River Habitat Survey and Waterways Breeding Bird Survey 1998–2000: final report

R&D Technical Report W1-043
BTO Research Report 291

Research Collaborator & Authors:

John H Marchant, David G Noble, David I Leech & Steve N Freeman

BTO, The Nunnery, Thetford, Norfolk, IP24 2PU

Registered Charity No. 216652

Publishing Organisation:

Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS32 4UD

Tel: 01454 624400 Fax 01454 624409

ISBN: 1844320243

Dissemination Status
Internal: Released to Regions
External: Released to Public Domain

Statement of Use
This report is intended for Environment Agency staff involved with Conservation and Ecology for information.

Research Collaborator & Author
This document was produced under R&D Project W1-043 by:
BTO, The Nunnery, Thetford, Norfolk, IP24 2PU

Environment Agency's Project Manager
The Environment Agency's Project Manager for R&D Project W1-043 was:
Geraldine Daly, Head Office Conservation, Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD

This report is also known as BTO Research Report 291

Recommended citation: Marchant, J.H., D.G. Noble, D.I. Leech & S.N. Freeman. 2002. *River Habitat Survey and Waterways Breeding Bird Survey 1998–2000: final report.* R&D Technical Report W1-043/TR, BTO Research Report 291.

CONTENTS

LIST OF TABLES AND FIGURES

Tables

Figures

EXECUTIVE SUMMARY

1 The BTO began pilot work for the Waterways Breeding Bird Survey (WBBS) in 1998. The rationale for this project is described. Work in 1998 (Phase 1) demonstrated that the method devised for WBBS was popular with observers and provided data that would be suitable either for a long-term national monitoring scheme or for short-term site surveys. Links were demonstrated with the Environment Agency's River Habitat Survey (RHS), and topics for further study were identified.

2 The Environment Agency funded further work on WBBS in 1999 and 2000 (Phase 2). The main aims of this work have been to investigate the potential of WBBS for monitoring population change, in relation to the Waterways Bird Survey (WBS), and to collect data to help refine the links between WBBS bird counts and RHS habitat variables.

3 Progress to 1999 has been reported separately. In 2000, 172 surveys were conducted, of which 106 were from the random sample and 61 were WBS plots, which had been selected by their volunteer observers and were non-random. In all, WBBS had surveyed 263 different waterway stretches. Results for birds and mammals in 2000 are summarised, confirming Chaffinch as the most widespread bird species along waterways, and Mallard as the most abundant waterbird. Otters were detected on 13% of stretches and Water Voles on 12%.

4 Of the sites surveyed in 1999, 108 had also been surveyed during 1998. In 2000, there were 148 repeat surveys from 1999, including 90 for randomly selected stretches and 54 for non-random WBS sites. These repeat surveys allow the estimation of population change. Comparisons between year-to-year population changes, derived from the random and non-random WBBS samples, the full WBS, and the subset of WBS plots on which WBBS was also conducted, suggest that estimates of population change were poorly consistent between methods, even within the same sample of plots. The variability of the data, and the short run of years preclude detailed analysis.

5 The Environment Agency commissioned accredited surveyors to collect RHS data on sites already covered by WBBS as part of the random sample. These were supplied on disc to BTO in August 2001, and were matched to 605 WBBS 500-metre sections.

6 A further preliminary analysis of RHS and WBBS data was undertaken. This confirmed several relationships identified from an earlier study and extended the results to cover a much larger sample, which for the first time was randomly selected and fully inclusive of waterway types. This analysis confirmed that there are many strong correlations between WBBS bird counts and RHS variables. Although there are strong inter-correlations between the RHS variables, many of the links with birds are likely to have a biological basis. In particular, two main groups of waterbird species emerged, one associated with well-vegetated lowlands and another characteristic of rockier upland rivers. Within these groups, correlations for individual species were well matched to known features of their ecology. Further analysis is needed of this large and complex data set. The indications are strong, however, that RHS will have a high potential for predicting bird communities, and that RHS is a useful tool for interpreting bird data collected by WBBS.

1 INTRODUCTION

1.1 The Waterways Bird Survey

Since 1974, the BTO has been conducting censuses alongside linear waterways, both rivers and canals throughout the United Kingdom with the aim of monitoring changes in bird populations in these important, yet vulnerable, habitats. The Waterways Bird Survey (WBS) collects data concerning both population changes and the location of breeding territories in relation to physical features of the waterway environment. These data can be used to investigate the ways in which breeding birds use river and canal habitats at a variety of spatial and temporal scales. The primary role of the WBS has been to record population changes among species poorly represented in the BTO's Common Birds Census (CBC). Carter (1989), Marchant *et al.* (1990) and Marchant & Balmer (1994) have provided overviews of the WBS and its results.

By 2000, the WBS had completed 27 seasons of mapping fieldwork and recorded much valuable information concerning population changes and relationships between bird abundance and habitat (e.g. Rushton *et al.* 1994, Marchant & Beaven 2000). Surveys continued in 2001 but at a much-reduced level because of Foot and Mouth Disease and the consequent restrictions on access to the countryside (Marchant *et al.* 2002).

To fulfil their statutory duties for wildlife conservation, the Environment Agency requires good-quality information concerning the distribution and numbers of breeding birds along waterways, and concerning the way in which bird populations relate to the habitat available. WBS, however, has not been as useful to the Agency and the bodies that preceded it as BTO had expected. Fewer than 500 sites have been covered in total, and the survey has proved quite time-consuming for BTO staff (although less so in recent years because territory totals are calculated by the volunteers themselves). In particular, WBS is not geared to the Agency's River Habitat Survey (RHS) that now underpins most assessments of conservation value on waterways throughout the UK. WBS receives no dedicated funding, and its future is uncertain.

1.2 Use of transect methods to monitor the UK's breeding birds

A major development in monitoring breeding birds since the start of WBS has been the introduction of the BTO/RSPB/JNCC Breeding Bird Survey (BBS) in 1994 (e.g. BTO 2000, Noble *et al.* 2001). In this new scheme, volunteer observers make two counting visits per breeding season to standardised transect routes through 1-km squares selected randomly from the national grid. Repeat surveys provide information concerning population change between years. Over 2250 squares were surveyed in 2000. Compared with mapping surveys, this method has led to substantial improvements in the efficiency of data processing, input and analysis. The BBS method has proved popular and enjoyable for volunteers, and the BBS is now well established as an ongoing monitoring scheme.

As from 2001, BBS has taken over the task of monitoring the large-scale population changes of the more abundant and widespread breeding bird species in the UK from CBC. This will bring improvements in the representativeness of the results and an increase in the range of species that can be monitored. For birds that are waterways specialists and are currently indexed by WBS, however, our preliminary studies have shown that BBS alone cannot be a full replacement for

the WBS's monitoring function. Marchant *et al.* (1996) concluded that, if BBS were to be the sole replacement for WBS:

- *the precision of monitoring would be generally lower and fewer waterbird species would therefore be monitored;*
- *there would not be an adequate way of distinguishing population changes of waterbirds along waterways from those occurring in other wetland habitats;*
- *monitoring samples would be inadequate to provide results at regional or catchment scales.*

There are nine species that would be monitored better by WBS than BBS, based on a projected annual sample of 3000 BBS squares: these are, ordered from greatest to least difference, Kingfisher, Goosander, Dipper, Common Sandpiper, Little Grebe, Sand Martin, Grey Wagtail, Mute Swan and Reed Warbler (Marchant *et al*. 1996). For waterside specialists like these, it is naturally more efficient to concentrate fieldwork alongside waterways than to use the area-based (kilometre-square) sampling units of BBS.

A priority of the Environment Agency is to link bird surveys to its River Habitat Survey (Raven *et al.* 1997), and thus increase the power of its assessments of waterway conservation value. Since RHS collects data using transects, this aim would be best achieved by transect methods of bird censusing, employed where possible in parallel with RHS sections (Marchant *et al.* 1996, Langston *et al.* 1997). These authors suggested that WBS could be modified to meet this objective by remodelling it to use transect methods like those of BBS, and demonstrated that field methods along waterways could be switched successfully from territory mapping to line transects that could be much more efficient.

