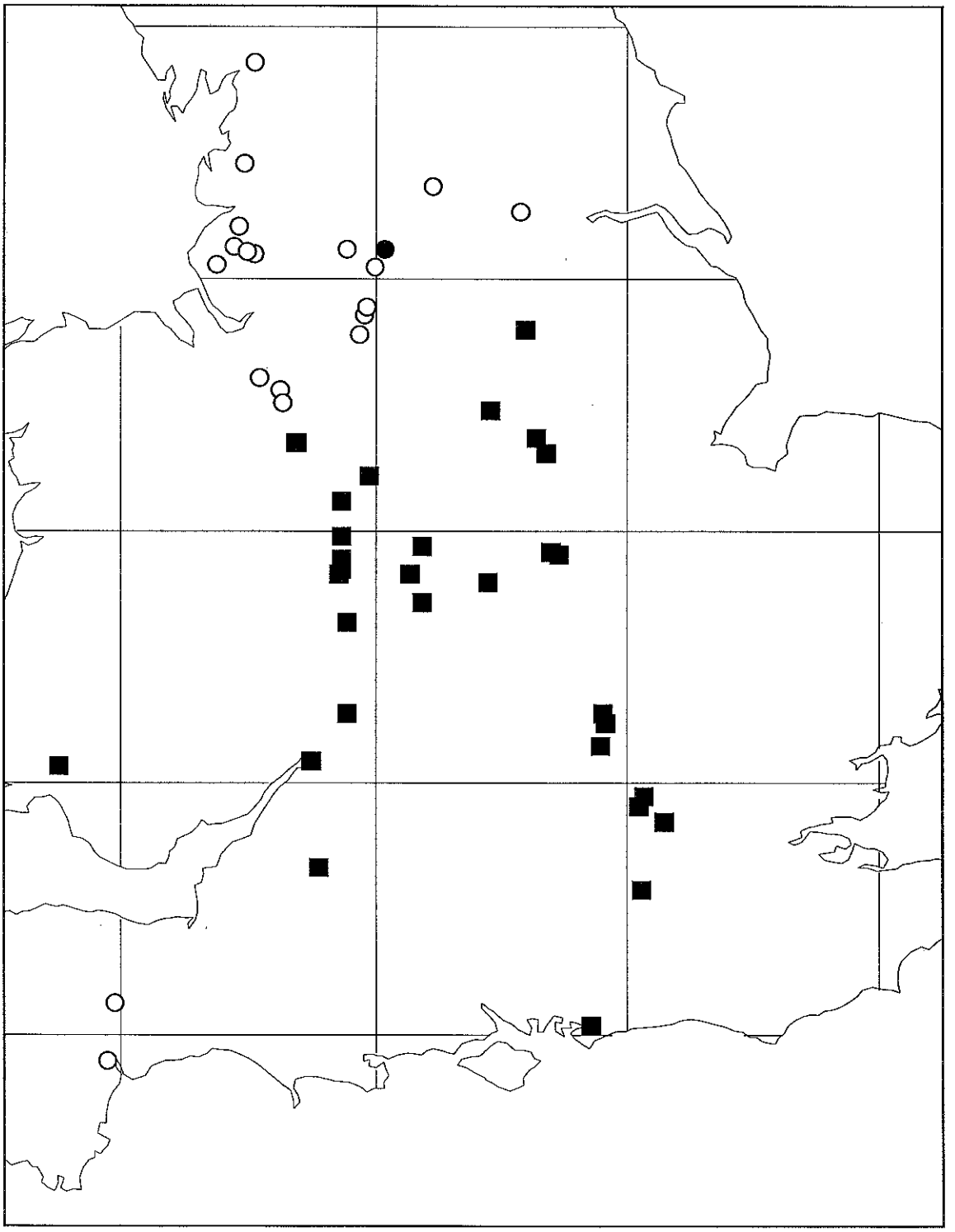
North West	Rochdale	400	3.3	135	SD889113 - 884083	1991-95	(5)
North East	Selby	396	4.8	8	SE572266 - 598295	1991-93	(3)
North West	Shropshire Union	403	5.1	40	SJ541603 - 585589	1991	(1)
North West	Shropshire Union	453	5.0	50	SJ638507 - 629549	1995-97	(3)

Notes:

* Site 223, which had a closed season in 1989 but not subsequently, appears also in Table 1.

† At site 364, 5.5 km were surveyed in 1990-92 and 1994-95 and 3.0 km in 1996-97.

Figure 1. **The distribution of Waterways Bird Survey canal stretches contributing to the review of existing data. Plots with a close season ("closed") are shown with filled squares and those without ("open") with open circles. The single site where the fishing season changed during the study period is shown with a filled circle.**



2.1.2 Differences between the samples of "closed" and "open" canals

The main ways in which the two samples differed are shown in Table 3. Differences in the mean length and mean altitude of plots were minor. Geographical differences are quantified in terms of mean easting and northing in kilometres from the origin of the national grid. Sites with a close season were significantly more southerly and easterly than the "open" sites. As well as outnumbering the "open" sites, the "closed" sites provided on average more surveys per site; there were almost twice as many surveys (plot-years) on "closed" stretches than on "open" ones. The proportion of "closed" to "open" surveys varied between years, and was especially high in 1989.

Table 3. Comparisons of WBS plot characteristics in the samples with ("closed") and without ("open") a close season for fishing.

Characteristics of sample	closed sites	open sites
Number of plots overall	31	20
Mean length (km) *†	4.68 ± 0.34	4.78 ± 0.25
Mean altitude (m) *	60.5 ± 7.2	68.3 ± 13.7
Mean national grid easting (km) *	431 ± 10.1	368 ± 8.8
Mean national grid northing (km) *	265 ± 12.5	375 ± 22.1
Predominant EA regions	Midlands, Thames	North West, North East
Total number of plot-years	160	83
Number of plots in 1989	15	4
Number of plots in 1990	16	8
Number of plots in 1991	15	10
Number of plots in 1992	17	8
Number of plots in 1993	19	7
Number of plots in 1994	19	9
Number of plots in 1995	18	11
Number of plots in 1996	20	12
Number of plots in 1997	21	14

Notes:

* Means and standard errors are tabulated. Site 223, which had a closed season in 1989 but not subsequently, appears in both samples.