All the aims of monitoring breeding birds along waterways could be met by a scheme that both:

! *supplemented BBS data with counts from rivers and canals, thus maintaining or expanding the level of bird population monitoring currently available through BBS and WBS and satisfying the needs of organisations with specific interests in bird monitoring, such as JNCC and RSPB; and*
! *provided bird and bird–habitat data, relevant to nature conservation along waterways, that would fulfil the requirements of the Environment Agency, and its sister organisations in Scotland and Northern Ireland, that have responsibilities specific to linear waters.*

1.3 The Waterways Breeding Bird Survey (Phase 1)

In pursuit of these objectives, the BTO, with financial support from the Environment Agency and from several water companies, launched the Waterways Breeding Bird Survey (WBBS) as a pilot scheme in 1998. Specific aims of Phase 1 were to test:

! *methods of random selection of waterway stretches;*
! *to what extent random coverage of waterway stretches can be achieved;*
! *what modifications are required to BBS methods when used along waterways;* and
! *whether the data collected by BBS-style methods would be sufficient to meet the aims of an ongoing national survey*.

To meet the last of these objectives, it was estimated that coverage of about 100 WBBS stretches would provide sufficient data, at least for the single season of investigation planned for 1998.

Minimal modifications were made to the BBS transect method, aside from directing observers to cover waterways. The survey required two counting visits during the breeding season, during which all birds seen or heard were recorded. Transect sections were each 500 metres long, thus matching RHS section lengths. Separate totals of birds seen or heard were produced for each section and for three distance categories, plus an 'in-flight' category. Mammal data were also collected. The WBBS has considerable benefits over the existing WBS due to the relative simplicity of the methods, and to the efficient use of observers' and analysts' time.

The survey received a very positive response from volunteer organisers and counters, and all aspects of the pilot survey worked extremely well (Marchant & Gregory 1999). A total of 103 stretches of waterway comprising 600 500-metre sections were surveyed during the 1998 pilot survey in time for inclusion in the report, in line with our target figure.

A further element to the 1998 WBBS pilot work was introduced at the request of the Environment Agency, who required new data concerning comparative breeding bird numbers on canals with and without a close season for coarse angling. A further 61 canal stretches, selected specifically to investigate the possible effects on breeding bird numbers of a close season for coarse angling, were also surveyed in 1998 using WBBS methods; the results of this study were reported separately (Marchant *et al.* 1999). These plots were selected by hand, with a view to creating a comparable sample of sites with and without a close season. Stretches of canal that had already been selected randomly for coverage were also included in this second sample; five stretches were common to both samples.

Some stretches in both samples were existing WBS plots. This arose by chance in three cases, as the random sampling picked out sites already being studied by WBS observers, and by design in the sample picked for the fishing-season study. In total, 18 WBBS stretches were also surveyed using the WBS mapping method in 1998.

The pilot survey demonstrated that WBBS could be used to collect extensive data for waterbirds, for other bird species, for mammals and for waterside habitats. Waterbirds were located on considerably higher proportions of WBBS stretches than BBS squares, confirming the value of specialised waterside transects in supplementing BBS monitoring. Further conclusions of the pilot work in 1998 were as follows (Marchant & Gregory 1999, Marchant *et al.* 1999).

- *Together, BBS and WBBS would provide more precise and more representative data concerning waterbird population changes than are currently available through WBS and CBC.*
- *As well as supplementing overall population monitoring, WBBS could be used to calculate broad-scale bird population trends that are specific to the waterway habitat and are fully representative of waterways nationally; this would cover a wider range of bird species than are presently monitored by the mapping WBS. WBBS could provide information concerning bird population trends at smaller scales such as regions and catchments as well as at a national scale; such data would be of value to the Agency and to other bodies with duties to manage and conserve waterways.*
- *Developing a transect bird census method for waterways alongside WBS mapping would provide an alternative standard method for one-off or short-term surveys, for example for site appraisal before or after management operations.*

! *Initial work showed that there were promising links between WBBS and RHS data (Table 6). This result was based on RHS surveys from the hand-selected canal stretches, however, and not on a random sample.*

Several elements of WBBS requiring further fieldwork were identified by the work in 1998 and plans were laid to address them during the 1999 and 2000 breeding seasons.

1.4 Aims of WBBS in 1999–2000 (Phase 2)

Repeat WBBS surveys allow the results to be investigated not only within but also between years. Continuation of WBBS for a second and a third breeding season in Phase 2 therefore adds a new dimension to the pilot surveys.

The main aims of Phase 2 have been:

! *to investigate the value of WBBS for measuring population change, in comparison with the monitoring results of WBS;* and
! *to prepare for a more thorough investigation of the links between WBBS counts and RHS habitat data, using a large random selection of waterway stretches.*

By the end of Phase 2, we therefore aimed to have a large sample of random WBBS stretches covered for two or three successive seasons. These would provide estimates of year-to-year population change that would be compared with the data provided independently by WBS. WBS observers using both methods on their plots would provide special insight into the WBS–WBBS comparison.

The Agency and BTO aimed to obtain both RHS and WBBS data, even if only for one year, for a high proportion of the random stretches. Directly comparable data from these two surveys, and more sophisticated modelling techniques applied to their analysis, should in the longer term allow WBBS to reach its full potential for waterway management, and test the value of RHS as a predictor of breeding bird numbers.

The eventual aims of linking RHS and WBBS data are provisionally as follows (S.J. Ormerod, pers. comm.):

! *to enable the development of models, applicable throughout the UK, that predict the presence and absence of river birds from RHS data;*
! *to illustrate the value of modelling the distribution of river birds for their use as biological indicators;*
! *to use this example to demonstrate a robust, generic protocol for presence–absence modelling that will be transportable to other river organisms such as plants, invertebrates, fish and mammals;* and
! *to use this example to demonstrate a robust, appropriate and transportable protocol for testing model accuracy in presence–absence prediction.*

Detailed analyses of these data fall beyond the scope of the present project, however.

Progress to 1999 has been reported separately (Marchant & Noble 2000). The present report incorporates and updates results for that year and covers results and analyses for the years 1998-2000.

1.5 Future developments: Phase 3, 2001–04

Following the success of WBBS during its first three field seasons, 1998-2000, fieldwork is now funded by the Agency for a further three seasons of fieldwork from 2001 to 2003. We plan to extend the comparisons of WBBS with WBS and BBS as a method of monitoring bird population change over a longer period of years, and to expand the WBBS sample, with a view to WBBS becoming an ongoing survey that could take over the monitoring functions of WBS.

The first interim report on Phase 3, covering progress to 2001, is already available. The start of the planned expansion of the survey was postponed from 2001 to 2002, however, because of Foot and Mouth Disease and the consequent restrictions on access to the countryside that applied for much of 2001 (Marchant *et al*. 2002). This work will be fully reported in spring 2004.

2 METHODS

2.1 Methods of the Waterways Bird Survey (WBS)

2.1.1 WBS fieldwork methods

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. Details of the habitats available to the birds are also mapped. Plots are chosen by the observers themselves, under guidance from BTO staff, and are stretches of waterway that are typically 4–5 kilometres long and of relatively easy access, of which at least one bank can be walked. Observers are asked to make nine visits to their site each breeding season. WBS coverage is restricted to waterside specialist birds such as grebes, ducks, geese, swans, waders, and reedbed passerines. WBS procedures have been described in full by Taylor (1982), and guidelines for assessing territory numbers were expanded by Marchant (1994).

2.1.2 Calculation of year-to-year population change from WBS data

The units of WBS mapping results are apparently occupied territories, whereas for WBBS and BBS they are the numbers of birds counted. Long-term monitoring from WBS data is possible for around 24 species that occur on at least 15 or so plots in each year, where the number of territories can be modelled as a function of year and site. Year-to-year changes identified from WBS data are typically presented using a ratio-estimator method that simply pairs the year-1 and year-2 data for those plots that were surveyed in both years (e.g. Marchant & Beaven 2000, Marchant 2001). This approach is taken here when considering population change between 1998 and 2000.