† Where sites changed length between years (3 cases: 2 "closed", 1 "open"), the figure taken was the average length across all years for which there were data.

2.1.3 Methods of analysis for WBS data

There were 160 surveys where a close season was in force and 83 where the fishing season was open all year (Table 3). To obtain an overview of differences in species density between the two samples, territory counts for each species were divided by plot length to give a measure of density. This density measure would not necessarily be an accurate one, because of census errors and because some territories would have overlapped the ends of the stretches surveyed, but is a valid figure for comparisons between these samples, given that their mean plot lengths are very similar. Means were first calculated across years surveyed for each plot, and then across plots.

Differences in bird density between the two samples do not infer that there is necessarily a relationship between bird density and fishing regime, given that geographical factors in particular were known to differ between the two samples. Generalised linear modelling was used to investigate the influence of fishing season on the survey data, relative to other factors that were measured. The response variable, the number of territories recorded on the survey, was modelled against length of stretch, the year, national grid easting and northing, altitude and fishing season. Poisson error terms and a log link function were used. Since auto-correlation would be expected between counts made in successive years at the same sites, allowance was made for this by treating site code as a repeated subject.

2.2 Methods of the pilot Waterways Breeding Bird Survey

2.2.1 Field methodology

The methods employed for the pilot WBBS were modelled very closely on those devised for the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a national bird monitoring programme that began in 1994. BBS uses a transect method in which two visits are made, termed "early" and "late", one in the first and one in the second half of the breeding season (BTO 1998, Gregory *et al.* 1998). The transect is divided into up to ten sections. During each visit, all birds seen or heard are counted, section by section, in each of three distance bands from the transect line (0-25 metres, 25-100 metres, and >100 metres, summing counts from both sides of the transect line); birds seen only in flight are recorded separately.

This part of the pilot WBBS differed from BBS in that:

- sites were not selected randomly;
- routes within sites followed the canal rather than a predetermined pattern based on the national grid;
- the sections composing each transect stretch were each 500 metres, to match the Environment Agency's River Habitat Survey, not 200 metres as in BBS;
- transects were not fixed at 2 km, as in BBS, but were of variable length, with a maximum of 5 km (ten 500-metre sections); and

- habitat recording was extended from the BBS standard to allow extra information to be recorded about the canal itself.

WBBS observers coded the main features of up to three habitat types per 500-metre section of canal, of which the first habitat was the canal itself and the other one or two were those considered by the observer to be the most important adjoining habitats. The system of habitat coding used was that devised by Crick (1992) and now used for all BTO monitoring surveys.

2.2.2 Selection of locations for WBBS coverage

The selection of canal stretches was made initially by the Environment Agency (A Taylor, pers comm), who prepared a list of sites that incorporated the locations of currently active WBS mapping surveys as previously supplied to them by the BTO. Minor modifications suggested by the authors, aimed at improving the geographical spread of each subsample, were incorporated into a final target list of 32 "open" and 31 "closed" stretches.

The sample size was set with the aim of covering at least 30 stretches in each of the two categories. About half the stretches in each sample, 33 stretches in all, were reserved for coverage by BTO staff specially chosen for their experience in bird survey work. For stretches already being covered each year by WBS, the WBS observer was contacted directly and asked to carry out extra field visits using WBBS methods in addition to the normal WBS mapping census. Further volunteer observers for the remainder of the WBBS canal stretches were sought through the BTO's regional network.

As another part of the same Environment Agency contract, a further 200 WBBS plots throughout the United Kingdom, including both canals and rivers, had been selected randomly for coverage in 1998 by BTO volunteers; the purpose of this was to test the potential of the method more generally for monitoring breeding birds along linear waters (Marchant *et al.* in prep). Canals from this random sample were added to the sample selected for the present study, provided that they were in England or Wales and that their fishing season was known; this made a grand total of 72 target stretches.

On the Environment Agency list of target plots, stretches were defined by the start and end points of the existing WBS plot, if any, or simply by the canal name and the name of a town or village. Stretches selected randomly were identified by a 2x2-km tetrad from the national grid. In both cases, start and end points for fieldwork were not pre-set, but were left for the observer to determine with regard to:

- the requested location;
- the requirement for a whole number of complete 500-metre transect sections;
- convenience of access;
- the observer's preference for the number of sections to be covered (maximum ten).

Staff fieldworkers were asked to survey ten sections per stretch whenever possible, but some stretches were curtailed to enable two stretches to be covered in a single fieldwork session.

Observers found little difficulty in applying BBS-style transect methods to canals, where towpaths provided easy access directly alongside the waterway.

2.2.3 WBBS coverage achieved

Of the 72 target stretches, some designated for coverage by volunteers were not surveyed, generally because no observer could be found. The 66 WBBS canal stretches surveyed for this study are listed in Table 4 (canals with a close season) and Table 5 (those without). Some characteristics of the stretches in each of the samples are summarised in Table 6.

In all, 32 stretches with a close season for fishing were surveyed, and 34 without. As requested by the Agency, at least 15 of each type were covered by BTO staff: of 33 stretches surveyed by staff, one third each were surveyed by DEB, SJG and AMW. A number of the plots had also been surveyed for the WBS during 1989-97 and included in the samples shown here in Tables 1 and 2 and in Figure 1; thus there is some spatial but no temporal overlap between the WBS and WBBS samples.

As in the WBS sample, there was a very marked difference in the geographical distribution of "closed" and "open" canals surveyed by the WBBS (Figure 2). Most of the "open" stretches were in the Agency's North West region and most of the "closed" sites in the Midlands. The WBBS samples were generally, however, less clumped and distributed more evenly than the WBS sites (Figure 1).

Table 4. **Waterways Breeding Bird Surveys in 1998 along canals with a close season for fishing ("closed").**

Canal name	County	Grid references of start and finish points	Observer category	Number of 500m sections
Basingstoke	Hampshire	SU809536-SU853527	volunteer	9
Birmingham & Fazeley	West Midlands	SP202984-SP186938	staff	10
Bridgwater & Taunton	Somerset	ST301365-ST322325	staff	10
Cannock Extension	Staffs	SK021069-SK019045	volunteer	5
Chesterfield	Notts	SK649808-SK611788	staff	10
Chichester	Sussex	SU858036-SU842013	volunteer	8
Dudley	West Midlands	SO932892-SO953883	staff	10
Erewash	Derbyshire	SK454471-SK469431	staff	10
Gloucester & Sharpness	Glos	SO737049-SO758093	staff	10
Grand Union	Bucks	SP869398-SP877372	volunteer	6
Grand Union	Beds	SP915230-SP929202	volunteer	8
Grand Union	Herts	TQ062940-TQ044902	volunteer	10
Grand Union	Leics	SP695916-SP664927	staff	8
Grand Union	Leics	SP727879-SP725901	volunteer	10
Grand Union	Gr London	TQ182836-TQ144843	volunteer	10
Grand Union	Northants	SP626619-SP630602	volunteer	4
Grand Union	West Midlands	SP181804-SP144818	volunteer	8
Grantham	Notts	SK639367-SK608368	volunteer	8
Grantham	Notts	SK709292-SK676307	volunteer	10
Kennet & Avon	Avon	ST782657-ST755642	staff	10
Kennet & Avon	Wiltshire	SU224635-SU179618	staff	10
Knottingley & Goole	Humberside	SE648187-SE667193	staff	4
New Junction	S Yorkshire	SE634151-SE650184	staff	7
Oxford	Warks	SP382831-SP421822	staff	10
Royal Military	Kent	TQ958292-TQ938248	staff	10
Shropshire Union	Staffs	SJ849142-SJ875102	volunteer	10

Staffordshire & Worcs	Staffs	SJ995229-SJ971214	volunteer	6
Stratford-on-Avon	Warks	SP187711-SP189672	volunteer	8
Swansea	Glamorgan	SN752065-SN724041	volunteer	6
Trent & Mersey	Staffs	SJ881442-SJ885393	staff	10
Trent & Mersey	Staffs	SK273274-SK238241	staff	10
Worcester & Birmingham	Hfd & Worcs	SO865576-SO889577	staff	5

Table 5. **Waterways Breeding Bird Surveys in 1998 along canals without a close season for fishing ("open").**

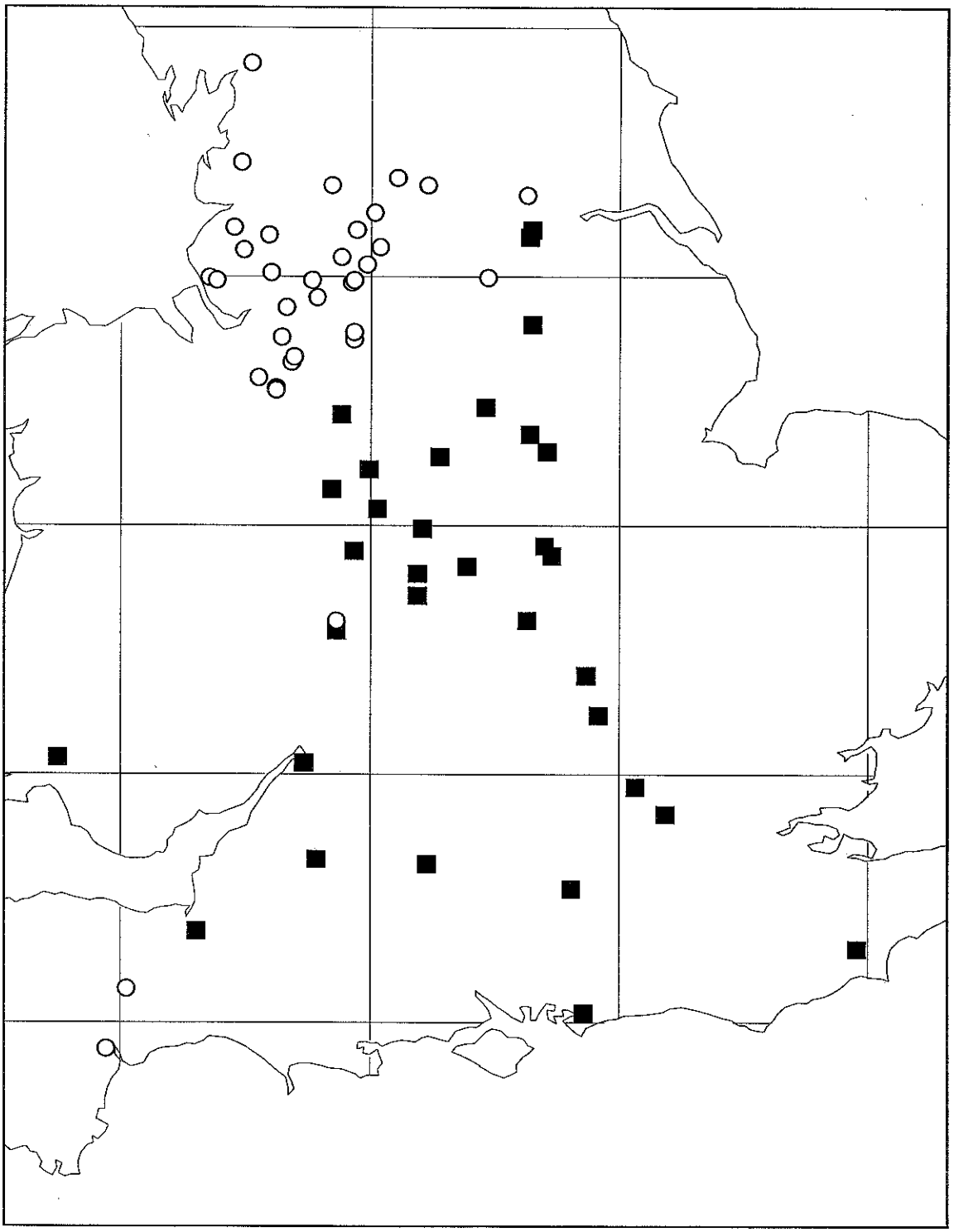
Canal name	County	Grid references of start and finish points	Observer category	Number of 500m sections
Ashton (derelict)	Gr Manchester	SJ925976-SJ948985	staff	6
Bridgewater	Cheshire	SJ669871-SJ625864	volunteer	10
Bridgewater	Gr Manchester	SJ762986-SJ799945	volunteer	10
Bridgewater	Gr Manchester	SJ784912-SJ796937	volunteer	6
Droitwich	Hfd & Worcs	SO868611-SO884627	staff	5
Exeter	Devon	SX940894-SX963860	volunteer	10
Grand Western	Devon	ST023134-SS999131	volunteer	10
Huddersfield Narrow	Gr Manchester	SD984041-SD977025	volunteer	4
Huddersfield Narrow	W Yorkshire	SE039119-SE079139	staff	10
Lancaster	Cumbria	SD520854-SD537831	volunteer	7
Lancaster	Lancashire	SD487452-SD486488	staff	10
Leeds & Liverpool	Lancashire	SD458193-SD461149	volunteer	10
Leeds & Liverpool	Lancashire	SD494104-SD453112	volunteer	10
Leeds & Liverpool	Lancashire	SD596168-SD599124	staff	10
Leeds & Liverpool	Lancashire	SD843365-SD845327	staff	10
Leeds & Liverpool	Merseyside	SJ350994-SJ341969	staff	10
Leeds & Liverpool	Merseyside	SJ387981-SJ350994	staff	10
Leeds & Liverpool	W Yorkshire	SE107399-SE125384	staff	5
Leeds & Liverpool	W Yorkshire	SE222368-SE238366	staff	5
Leigh Branch	Gr Manchester	SD602018-SJ630996	volunteer	8
Llangollen Branch	Cheshire	SJ621551-SJ617524	staff	6
Macclesfield	Cheshire	SJ930744-SJ925716	volunteer	6
Macclesfield	Cheshire	SJ933779-SJ936814	volunteer	8
Middlewich Branch	Cheshire	SJ689658-SJ679632	staff	6
Peak Forest	Gr Manchester	SJ935984-SJ944951	staff	8
Rochdale	Gr Manchester	SD885079-SD893038	volunteer	10