2.2 Methods of the Waterways Breeding Bird Survey (WBBS)

2.2.1 Selection of sites for coverage

A major innovation of WBBS is its use of random waterway sites for bird surveys. This sampling strategy allows WBBS results to be treated as representative of UK waterways generally.

An ideal way of selecting random lengths of a linear feature, such as waterways, would be from a complete catalogue that was either fully digitised or contained grid references of reference points at regular intervals. Complete surveys of waterways have been undertaken in some Agency regions, and computerised catalogues have been created, such as the Anglian Region's Rivers Environmental Database (REDs), but there has been no national coordination of such work. Digitised data on map features including waterways are held by the Ordnance Survey (OS), but this database has been too expensive for any conservation-related body to obtain. As yet, therefore, there is no complete national list of waterway sections that is available for our use.

In the absence of linearly based data to work from, an alternative approach was taken. National grid squares were therefore selected at random, discarding those without a waterway running through them, and seeking coverage of the waterway stretch inside or adjacent to the selected square.

The tetrad (2x2 km) was selected as the most appropriate grid-square size since, after a trial run, it emerged that too high a proportion of 1-km squares held no waterway. Larger squares (5x5 or 10x10 km) frequently held more than one waterway, and so raised questions about which to select from within the square. RHS reference sites have been chosen from 10-km squares, however, using the protocol of taking the stretch closest to a predetermined point within the square.

A clear definition of the water bodies that formed the population being sampled was required. The linear waters that were to be studied could have included rivers, canals, stretches that could be defined as both river and canal, and various kinds of ditches and drains. For rivers, a policy was needed on whether headwaters should be excluded and how this could be achieved, and also on whether broad or tidal stretches should be included. For the purpose of the WBBS pilot, a waterway was defined as any double blue line, with shaded in-fill, on the OS 1:25,000 Pathfinder map series. Single blue lines, typically minor headwaters and drainage ditches, and all non-linear water features, were ignored. Enquiries with OS revealed that double blue lines with 'water stipple' are used on this scale only for features that are 6.5 metres or more wide (W. Debeugny, pers. comm.). Rivers were considered to finish at the normal tidal limit as marked as 'NTL' on the OS maps; no width limit was applied.

Stratification, for example by waterway type, RHS data, water quality, waterbird density or observer density, may be applied to WBBS in the future, either to reduce the variance of selected results or to make best use of the available manpower. No stratification of the sample was required to meet the aims of survey's initial phases.

For each selected random waterway, a map was prepared showing the boundaries of the random tetrad and the selected waterway. The waterway was picked out with a highlighter pen, typically for several km from the tetrad boundary, in both directions. These maps were sorted by BTO region and sent to the relevant BTO RR, whose job it was to match each site with an observer.

Start and end points of the survey stretch, within the highlighted length of waterway, 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;* and
- *the observer's preference for the number of sections to be covered (maximum ten).*

These concessions were designed to ensure that access problems could be overcome in the majority of cases, and a survey route set up that could be used on a long-term basis.

2.2.2 WBBS fieldwork methods

The BBS method had already proved to be enjoyable, popular with observers, and well fitted to its purpose. It was the transfer of this technique to waterways that was being tested. Modifications to BBS procedures were therefore kept to a minimum.

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 2000, Noble *et al.* 2001). The transect route is divided into up to ten sections of fixed length. 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.

WBBS instructions and recording forms are based heavily on those designed for BBS. Forms for 1998 and 1999 are each appended to the reports for those seasons (Marchant & Gregory 1999, Marchant & Noble 2000). Minor details of the design of forms were altered for 2000 but these do not affect the field methods of WBBS, which have been kept constant.

The methods for WBBS differ from those of BBS in that:

- *routes within sites follow the waterway rather than a predetermined pattern based on the national grid;*
- *the sections composing each transect stretch are each 500 metres, to match RHS, not 200 metres as in BBS;*
- *transects are not fixed at 2 km, as in BBS, but are of variable length, with a maximum of 5 km (ten 500-metre sections);* and
- *habitat recording is extended from the BBS standard to allow a third level of information to be recorded concerning the waterway itself.*

Other aspects of fieldwork and analysis are identical.

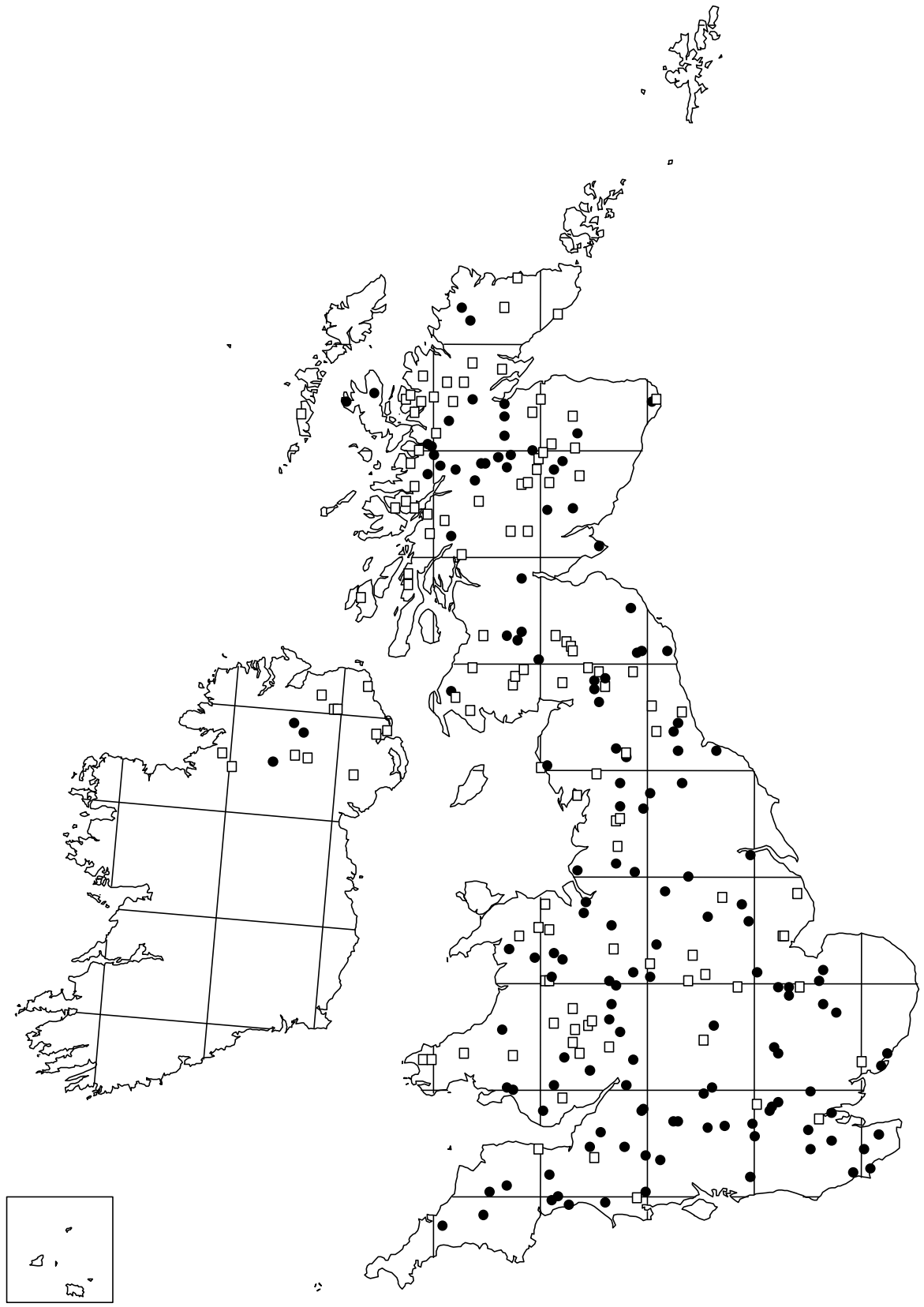
As under BBS, mammals and signs of mammals were noted on each counting visit. For each species of wild mammal detected, either presence or a pair of counts (one early in the season and one late) was recorded. WBBS observers coded the main features of up to three habitat types per 500-metre section of 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.

WBBS requires only two visits to count birds, compared to WBS's nine, and so is much quicker and simpler for observers. WBBS's transect data require relatively little processing and so there are gains in efficiency for analysts, too. Importantly, its random sampling design ensures that the results are representative of the waterway habitat at a national scale.

2.2.3 Application of WBBS methods in 1999–2000 (Phase 2)

The 201 random stretches selected for survey in 1998 were kept in the sample, and supplemented with a further 63, also selected randomly on the same basis. Many had been excluded from the 1998 sample because no regional organiser had been available but, in 1999, the sample was expanded to include stretches from all the BTO's UK regions. The 264 random stretches therefore represent a sample drawn from the whole of the UK (Figure 1).

Figure 1. **Distribution of the 263 random WBBS stretches selected for coverage. The 144 stretches surveyed at least once during 1998–2000 are shown as black circles, and those not surveyed are shown as open squares.**



RRs were asked to find observers to cover these sites in both 1999 and 2000 and to distribute packs of survey forms. No coverage of additional sites was requested.

WBBS survey packs were distributed from BTO headquarters to all current WBS observers with a request to contribute to both surveys in 1999 and 2000.

2.2.4 Calculation of WBBS results

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 'distance' categories (the three distance bands, and birds in flight). Being consecutive, the 500-metre sections that compose each stretch cannot be treated as independent and it is the whole stretch that is the WBBS's sampling unit. Taking the mean rather than the sum of the data from each section provides the most useful summary for each WBBS stretch, since it allows for those few cases where the number of transect sections that are covered changes between years.

Mean counts per unit length for each species, stretch and year were calculated as follows. First, counts were summed across all four distance categories. Missing data were changed to explicit zero counts in every case where a species recorded elsewhere in that year's data set was not found on a particular transect section. A mean count was then calculated across the sections that constituted each stretch; for each species and stretch, two estimates of bird density (number per 500 metres), one for the early and one for the late visit, were therefore obtained. Finally, the lower of these figures was discarded. The remaining figure, referring to an average 500-metre section, was multiplied by 20 to produce an estimate, for that stretch and year, of the number of birds per 10 km.

To calculate change measures between two consecutive years, ratio estimators were derived from all stretches covered in the two years in question. Double zeros were excluded, but the monitoring sample includes some stretches where a zero was recorded in one of the years.

2.3 River Habitat Survey data collection

2.3.1 RHS surveys of WBBS sites

During 1998–2000, the Environment Agency commissioned accredited RHS surveyors to collect RHS data from the sites selected randomly for WBBS for which bird data had been obtained. Grid references of the start and finish points of each monitored stretch, and the number of 500-metre sections, were passed from BTO on to the RHS field teams as they became available.

These RHS data were added to the complete database in the standard way, with added database codings of either 'BTO_WBBS' or 'extra'.

2.3.2 Matching of RHS and WBBS sites

Version 3.2 of the RHS database on CD, dated October 2000, was received by BTO at the end of August 2001. This contained information collected from all surveys conducted up to mid August 2000.

Using the six-figure grid references attached to each RHS site, and the maps of 500-metre sections supplied by WBBS observers, a table was constructed in which the relevant WBBS section was matched to its equivalent RHS survey.

Matching was rarely precise, however. There were many cases where RHS surveyors had carried out a different number of 500-metre surveys from the number of WBBS sections with which they had been supplied. It is likely that the main reason for this was the different way in which RHS and WBBS surveyors are asked to define 500-metre sections. WBBS observers, like BBS participants, mark up a map beforehand to show the section boundaries, and then locate those boundaries in the field, with reference to the map. RHS surveyors, on the other hand, are asked to pace out the 500 metres along the side of the waterway. On this basis, it is likely that RHS sections would be slightly shorter than the WBBS ones, because in WBBS surveys any deviations of the waterside path too minor to appear on the Pathfinder map would be ignored.

Overlain on this, however, it was clear also that both sets of observers had made errors in map reading. Sometimes, for example, two RHS grid references that were presumably from consecutive surveys both fell within a single WBBS section. In other cases, WBBS surveys marked on the maps supplied by the observer were clearly longer or shorter than 500 metres. In all such cases of obvious discrepancy, best judgements were made about the errors likely to have been committed and concerning which of the candidate surveys would make the best match of the two sets of data. The aim of matching was therefore to find the RHS survey likely to have the longest overlap with each random WBBS section.

Future problems of this kind could be minimised by ensuring that RHS fieldworkers carried a map of the WBBS sections with them, and recorded WBBS square and section number as part of the RHS database.

In all, of 654 RHS sections coded as either 'BTO_WBBS' or 'extra', a successful match to a WBBS section was made for 605. These 605 matched WBBS sections were drawn from the total of 889 WBBS sections covered during 1998–2000 as part of the random sample.

2.3.3 Extraction and manipulation of RHS data for matched sites

RHS data for those sites that had been matched successfully with WBBS sites (those coded as 'BTO_WBBS' or 'extra') were extracted from the full RHS database (Microsoft Access). Within each 500-metre RHS survey section, data concerning channel features, channel substrate, and channel and bank vegetation type and structure were collected at 50-metre intervals, termed 'spot checks', as well as the 'sweep-up' variables that related to the whole 500-metre section. Spot-check and sweep-up variables sometimes measured the same thing. As the full RHS data set contains several hundred variables, many of them non-independent, it was necessary to reduce the number used in the final analysis.

Several steps were therefore taken to reduce the data set:

'Sweep-up' variables

1. 119 'sweep-up' variables were removed as they were judged to be of relatively little ecological importance to waterbirds. A list of these variables can be found in Appendix 3a.
2. A further 20 'sweep-up' variables were removed due to a predominance of missing values or due to all values given being equal (Appendix 3a).

3. i) If data were available for the left and right riverbanks separately, these data were combined to give a single variable. This was achieved by using the higher of the values available from the two banks (14 variables – see Appendix 3a). If a variable was scored as 'Present' on the left bank, but 'Extensive' on the right, then the combined variable was scored as 'Extensive'; an equivalent approach was taken for numeric variables.

   E.g. *If* Left = Present *and* Right = Extensive, *then* Combined = Extensive
   If Left = 4 *and* Right = 3, *then* Combined = 4

   ii) The single exception to this procedure concerned the variable indicating the extent of bank reinforcement. Here, the minimum value was used as the combined variable. Hence, if the left bank was scored as reinforcement 'Present', and the right bank as reinforcement 'Absent', the combined variable would be scored as 'Absent'. This would indicate that there was still some un-reinforced bank present on this stretch of waterway. It is the extent of un-reinforced, and not reinforced, bank that likely to be the ecologically important variable in terms of controlling the abundance of the majority of riparian bird species (the exception potentially being those species for which reinforcements may provide additional nesting cavities.)

   E.g. *If* Left = Present *and* Right = Absent, *then* Combined = Absent

4. For specific categorical variables, if the total number of 'sweep-up' sites scored as 'Extensive' amounted to fewer than 10% of the total number of 'sweep-up' sites contained in the whole dataset, the 'Extensive' category was amalgamated with the 'Present' category, such that this variable could only be scored as 'Present' or 'Absent'. 'Present' and 'Extensive' categories were also amalgamated for those variables where fewer than 10% of 'sweep-up' sites were scored as 'Present'.