Rochdale	Gr Manchester	SD947182-SD917140	volunteer	10
Rochdale	W Yorkshire	SE015259-SE039245	staff	7
Selby	N Yorkshire	SE620320-SE585290	staff	10
Sheffield & S Yorks	S Yorkshire	SK468997-SE504001	volunteer	7
Shropshire Union	Cheshire	SJ553599-SJ581588	staff	6
Shropshire Union	Cheshire	SJ629549-SJ638504	volunteer	10
Trent & Mersey	Cheshire	SJ644753-SJ666759	staff	6
Trent & Mersey	Cheshire	SJ695671-SJ683689	volunteer	5

Table 6. Comparisons of WBBS plot characteristics in the samples with ("closed") and without ("open") a close season for fishing.

Characteristics of the sample		closed	open
Number of stretches:	volunteers	16	17
	BTO staff	16	17
	total	32	34
Mean number of 500-m sections per stretch:			
	volunteers	7.9	8.3
	BTO staff	9.0	7.6
	total	8.4	8.0
Total number of 500-metre sections		270	271
Number of sections with a matched RHS		229	237

Figure 2. **The distribution of Waterways Breeding Bird Survey canal stretches from which data were collected in 1998. Plots with a close season ("closed") are shown with filled squares and those without ("open") with open circles.**



2.2.4 IFE River Habitat Surveys

In parallel with the WBBS work, the Agency contracted the Institute of Freshwater Ecology (IFE) to collect habitat data for the WBBS stretches using the Agency's River Habitat Survey (RHS) methodology. RHS is a standardised method of habitat description for 500-metre sections of linear waters (Raven *et al.* 1997). Attributes of the waterway are recorded at ten "spot-checks" at 50-metre intervals, while a "sweep-up" collects further data over the full 500 metres. The basic list of RHS attributes was extended for these surveys to include a small number of extra features, such as locks and overhead wires, that were expected to be of importance to waterbird distribution.

IFE provided BTO with selected data on disc from 552 River Habitat Surveys and also with a preliminary analysis of the data (Dawson *et al.* 1998). Surveys had all been made in 1998, between May 11 and August 19 and mainly in late July and early August. IFE had been supplied by BTO with the starting and ending grid references for WBBS stretches and where possible with the number of transect sections that the WBBS observer intended to survey within those limits. The RHS surveys were subsequently matched to WBBS 500-metre transect sections as closely as possible, ensuring that the central grid reference lay between the limits of the WBBS section. Not all the RHS data could be matched to WBBS sections, in most cases because WBBS observers had not completed their fieldwork or had made late changes to their boundaries. In all 466 of the RHS sections could be matched to WBBS sections (Table 6), amounting to 86% of the WBBS sample.

2.2.5 Methods of analysis for WBBS and RHS data

WBBS data for each species and 500-metre section consisted of two counts (from one visit early in the season and one late), each divisible into four categories (the three distance bands, and birds in flight). Analysis was restricted to waterside species likely to be breeding on or adjacent to the canal and therefore subject to fishing disturbance; the list of species was essentially that of the WBS, but Whitethroat and Grey Heron were excluded.

Mean counts per unit length, for each species, observer category and fishing season category, were calculated as follows. First, counts were summed across all four distance categories. Second, a mean count was calculated across the sections that constituted each stretch; for each species and stretch, this produced two estimates of bird density (number per 500 metres), one for the early and one for the late visit. This step was necessary because bird counts on adjacent 500-metre sections could not be taken as independent estimates of bird numbers. Third, the lower of these figures was discarded and the higher figure was multiplied by 20 to convert the units to birds per 10 km. Finally, the resulting figures were averaged, for each species, within each of the four categories of plots. In a separate analysis, only birds in the first distance category (up to 25 metres from the transect line) were counted; because of their proximity to the water these would have been the birds most at risk from fishing disturbance.