5. Variables that were thought likely to be ecologically similar in respect to the abundance of riparian bird species (e.g. the extent of cascades and the extent of rapids) were also amalgamated into a single variable (e.g. fast flowing disturbed water). Details of these amalgamations are given in Appendix 3a. In all cases, the maximum value for the two variables was chosen as the amalgamated value (see 3i above).

   E.g. *If* Cascades = Present *and* Rapids = Absent, *then* Fast flowing disturbed water = Present

6. Any variable with two potential categories - 'Present' and 'Absent' – that was scored as 'Present' at fewer than 10% of sites was removed from the dataset.

'Spot-check' variables

1. 13 'spot-check' variables were removed from the analysis, either because of a lack of ecological relevance or due to the fact that 'sweep-up' variables containing similar information were already being used in the analysis (Appendix 3b).

2. 'Spot-check' variables were converted to 'sweep-up' variables by scoring each category (e.g. 'Extensive', 'Present', 'Absent', 'Rock substrate', 'Sandy substrate', etc) according to the proportion of spot-check sites allocated to this category at the level of the site. If, for example, 'Linear-leaved submerged vegetation' was recorded as present at 3 of the

10 ‘spot-checks’ along a particular waterway section, the variable ‘Linear-leaved submerged vegetation present’ was created and scored as 0.3 for that stretch of waterway. Features measured on both sides of the waterway were given as a proportion of 20, as two measurements were made at each of the 10 ‘spot-checks’.

3. If fewer than 10% of sites gave a value of greater than zero for the ‘feature present’ variables created (e.g. Linear-leaved submerged vegetation present), these variables were combined with the appropriate ‘feature extensive’ variable created (e.g. Linear-leaved submerged vegetation extensive) by summing the two values to give the proportion of the site at which the feature was either present or extensive (Overall presence of linear-leaved submerged vegetation). If the newly created ‘Overall presence’ variable still gave a value of greater than zero at fewer than 10% of sites it was removed from the data set.

   If fewer than 10% of sites gave a value of greater than 10% for continuous variables (e.g. rock channel substrate, sandy channel substrate) created in Step 2 that were not divided into present and extensive variables, the variable was removed from the data set.

4. Ecologically similar variables (e.g. Floating-leaved and Free-floating vegetation present) were amalgamated by creating a variable (e.g. Floating vegetation present) that indicated the proportion of sites at which either one or both of the variables was scored as present.

   E.g. If Floating-leaved vegetation was present at 2 of the 10 ‘spot-checks’, and Free-floating vegetation was present at 2 of the 10 ‘spot-checks’, and both were present at a further 3 of the 10 ‘spot-checks’, then the new variable (Floating vegetation present) would be scored as 7/10 = 0.7 for that site.

A full list of the variables contained in the final RHS dataset used in the analysis with WBBS data reported in section 3.5 can be found in Appendix 2. Appendix 3 contains those variables removed from the analysis, plus details of the manipulations of those variables used.

2.3.4 Methods of comparing bird counts and RHS habitat features

The analysis of WBBS data was originally restricted to those species recorded by the WBS, and therefore excluded the predominantly terrestrial species that were recorded during survey visits (e.g. Blackbird and Wren). This data set was further reduced to exclude those species that were recorded as present in fewer than 40 (7% of) RHS sections. A full list of the remaining 19 waterbird species, for which abundance data were analysed with respect to RHS data, is given in Appendix 2b.

The bird-count variable chosen for analysis alongside RHS data, for each 500-metre section, was the higher of the two sums (from the early and late survey visits respectively) of the counts in all categories (distance categories 1–3 and birds in flight) (see Section 2.2.4). This figure was summed across all years in which WBBS data were available, and then divided by the number of years’ data contributing to this total to give the average count over the period 1998–2000. As the RHS data can be taken to apply to any year, at least within the short period that WBBS has been running, the date of RHS survey was not considered relevant to the analysis.

The relationship between species abundance, as measured by the WBBS, and each of the 47 habitat variables in the final RHS dataset was analysed separately using the GENMOD procedure in SAS 8.0, specifying a Poisson distribution for the dependent variable. In order to control for

the increased probability of finding significant relationships between variables, due to the large number of individual tests performed on each dependent variable (N = 47), a Bonferroni correction was applied to the results.

Data collected from consecutive sections surveyed along the same watercourse may not be statistically independent. While this preliminary analysis has assumed that all sections are independent, it may be necessary to control for such non-independence in subsequent, more detailed multivariate analyses, for example by using nesting techniques.

3 RESULTS

3.1 Coverage achieved by WBBS in 1998–2000

The numbers of WBBS stretches surveyed are shown in Table 1. As each stretch is composed of 1–10 500-metre sections, the total numbers of these sections are approximately six times higher than the numbers tabulated. Numbers of stretches may not be fully known yet, as some observers may not have submitted their forms in time to be included in this analysis. Any data received late will be included in future analyses.

Table 1. Totals of WBBS stretches surveyed in 1998–2000.

Reason for survey	1998	1999	2000	Surveyed at least once
Random stretches	107	116	106	144
For comparison with WBS data	15	64	61	72
Other non-random stretches	46	4	5	47
TOTAL	168	184	172	263

Of the 263 stretches that had been selected randomly, 107 were surveyed in 1998, 116 in 1999 and 106 in 2000 (Table 1).

WBS observers responded well to the request for WBBS coverage of their sites in Phase 2. Other non-random stretches surveyed, and WBS plots surveyed in 1998, were mainly those selected for the study of canal fishing seasons. A handful of stretches for which data had not been requested in Phase 2 were nonetheless surveyed in both 1999 and 2000; these data have been input into the database but are not included in the present analyses.

In addition, BTO observers conducted mapping surveys on 121 WBS plots in 1998, 105 plots in 1999 and 97 plots in 2000.

Figure 1 demonstrates the wide geographical scatter of the 263 randomly selected plots, but also indicates the absence of monitored stretches in some parts of the UK. The pattern of distribution follows from the area-based method of selection, which, as the density of river courses in a catchment is greatest in the upper reaches, is more likely to score a hit with random tetrads that lie close to the watershed. Few stretches were selected in coastal regions and there were concentrations in some areas of higher ground, for example the Grampians, Southern Uplands and Welsh Marches. Eastern East Anglia, where river courses are few and well scattered, was not represented in the sample as, by chance, none of the tetrads selected there contained a waterway.

Only 144 (55%) of the selected stretches have been covered and it is therefore possible that there was subjectivity in plot selection, for example if observers' choice of stretches to cover were related to habitat or to the number of birds that they expected to find. There is no evidence, however, that this was likely to be the case. Clumping of stretches covered, within the sample selected, was more likely to stem from:

! *regional variation in the number of observers available to participate;* **and**

! *regional variation, due largely to topographical factors influencing the accessibility of waterways.*

A full list of stretches covered is given in Appendix 1.

A habitat form accompanies each WBBS return (see examples in Marchant & Gregory 1999 and Marchant & Noble 2000). This records the name of the waterway and also the start and end grid references. Basic habitat details are recorded for each 500-metre section using the standard BTO coding.

There are no plans to analyse the BTO habitat data as part of the present project, given that the much more detailed RHS data are available. The BTO habitat data are valuable where RHS data for WBBS sites are lacking, and their collection maintains consistency between WBBS and BBS, which might eventually be merged.

3.2 Data collection for birds

WBBS observers have been successful in recording a wide variety of bird species during their visits. Table 2 lists those recorded on at least six of the randomly selected stretches, together with their mean frequencies overall, in each year between 1998 and 2000. The most widespread species on these stretches in 2000 were Chaffinch, Wren, Woodpigeon, Robin and Blackbird; the five most abundant species recorded were Woodpigeon, Starling, Rook, Mallard and Wren.

Standard errors are not tabulated but were larger than the means in all cases. Differences between years in the mean figures reported for particular species are influenced by chance and by the effects of plot turnover, and therefore do not necessarily reflect population changes among the birds themselves.