RHS data, even in the restricted form requested from IFE, consisted of 262 variables per 500-metre section. Given that many of the features varied little on canals and also the high degree of inter-correlation between them, we selected a more manageable number of variables that we considered the most likely to influence bird numbers, and included these in our analyses. Priority was given to continuous variables such as water width and to summary variables, compiled from

the ten RHS spot-checks, that could be treated as continuous. For comparison with these data, for which the 500-metre section and not the transect stretch was the unit, bird counts for each 500-metre section were compiled by summing across distance categories as described above and then taking the higher count (early or late). To assess whether RHS was likely to add information that was useful in interpreting the bird counts, Pearson correlations were calculated between bird counts and ten selected RHS variables.

Generalised linear modelling was used to investigate the effect of fishing season on the bird counts, relative to other factors that were measured. For the WBBS data, relevant factors were concerned only with habitat and geographical location, since year (1998) and section length (500 metres), that had been variable in the WBS data set, were constant throughout. Since each of the RHS factors investigated had been found to be correlated with the counts of several waterside bird species, they were all included in the model. The response variable, the number of birds counted in each 500-metre transect section (combining all distance categories), was modelled against national grid easting and northing, the ten RHS habitat variables, and fishing season. Poisson error terms and a log link function were used. Serial auto-correlation would be expected between counts made in successive sections within the same stretch; allowance was made for this by treating the stretch as a repeated subject. Owing to missing data in the RHS tables, the sample size of sections that could be included in the modelling analysis was reduced to 321.

3 RESULTS

3.1 Bird densities on the "closed" and "open" canals sampled

The mean density figures calculated for each species from 1989-97 WBS data are tabulated in Table 7, separately for "closed" and "open" stretches. In all, 38 WBS species held territory, 28 on "closed" stretches and 34 on "open" ones. Equal numbers of species held higher densities on "closed" canals and on "open" canals, but densities across all WBS species were higher on the "open" sites. A substantial difference in density in favour of "open" canals was noted for Mallard, which was the most abundant WBS species on both samples of canals but was 41% commoner on the "open" sites.

Similar data are presented in Tables 8 and 9, derived from the WBBS counts in 1998. Mean bird counts per unit length of WBBS stretch are listed in Table 8, for all distance categories combined. Densities values were often higher than those from the WBS data in Table 7. While chance effects play a part, the main reason is the difference in the units of recording; WBS counts breeding bird territories, while WBBS totals may have included both birds of a breeding pair and also individuals in adult plumage that were not breeding. It is noteworthy that a single year's WBBS, with just two bird-counting visits per stretch, has provided data comparable to those from eight years' more intensive WBS mapping surveys; this emphasises the value of WBBS transect methodology for studies of breeding waterbirds.

Results obtained by staff and by volunteer observers are presented separately in Table 8. In their assessment of which type of canal held the higher densities of birds, volunteers and staff agreed for 14 species and disagreed for 18 species; there is no clear indication from the WBBS data, therefore, that one fishing regime supports higher breeding bird densities than the other.

A paired t-test suggested that volunteers found significantly more birds than staff on canals lacking a close season ($P=0.007$) but that there was no difference on "closed" canals ($P=0.878$). This inconsistent outcome suggests that differences between the results of volunteers and staff were more likely to have stemmed from chance, given that sample sizes (16-17 stretches) were relatively small, than from differences in observer efficiency. Results from the two classes of observer have been combined in subsequent analyses.

Table 9 presents mean densities from WBBS for birds within 25 metres of the transect line only. Those waterbirds not found in this innermost zone are excluded. For all but a few species, mean densities are similar between the two types of canal. Density estimates were higher on the "closed" canals for 22 waterside species and on the "open" canals for 12 species. Apart from the geese and swans, which all provided higher density estimates on the "closed" canals, no trends were obvious at the guild or family level.

Table 7. **Linear densities (territories per 10 km) of waterside bird species recorded along canals in the WBS samples of plots with ("closed") and without ("open") a closed season for fishing. Figures presented are the mean and standard error across all plots in the sample ("closed" n = 31; "open" n = 20); where a plot was surveyed in more than one of the years 1989-97, the figure used was the average density across all years for which there were data. Zero counts are all included.**

Species	Density on "closed" canals (territories/10 km)	Density on "open" canals (territories/10 km)	Type with higher mean density
Little Grebe	0.20 ± 0.15	0.01 ± 0.01	closed
Great Crested Grebe	0.59 ± 0.36	0.21 ± 0.21	closed
Grey Heron	0	3.29 ± 3.29	open
Mute Swan	1.99 ± 0.49	1.73 ± 0.78	closed
Greylag Goose	0.04 ± 0.02	0.01 ± 0.01	closed
Canada Goose	3.81 ± 1.34	3.37 ± 1.78	closed
Egyptian Goose	0	0.01 ± 0.01	open
Shelduck	0.01 ± 0.01	0.75 ± 0.56	open
Muscovy Duck	0	0.17 ± 0.17	open
Mallard	33.72 ± 6.77	47.56 ± 6.93	open
Teal	0	0.02 ± 0.01	open
Gadwall	0.04 ± 0.03	0	closed
Shoveler	0	0.01 ± 0.01	open
Mandarin Duck	0.06 ± 0.06	0.04 ± 0.04	closed
Pochard	0.04 ± 0.02	0	closed
Tufted Duck	0.98 ± 0.33	0.42 ± 0.25	closed
Water Rail	0	0.24 ± 0.24	open
Moorhen	18.8 ± 2.82	18.19 ± 2.18	closed
Coot	8.59 ± 2.94	4.73 ± 1.70	closed
Oystercatcher	0	0.54 ± 0.37	open
Lapwing	1.36 ± 0.50	4.23 ± 1.41	open
Ringed Plover	0.02 ± 0.02	0	closed
Curlew	0.40 ± 0.38	0.33 ± 0.27	closed

Redshank	0.11 ± 0.09	0.36 ± 0.33	open
Common Sandpiper	0.01 ± 0.01	0.05 ± 0.05	open
Snipe	0	0.10 ± 0.10	open
Kingfisher	0.68 ± 0.16	0.54 ± 0.21	closed
Sand Martin	2.03 ± 1.57	0.33 ± 0.33	closed
Yellow Wagtail	0.52 ± 0.24	0.28 ± 0.13	closed
Grey Wagtail	1.11 ± 0.28	1.55 ± 0.50	open
Pied Wagtail	1.37 ± 0.28	2.46 ± 0.51	open
Dipper	0	0.03 ± 0.03	open
Cetti's Warbler	0	1.33 ± 1.33	open
Grasshopper Warbler	0.12 ± 0.09	0	closed
Sedge Warbler	8.21 ± 2.07	12.53 ± 5.53	open
Reed Warbler	4.66 ± 2.37	8.62 ± 8.08	open
Whitethroat	5.95 ± 1.20	5.12 ± 1.33	closed
Reed Bunting	6.19 ± 1.32	5.75 ± 2.07	closed

Table 8. **Linear densities (birds per 10 km) of waterside bird species, as measured by WBBS transect methods, along canals with ("closed") and without ("open") a close season for fishing (all observations included). Data collected by volunteer observers and by BTO staff are summarised separately. Figures given are mean and standard error, across all stretches in each sample. For sample sizes see Table 6.**

Species	Observer *volunteers* v *staff* s	Birds per 10 km on "closed" canals	Birds per 10 km on "open" canals	Type with higher mean density
Little Grebe	v	0.2 ± 0.2	0.2 ± 0.2	closed
	s	0.8 ± 0.6	0.6 ± 0.6	closed
Great Crested Grebe	v	1.3 ± 0.9	2.7 ± 2.6	open
	s	3.7 ± 1.8	0.4 ± 0.3	closed
Mute Swan	v	19.3 ± 10.5	12.9 ± 5.2	closed
	s	13.0 ± 2.4	8.8 ± 2.7	closed
Greylag Goose	v	0	0.6 ± 0.6	open
	s	1.9 ± 1.1	0.5 ± 0.5	closed
Canada Goose	v	28.3 ± 12.0	24.8 ± 9.8	closed
	s	27.5 ± 9.0	11.8 ± 4.3	closed
Egyptian Goose	v	0	0	-
	s	0.1 ± 0.1	0	closed
Shelduck	v	0.3 ± 0.3	6.5 ± 3.9	open
	s	2.2 ± 1.4	0.6 ± 0.4	closed
Mallard	v	63.2 ± 14.6	70.6 ± 11.9	open
	s	54.7 ± 9.0	67.7 ± 10.0	open
Teal	v	0.1 ± 0.1	0.3 ± 0.3	open
	s	0	0	-
Gadwall	v	0	1.1 ± 0.9	open
	s	1.4 ± 0.9	0.2 ± 0.2	closed
Shoveler	v	0	1.0 ± 0.9	open
	s	0.2 ± 0.2	0	closed
Mandarin Duck	v	0.1 ± 0.1	0.1 ± 0.1	closed
	s	0.4 ± 0.3	0.1 ± 0.1	closed
Pochard	v	0.1 ± 0.1	0.1 ± 0.1	open
	s	0	0	-
Tufted Duck	v	3.7 ± 2.4	1.7 ± 1.2	closed
	s	6.4 ± 3.3	1.0 ± 0.6	closed

Goosander	v	0.2 ± 0.2	0	closed
	s	0.3 ± 0.3	0	closed
Ruddy Duck	v	0	0.2 ± 0.2	open
	s	0	0.4 ± 0.4	open
Water Rail	v	0	0.6 ± 0.5	open
	s	0.1 ± 0.1	0	closed
Moorhen	v	25.3 ± 6.6	20.7 ± 3.3	closed
	s	18.4 ± 3.9	17.2 ± 4.4	closed
Coot	v	20.3 ± 7.1	16.7 ± 5.5	closed
	s	5.2 ± 2.5	7.1 ± 3.5	open
Oystercatcher	v	0	1.0 ± 0.6	open
	s	1.3 ± 0.6	0.6 ± 0.4	closed
Lapwing	v	0.7 ± 0.5	16.4 ± 5.8	open
	s	6.9 ± 3.4	1.5 ± 0.5	closed
Ringed Plover	v	0.2 ± 0.2	0	closed
	s	0	0	-
Curlew	v	0.2 ± 0.2	0.5 ± 0.4	open
	s	1.6 ± 1.1	1.5 ± 1.1	closed
Redshank	v	0.2 ± 0.2	2.8 ± 1.9	open
	s	0.3 ± 0.2	0	closed
Common Sandpiper	v	0.2 ± 0.2	0.1 ± 0.1	closed
	s	0.8 ± 0.6	0.3 ± 0.2	closed
Snipe	v	0	0.4 ± 0.4	open
	s	0	0	-
Kingfisher	v	1.9 ± 0.8	0.5 ± 0.3	closed
	s	2.5 ± 0.9	1.4 ± 0.6	closed
Sand Martin	v	1.0 ± 1.0	2.2 ± 2.0	open
	s	2.1 ± 2.1	0.6 ± 0.6	closed
Yellow Wagtail	v	0.8 ± 0.6	0	closed
	s	3.5 ± 2.5	0.6 ± 0.6	closed
Grey Wagtail	v	1.4 ± 0.7	1.4 ± 0.6	closed
	s	0.3 ± 0.2	2.5 ± 0.8	open
Pied Wagtail	v	3.2 ± 1.1	4.9 ± 1.0	open
	s	3.8 ± 0.7	4.9 ± 1.1	open
Dipper	v	0.2 ± 0.2	0.1 ± 0.1	closed
	s	0	0.2 ± 0.2	open
Cetti's Warbler	v	0	1.9 ± 1.9	open
	s	0.3 ± 0.3	0	closed