Table 2. Birds recorded on randomly selected WBBS stretches between 1998 and 2000. Numbers of birds given per 10 km represent the means from all random stretches covered, including those where the species was not found. The number of occupied stretches is also given. No figures are presented where the sample size was fewer than six plots.

Species	Birds per 10 km (number of stretches occupied)		
	1998 (n=107)	1999 (n=116)	2000 (n=106)
Little Grebe	1.3 (12)	1.1 (12)	0.5 (6)
Great Crested Grebe	0.8 (6)	1.0 (9)	.
Cormorant	2.4 (27)	2.7 (29)	2.8 (24)
Grey Heron	5.3 (63)	4.8 (71)	5.4 (69)
Mute Swan	10.4 (40)	7.4 (45)	5.8 (38)
Greylag Goose	7.0 (13)	4.7 (11)	2.5 (11)
Canada Goose	7.6 (35)	7.9 (27)	10.4 (28)
Shelduck	13.5 (10)	9.2 (10)	15.8 (10)
Gadwall	1.3 (7)	0.9 (6)	1.5 (8)

Species	Birds per 10 km (number of stretches occupied)		
	1998 (n=107)	1999 (n=116)	2000 (n=106)
Teal	0.5 (8)	0.4 (6)	0.8 (11)
Mallard	42.3 (91)	43.0 (98)	47.3 (86)
Tufted Duck	7.0 (17)	4.1 (17)	3.4 (16)
Goosander	1.4 (18)	1.2 (14)	1.1 (15)
Sparrowhawk	0.9 (20)	0.5 (16)	0.7 (11)
Buzzard	2.3 (31)	2.4 (43)	2.8 (38)
Kestrel	1.6 (35)	1.3 (28)	1.8 (23)
Red Grouse	.	.	0.3 (6)
Red-legged Partridge	2.2 (16)	2.5 (15)	2.1 (17)
Grey Partridge	1.0 (12)	0.4 (9)	1.0 (12)
Pheasant	8.8 (59)	11.4 (68)	11.2 (63)
Moorhen	9.5 (62)	10.3 (63)	11.1 (57)
Coot	5.9 (29)	7.2 (24)	5.5 (22)
Oystercatcher	7.8 (26)	8.7 (32)	8.2 (26)
Lapwing	21.1 (35)	8.2 (39)	9.2 (36)
Snipe	0.8 (10)	0.6 (12)	0.6 (11)
Curlew	4.2 (25)	5.0 (30)	4.3 (26)
Redshank	1.7 (8)	1.5 (7)	2.1 (12)
Common Sandpiper	5.2 (34)	3.6 (30)	4.2 (35)
Black-headed Gull	33.0 (35)	11.4 (32)	17.1 (36)
Common Gull	4.8 (15)	4.4 (14)	13.9 (14)
Lesser Black-backed Gull	8.2 (22)	5.1 (28)	5.6 (25)
Herring Gull	18.7 (28)	8.2 (28)	8.9 (23)
Common Tern	1.0 (11)	1.1 (13)	.
Feral Pigeon	14.8 (23)	13.9 (21)	15.7 (24)
Stock Dove	5.4 (30)	8.4 (39)	6.3 (36)
Wood Pigeon	64.2 (89)	76.0 (94)	80.5 (90)
Collared Dove	5.4 (43)	5.8 (45)	7.5 (46)
Turtle Dove	1.2 (9)	1.9 (15)	1.4 (11)
Cuckoo	2.3 (41)	2.4 (37)	2.3 (43)
Little Owl	0.3 (6)	.	.
Tawny Owl	.	0.2 (6)	0.2 (6)
Swift	30.3 (61)	21.3 (59)	21.2 (54)
Kingfisher	1.9 (30)	1.6 (37)	1.7 (29)
Green Woodpecker	1.9 (29)	1.8 (31)	2.2 (34)
Great Spotted Woodpecker	2.5 (37)	1.3 (32)	1.6 (35)
Skylark	11.4 (56)	10.2 (54)	9.2 (51)
Sand Martin	16.3 (29)	10.7 (32)	14.7 (28)

Species	Birds per 10 km (number of stretches occupied)		
	1998 (n=107)	1999 (n=116)	2000 (n=106)
Swallow	15.1 (73)	18.4 (87)	19.4 (79)
House Martin	14.8 (48)	18.7 (53)	16.1 (50)
Tree Pipit	0.2 (6)	0.8 (11)	0.4 (9)
Meadow Pipit	19.7 (38)	18.8 (42)	20.0 (41)
Yellow Wagtail	2.3 (12)	1.6 (11)	1.8 (9)
Grey Wagtail	3.6 (42)	5.2 (63)	5.6 (55)
Pied Wagtail	6.2 (63)	6.4 (63)	6.4 (69)
Dipper	3.3 (39)	2.8 (42)	3.2 (44)
Wren	37.6 (87)	43.9 (101)	45.5 (92)
Dunnock	8.1 (63)	6.8 (71)	7.4 (65)
Robin	18.1 (77)	20.1 (93)	21.8 (89)
Redstart	1.1 (11)	1.0 (12)	0.9 (13)
Whinchat	0.7 (11)	0.8 (11)	1.2 (11)
Stonechat	.	0.4 (6)	1.1 (10)
Wheatear	2.3 (16)	1.9 (21)	1.6 (10)
Blackbird	32.6 (85)	31.5 (95)	37.0 (88)
Song Thrush	10.4 (73)	10.9 (80)	11.5 (81)
Mistle Thrush	4.8 (48)	5.3 (57)	4.7 (53)
Sedge Warbler	6.6 (31)	7.4 (37)	10.0 (41)
Reed Warbler	7.4 (23)	8.8 (24)	9.2 (23)
Lesser Whitethroat	0.9 (12)	0.4 (7)	0.5 (8)
Whitethroat	7.6 (50)	7.7 (44)	7.7 (50)
Garden Warbler	2.7 (35)	2.7 (39)	2.3 (30)
Blackcap	10.8 (61)	8.7 (66)	9.2 (64)
Wood Warbler	.	.	0.5 (7)
Chiffchaff	8.1 (56)	4.9 (53)	6.0 (45)
Willow Warbler	16.0 (78)	15.4 (88)	13.9 (69)
Goldcrest	2.2 (30)	3.4 (36)	4.5 (43)
Spotted Flycatcher	1.4 (21)	1.6 (28)	2.2 (29)
Long-tailed Tit	6.7 (52)	8.2 (56)	7.7 (49)
Marsh Tit	0.5 (10)	0.5 (11)	0.7 (11)
Willow Tit	0.5 (9)	0.2 (6)	.
Coal Tit	2.5 (25)	3.4 (33)	2.4 (30)
Blue Tit	30.3 (84)	23.5 (91)	26.7 (85)
Great Tit	17.8 (82)	13.3 (87)	14.5 (83)
Nuthatch	0.9 (18)	1.6 (23)	1.5 (20)
Treecreeper	1.6 (29)	2.2 (39)	1.9 (29)
Jay	2.3 (27)	1.9 (32)	1.7 (29)

Species	Birds per 10 km (number of stretches occupied)		
	1998 (n=107)	1999 (n=116)	2000 (n=106)
Magpie	11.0 (66)	12.1 (74)	10.5 (66)
Jackdaw	23.2 (56)	26.1 (60)	24.4 (62)
Rook	57.8 (57)	70.7 (59)	50.6 (51)
Carrion Crow	32.2 (88)	31.0 (92)	33.1 (86)
Hooded Crow	0.6 (8)	0.9 (12)	0.6 (9)
Raven	0.5 (9)	0.7 (13)	0.7 (16)
Starling	64.6 (65)	60.5 (72)	55.9 (73)
House Sparrow	9.9 (45)	11.0 (47)	14.1 (48)
Tree Sparrow	.	.	1.0 (6)
Chaffinch	38.6 (93)	39.6 (101)	41.2 (95)
Greenfinch	8.8 (58)	8.5 (61)	9.7 (58)
Goldfinch	9.3 (55)	8.4 (62)	10.0 (65)
Siskin	0.8 (10)	1.1 (10)	1.0 (11)
Linnet	7.0 (27)	8.8 (38)	7.1 (29)
Lesser Redpoll	0.4 (7)	.	0.3 (6)
Bullfinch	1.6 (24)	1.1 (22)	0.8 (17)
Yellowhammer	3.8 (35)	4.1 (38)	3.6 (37)
Reed Bunting	5.1 (44)	5.3 (42)	4.2 (38)
Corn Bunting	0.8 (7)	.	1.0 (7)

3.3 Data collection for mammals in 2000

The mammal data recorded by WBBS are likely to be minimum figures, because mammal recording was secondary to the main tasks of recording birds and habitat and, in general, was not systematic. The recording form used is as included in our previous annual report Marchant & Noble 2000).

Across the 172 WBBS returns for 2000, mammal forms were completed and returned for 155 (90%). Mammal recording was therefore well supported by WBBS volunteers, as in 1998–99.

No mammals were recorded from four stretches, and half the sites recorded fewer than three species. Fifteen stretches recorded 10 or more mammal species; the maximum was 14. In all, 27 species were recorded (Table 3). The mammal species found most frequently were diurnal species and those that left obvious signs of presence.

Of specialist waterway mammals, Otters were found on 13% of stretches in 2000 (15% in 1998, 11% in 1999), Water Vole on 12% (9% in 1998, 16% in 1999), and American Mink on 22% (8% in 1998, 21% in 1999). Increases in the frequency of recording over time should not necessarily be interpreted as an indication that the population size of the species concerned has increased, however, as these figures will also be influenced by the observer's increasing knowledge of the stretch; decreases are more likely to be biologically significant.

Table 3. Mammals recorded on all WBBS stretches reporting mammal data in 2000 (n=155). Species are ranked according to the proportion of stretches that they occupied. The number of animals counted is the sum of early and late counts across all occupied stretches.

Species	Animals counted	Number of occupied stretches	% of stretches occupied
Rabbit	1,986	110	71%
Mole	24	89	57%
Red Fox	12	78	50%
Grey Squirrel	115	72	46%
Brown Hare	95	44	28%
Roe Deer	59	35	23%
Feral/domestic cat	36	34	22%
Shrew species	5	34	22%
American Mink	0	34	22%
Hedgehog	0	32	21%
Badger	1	31	20%
Brown Rat	6	27	17%
Stoat	3	25	16%
Otter	2	20	13%
Water Vole	12	19	12%
Red Deer	565	15	10%
Weasel	2	15	10%
Muntjac Deer	15	12	8%
Mountain Hare	19	5	3%
Red Squirrel	2	5	3%
Fallow Deer	1	2	1%
Field Vole	0	2	1%
Feral Goat	2	1	1%
Bank Vole	1	1	1%
Pine Marten	1	1	1%
Daubenton's Bat	0	1	1%
Wood Mouse	0	1	1%

3.4 Comparisons of bird population change measures

3.4.1 Samples of repeat surveys

Repeat surveys, conducted in two consecutive years, provide the measures of population change that are reported here. The numbers of repeat surveys are shown in Table 4.

Table 4. Surveys repeated from the previous year.

Survey type	1999	2000
Random WBBS stretches	91	90
WBBS for comparison with WBS data	14	54
Other non-random WBBS stretches	3	4
Total WBBS repeat surveys	108	148
WBS mapping repeat surveys	98	84

As planned, therefore, there are sufficient numbers of repeat surveys at the end of Phase 2 for comparisons to be made:

- *between random WBBS stretches and WBS data (91:98 paired sites for random WBBS:WBS sites in 1998–99, and 90:84 in 1999–2000);*
- *between random and WBS-linked parts of the WBBS sample (90:54 sites in 1999–2000);* **and**
- *between WBBS and WBS data for the same waterway stretches (54 WBBS repeat surveys on WBS plots in 1999–2000, of which 50 also had repeat WBS surveys).*

Percentage changes, and their confidence intervals and sample sizes, from the various WBBS samples are presented in Table 5, along with percentage changes from WBS mapping surveys.

Table 5. Estimates of year-to-year change, 1998–99 and 1999–2000, from WBBS transect and WBS mapping results. In each WBBS column, figures given are the percentage change, the confidence limits in brackets, and the number of contributing surveys. Confidence intervals are recorded as unavailable where the number of surveys is less than five. Data are presented only for species for which estimates were available from all three WBBS samples.