Grasshopper Warbler	v s	0.1 ± 0.1 0.5 ± 0.4	0.6 ± 0.6 0	open closed
Sedge Warbler	v s	7.8 ± 2.7 13.7 ± 5.3	9.8 ± 4.4 3.8 ± 1.1	open closed
Reed Warbler	v s	8.4 ± 5.8 6.5 ± 4.1	9.0 ± 4.4 14.4 ± 11.0	open open
Reed Bunting	v s	6.2 ± 2.2 10.9 ± 3.9	8.0 ± 3.8 4.9 ± 1.5	open closed

Table 9. **Linear densities (birds per 10 km) of waterside bird species, as measured by WBBS transect methods, along canals with ("closed") and without ("open") a close season for fishing (only birds in 0-25m distance band included). Data collected by volunteer observers and by BTO staff are combined. Figures given are mean and standard error, across all stretches in each sample. For sample sizes see Table 6.**

Species	Birds per 10 km on "closed" canals	Birds per 10 km on "open" canals	Type with higher mean density
Little Grebe	0.3 ± 0.3	0.3 ± 0.3	closed
Great Crested Grebe	1.0 ± 0.6	1.3 ± 1.3	open
Mute Swan	10.5 ± 4.8	5.8 ± 1.4	closed
Greylag Goose	0.3 ± 0.2	0	closed
Canada Goose	15.2 ± 4.6	12.0 ± 4.5	closed
Egyptian Goose	0.1 ± 0.1	0	closed
Shelduck	0.2 ± 0.2	0.1 ± 0.1	closed
Mallard	49.9 ± 7.7	59.5 ± 7.5	open
Teal	0.1 ± 0.1	0	closed
Gadwall	0.3 ± 0.3	0	closed
Shoveler	0	0.1 ± 0.1	open
Mandarin Duck	0.2 ± 0.1	0.1 ± 0.1	closed
Pochard	0.1 ± 0.1	0	closed
Tufted Duck	1.8 ± 0.8	0.3 ± 0.2	closed
Goosander	0.2 ± 0.1	0	closed
Water Rail	0	0.2 ± 0.1	open
Moorhen	19.9 ± 3.6	16.8 ± 2.7	closed
Coot	10.7 ± 3.7	9.6 ± 3.0	closed
Oystercatcher	0	0.1 ± 0.1	open
Lapwing	0.1 ± 0.1	0.9 ± 0.4	open
Ringed Plover	0.1 ± 0.1	0	closed
Curlew	0.1 ± 0.1	0	closed
Common Sandpiper	0.5 ± 0.3	0.2 ± 0.1	closed
Snipe	0	0.1 ± 0.1	open

Kingfisher	0.9 ± 0.3	0.5 ± 0.2	closed
Sand Martin	0	1.0 ± 1.0	open
Yellow Wagtail	0.9 ± 0.6	0.1 ± 0.1	closed
Grey Wagtail	0.5 ± 0.2	0.8 ± 0.4	open
Pied Wagtail	1.6 ± 0.5	2.1 ± 0.6	open
Cetti's Warbler	0.1 ± 0.1	0.9 ± 0.9	open
Grasshopper Warbler	0.2 ± 0.2	0.2 ± 0.2	closed
Sedge Warbler	7.8 ± 2.0	5.7 ± 2.0	closed
Reed Warbler	6.6 ± 3.4	10.1 ± 5.0	open
Reed Bunting	5.8 ± 1.5	4.5 ± 1.5	closed

3.2 Correlations between WBBS bird counts and RHS data

A substantial number of significant correlations was found between the RHS habitat variables that had been selected and bird counts within 500-metre sections. These are tabulated in Table 10. It should be noted, however, that the correlative approach adopted here was only preliminary and that a full analysis of this aspect of the data was not part of the present project.

Many of the correlations found fit well with general ornithological knowledge. For example, reed-bed birds were all strongly associated with emergent reeds, sedges or rushes, and Mallard and Mute Swan were, as expected, the main urban species. A proportion of any set of significant correlations will inevitably be statistical artefacts, however, while others will be spurious in the sense that the real biological association will be with another unmeasured variable or set of variables.

No allowance was made in this analysis for the non-independence of transect sections. Water width, in particular, was likely to be very similar across all sections within a WBBS stretch; auto-correlation of this kind is likely to have exaggerated the significance of the correlations. Nevertheless, the strong relationships revealed by this analysis were taken as evidence that the RHS features listed should be taken account of in the more rigorous modelling approach that followed.

That so many links were found between RHS and WBBS data, despite the preliminary nature of the analysis, is encouraging for further investigation of this topic.

Table 10. **Summary of correlations between selected River Habitat Survey variables and bird counts within WBBS 500-metre sections. Species are ordered according to the strength of the correlation (* P<0.05, ** P<0.01, *** P<0.001).**

RHS variable	species correlated +vely	species correlated -vely
Water width (range 2.5-45 metres)	Sedge Warbler *** Shelduck *** Shoveler *** Cetti's Warbler *** Water Rail *** Reed Warbler *** Redshank *** Curlew *** Mute Swan ** Sand Martin ** Grasshopper Warbler * Great Crested Grebe * Reed Bunting *	Moorhen *** Mallard * Coot *
Number of spot-checks with emergent reeds/sedges/rushes (range 0-10)	Reed Warbler *** Cetti's Warbler *** Reed Bunting *** Sedge Warbler ** Yellow Wagtail ** Coot ** Curlew * Moorhen *	Grey Wagtail * Pochard * Lapwing *
Number of spot-checks with emergent broad-leaved herbs	Little Grebe ***	
Extent of trees (scored on each bank from 0=none to 6=continuous, summed across both banks: range 0-12)	Moorhen *** Grey Wagtail ** Reed Warbler **	Sedge Warbler ** Lapwing * Oystercatcher * Reed Bunting * Grasshopper Warbler * Great Crested Grebe * Little Grebe * Pied Wagtail *
Broadleaf/mixed woodland within 5m of banktop	Grey Wagtail * Coot *	Pied Wagtail * Reed Bunting *
Scrub within 5m of banktop	Shoveler ** Redshank * Tufted Duck * Lapwing * Shelduck *	Reed Warbler *

Tall herbs within 5m of banktop	Sedge Warbler *** Cetti's Warbler *** Great Crested Grebe ** Common Sandpiper ** Greylag Goose ** Reed Warbler * Reed Bunting * Shelduck *	
Rough pasture within 5m of banktop	Grasshopper Warbler *	
Improved grass within 5m of banktop	Yellow Wagtail *** Reed Bunting *** Curlew **	Coot ** Mallard *
Tilled land within 5m of banktop	Reed Warbler *** Moorhen * Sedge Warbler *	Pied Wagtail *
Urban/suburban land-use within 5m of banktop	Mallard *** Mute Swan ** Kingfisher ** Common Sandpiper * Pied Wagtail * Oystercatcher *	Reed Bunting *** Yellow Wagtail * Moorhen * Curlew * Sedge Warbler *

Note: land-use variables (within 5m of banktop) were scored present or absent for each bank at each of ten spot-checks, then summed across left and right banks (range 0-20).

3.3 Results of generalised linear modelling

Results from generalised linear modelling are presented in Table 11 for all those species for which data were adequate. Model fit was generally rather poor, owing to the variable nature of the bird count data.

Allowing for plot length, year, national grid eastings, national grid northings and altitude, the effects of fishing season were significant in the 1989-97 WBS data for only three species (Mallard, Sedge Warbler and Pied Wagtail), each in favour of "open" sites. In the separate analysis of WBBS data, national grid eastings and northings and eleven RHS habitat variables were taken into account. This analysis produced three more significant results, all for different species (Great Crested Grebe, Mandarin Duck and Kingfisher), and all in favour of "closed" sites. Chance effects are probably important for Great Crested Grebe and for Mandarin Duck, which both occurred on very few sites. Only Mandarin Duck, which has a very sparse and patchy distribution in Britain, retained a significant result after allowing for the number of tests made by applying the Bonferroni correction.

Table 11. **Results of generalised linear modelling of WBS and WBBS bird counts. Counts along WBS canal plots during 1989-97 were modelled against plot length, year, national grid eastings and northings, altitude and fishing season ("open" or "closed"), with allowance for auto-correlation between counts made at the same sites in different years. WBBS counts in 1998 were modelled against national grid eastings and northings, eleven RHS habitat variables (see Table 10) and fishing season. Poisson error terms and a log link function were used. Probabilities given are for the effect of fishing season on the counts of each species, after allowing for all other variables. The apparent direction of the effect is also indicated.**

Species	WBS 1989-97		WBBS 1998	
	Type with higher count	Uncorrected probability	Type with higher count	Uncorrected probability
Great Crested Grebe	closed	0.114	closed	0.006 **
Mute Swan	open	0.293	open	0.741
Canada Goose	open	0.417	open	0.712
Shelduck	-	-	closed	0.990
Mallard	open	0.011 *	open	0.099
Mandarin Duck	-	-	closed	0.0002 ***
Tufted Duck	open	0.909	closed	0.376
Moorhen	open	0.570	open	0.322
Coot	open	0.467	open	0.615
Lapwing	open	0.094	closed	0.483
Curlew	closed	0.159	-	-
Redshank	open	0.734	-	-
Kingfisher	closed	0.981	closed	0.044 *
Yellow Wagtail	closed	0.236	-	-
Grey Wagtail	open	0.245	-	-
Pied Wagtail	open	0.017 *	open	0.352
Sedge Warbler	open	0.036 *	closed	0.441
Reed Warbler	open	0.297	open	0.601
Whitethroat	closed	0.315	-	-
Reed Bunting	open	0.384	open	0.342

4 DISCUSSION

4.1 The value of RHS data for interpreting breeding-season counts of waterside birds

There is growing evidence of the value of RHS data for the interpretation and prediction of bird counts along rivers (Buckton & Ormerod 1997, Brewin *et al.* 1998). While this question is not central to the present project, the correlations presented in Table 10 provide evidence that RHS data are likely to be of similar value for canals, and for WBBS plots more generally. A more rigorous analysis should be undertaken of this aspect of the present data, taking account of the auto-correlation between adjacent canal sections. It would be of value to extend the initial approach taken here to develop and optimise predictive models and to explore the value of ordination analysis.

4.2 Do breeding bird numbers differ along canals with and without a fishing close season?

Both aspects of the present survey found that there were some differences in bird density between "closed" and "open" canals, but that these were mostly small and could be accounted for by a combination of the differences in geographical location between the two samples and the structural nature of the habitat. The WBBS analysis concentrated on waterside species, even though data had been collected for all birds, because these were the ones for which the results would have the greatest significance biologically. WBS data were available only for waterside species.

Significant effects of fishing season, after allowing for other factors, were found in six species, of which three were more abundant where there was no close season and three where a close season was in force. Non-significant results were similarly split between the two classes of canal. For no species were significant results obtained from both sets of data, although it was intriguing, and worthy of further analysis, that agreement between the two analyses in the direction of the effect was greater than would be expected by chance; there were eight species where both WBS and WBBS data found higher densities on "open" canals, after allowing for other factors, two species where both found higher densities on "closed" canals, and only three where the result from the two sets of data were different (Table 11).

It is perhaps likely that apparent effects of fishing season that remain could in fact be accounted for by other environmental factors that were not included in the models, but such further testing could not have altered the main conclusion of this report.

It can be concluded that neither the historical WBS data nor the newly collected WBBS counts provide evidence that counts of breeding birds differ systematically between canals with and without a close season for fishing.

It remains to be investigated, however, whether the breeding productivity of waterbirds may be affected by the fishing regime. It is increasingly apparent in ecological studies of birds that some sections of a species' range may have a greater rate of productivity than of mortality, and thus act as "sources" for the population, while in others ("sinks") the reverse may be true. Bird

numbers in "sinks" may be constantly replenished from "sources", such that no difference in breeding density may be apparent. More detailed study would be needed to discover whether the status of canals as "sources" or "sinks" is related to fishing disturbance. Such work would need to concentrate on nest-finding and on following egg and chick survival to fledging, at a range of sites with and without a close season, in relation to the fishing and other disturbance observed at each study site.

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