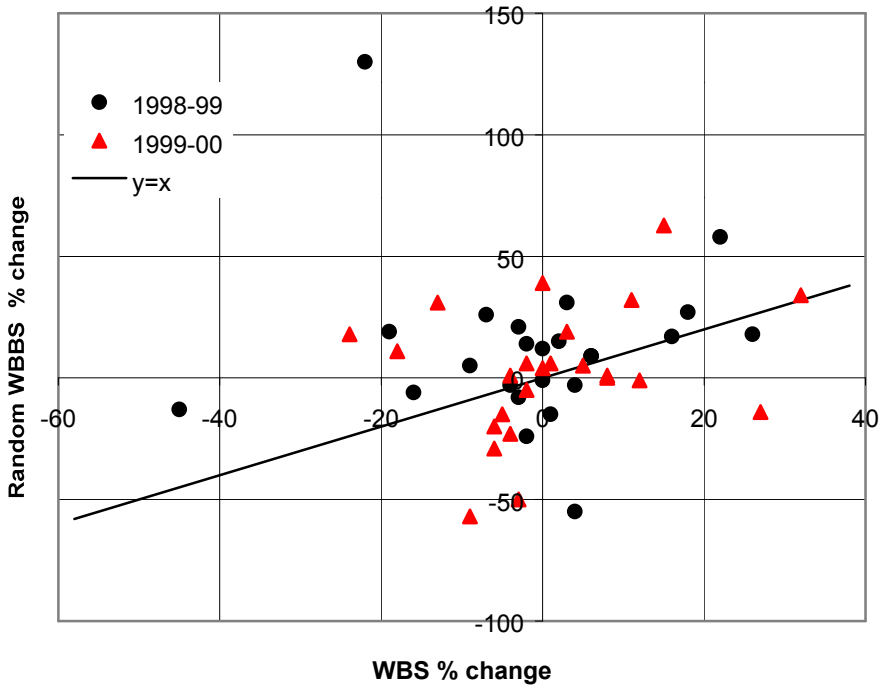
	% change from WBBS transects			% change from WBS mapping		
	Random		WBS-linked	all sites		WBBS-linked
Species	1998–99	1999–2000	1999–2000	98–99	99–00	99–00
Little Grebe	5, (-19, 29), 9	-29, (-104, 45), 5	-13, (n/a), 3	-9	-6	0
Great Crested Grebe	26, (-52, 105), 6	-17, (-126, 93), 5	-5, (-34, 25), 6	.	.	.
Cormorant	24, (-18, 66), 20	32, (3, 60), 15	50, (-59, 159), 11	.	.	.
Grey Heron	-3, (-23, 16), 46	8, (-17, 33), 46	-12, (-30, 6), 32	.	.	.
Mute Swan	-15, (-57, 26), 35	-15, (-44, 15), 33	-4, (-35, 26), 25	1	-5	-10
Greylag Goose	130, (n/a), 2	-57, (n/a), 4	2, (-77, 82), 8	-22	-9	-13
Canada Goose	18, (-17, 52), 28	-14, (-38, 11), 22	-1, (-50, 47), 18	26	27	43
Shelduck	-26, (-57, 5), 6	69, (40, 99), 6	-30, (-65, 4), 5	.	.	.
Mallard	9, (-12, 30), 83	1, (-11, 14), 75	-1, (-18, 15), 48	6	-4	-2
Tufted Duck	-3, (-34, 28), 13	11, (-39, 62), 12	-35, (-91, 21), 11	-4	-18	0
Goosander	58, (-44, 160), 6	-50, (-67, -33), 7	-26, (-54, 1), 10	22	-3	0
Sparrowhawk	-14, (-46, 17), 6	67, (n/a), 3	0, (n/a), 3	.	.	.
Buzzard	-23, (-53, 8), 25	21, (-25, 67), 29	-8, (-59, 43), 12	.	.	.
Kestrel	-18, (-44, 7), 12	38, (-26, 101), 11	0, (-49, 49), 10	.	.	.
Grey Partridge	-15, (-57, 27), 6	17, (n/a), 4	-20, (n/a), 2	.	.	.
Pheasant	25, (-3, 54), 51	7, (-20, 33), 50	12, (-28, 52), 29	.	.	.
Moorhen	15, (-3, 34), 55	5, (-9, 20), 48	-2, (-16, 12), 36	2	5	9
Coot	21, (0, 42), 23	4, (-24, 31), 18	-23, (-46, 0), 24	-3	0	2
Oystercatcher	-8, (-33, 17), 21	-5, (-28, 18), 20	18, (-11, 48), 11	-3	-2	0
Lapwing	-55, (-75, -34), 24	-1, (-44, 42), 23	-22, (-64, 21), 17	4	12	29
Curlew	12, (-19, 44), 17	-23, (-46, 1), 17	-4, (-50, 42), 7	0	-4	-14
Redshank	19, (-27, 66), 5	31, (-25, 87), 5	-12, (n/a), 4	-19	-13	9
Common Sandpiper	-6, (-23, 10), 16	6, (-9, 21), 21	25, (-8, 59), 11	-16	-2	4
Black-headed Gull	-60, (-98, -23), 24	13, (-88, 113), 20	223, (-231, 676), 14	.	.	.
Common Gull	-45, (-82, -8), 12	-39, (-74, -4), 7	163, (n/a), 2	.	.	.
L'r Black-backed Gull	-46, (-96, 4), 11	64, (-91, 218), 15	-42, (-109, 26), 10	.	.	.
Herring Gull	-54, (-108, 0), 17	36, (-114, 186), 14	261, (n/a), 2	.	.	.
Common Tern	19, (-50, 88), 8	0, (-56, 56), 8	46, (n/a), 4	.	.	.
Feral Pigeon	1, (-85, 88), 13	-15, (-35, 6), 16	42, (-42, 127), 12	.	.	.
Stock Dove	84, (-123, 290), 26	-39, (-82, 5), 27	-7, (-55, 40), 15	.	.	.
Woodpigeon	20, (-11, 52), 81	4, (-24, 32), 80	6, (-26, 38), 47	.	.	.
Collared Dove	-5, (-31, 21), 31	-1, (-21, 20), 34	13, (-4, 31), 24	.	.	.
Turtle Dove	7, (-63, 77), 10	-15, (-51, 20), 8	-50, (n/a), 2	.	.	.
Cuckoo	22, (-6, 50), 26	-12, (-33, 8), 24	0, (-59, 59), 8	.	.	.
Swift	14, (-36, 64), 45	10, (-22, 43), 43	-38, (-84, 8), 26	.	.	.
Kingfisher	-24, (-50, 2), 19	32, (-5, 69), 18	-28, (-58, 2), 10	-2	11	19
Green Woodpecker	16, (-30, 62), 19	-4, (-25, 17), 25	17, (-25, 59), 14	.	.	.
Great Spotted Woodp'r	-23, (-40, -5), 21	-6, (-33, 20), 19	-2, (-39, 35), 20	.	.	.
Skylark	-4, (-21, 14), 50	0, (-14, 14), 40	-4, (-25, 17), 18	.	.	.
Sand Martin	14, (-39, 67), 18	34, (-25, 92), 19	105, (-24, 233), 13	-2	32	90
Swallow	9, (-29, 46), 65	-2, (-26, 22), 63	-21, (-86, 44), 38	.	.	.
House Martin	12, (-33, 57), 36	-13, (-38, 11), 34	-10, (-60, 39), 20	.	.	.
Meadow Pipit	-15, (-33, 3), 27	12, (-31, 56), 31	-33, (-110, 43), 5	.	.	.

Species	% change from WBBS transects			% change from WBS mapping		
	Random		WBS-linked	all sites		WBBS-linked
	1998–99	1999–2000	1999–2000	98–99	99–00	99–00
Yellow Wagtail	-13, (-39, 14), 11	39, (-16, 93), 7	-37, (n/a), 4	-45	0	0
Grey Wagtail	27, (-10, 64), 30	8, (-16, 33), 43	8, (-18, 35), 19	18	15	6
Pied Wagtail	-3, (-21, 16), 43	19, (1, 36), 47	15, (-27, 56), 26	4	3	10
Dipper	-1, (-32, 29), 26	1, (-18, 20), 33	9, (-29, 47), 13	0	8	7
Wren	22, (11, 32), 78	-1, (-8, 6), 82	10, (0, 20), 47	.	.	.
Dunnock	-9, (-27, 9), 57	0, (-16, 15), 55	1, (-20, 23), 39	.	.	.
Robin	15, (3, 28), 72	13, (2, 24), 80	12, (-3, 28), 45	.	.	.
Redstart	7, (-62, 77), 7	-19, (-58, 20), 8	5, (-18, 28), 5	.	.	.
Blackbird	10, (0, 20), 80	5, (-5, 16), 80	2, (-9, 12), 48	.	.	.
Song Thrush	21, (3, 38), 65	5, (-12, 21), 65	0, (-19, 18), 44	.	.	.
Mistle Thrush	12, (-9, 34), 34	-17, (-40, 6), 35	-7, (-33, 19), 29	.	.	.
Sedge Warbler	17, (-10, 43), 29	18, (-3, 40), 29	13, (-16, 42), 23	16	11	3
Reed Warbler	31, (2, 60), 23	6, (-24, 36), 20	-4, (-16, 9), 11	3	1	3
Whitethroat	26, (3, 50), 36	0, (-20, 21), 36	6, (-24, 35), 29	-7	8	6
Garden Warbler	16, (-13, 46), 27	4, (-18, 27), 23	-26, (-50, -1), 15	.	.	.
Blackcap	-5, (-21, 11), 55	-3, (-19, 13), 54	-5, (-17, 8), 39	.	.	.
Wood Warbler	-57, (n/a), 2	30, (n/a), 3	200, (n/a), 2	.	.	.
Chiffchaff	-31, (-46, -16), 44	26, (0, 53), 41	56, (22, 90), 28	.	.	.
Willow Warbler	5, (-14, 24), 67	-2, (-16, 11), 58	-9, (-28, 9), 39	.	.	.
Goldcrest	31, (-16, 78), 18	34, (-19, 86), 26	47, (-21, 114), 13	.	.	.
Spotted Flycatcher	-30, (-65, 4), 12	-11, (-43, 20), 13	-15, (-61, 31), 8	.	.	.
Long-tailed Tit	50, (-6, 107), 34	-13, (-45, 19), 34	24, (-23, 71), 31	.	.	.
Marsh Tit	10, (-133, 153), 5	0, (-113, 113), 7	-33, (n/a), 2	.	.	.
Coal Tit	-17, (-52, 19), 13	-2, (-41, 38), 18	17, (-40, 73), 13	.	.	.
Blue Tit	-13, (-25, -2), 75	4, (-8, 17), 75	-2, (-15, 10), 46	.	.	.
Great Tit	-12, (-27, 2), 74	-1, (-15, 13), 74	21, (1, 42), 44	.	.	.
Nuthatch	64, (-1, 128), 12	-14, (-55, 27), 13	10, (-58, 77), 10	.	.	.
Treecreeper	17, (-35, 68), 16	13, (-29, 55), 19	-5, (-44, 35), 15	.	.	.
Jay	12, (-30, 55), 18	-13, (-46, 21), 16	33, (-49, 116), 15	.	.	.
Magpie	8, (-8, 24), 63	-13, (-28, 2), 60	-11, (-30, 9), 42	.	.	.
Jackdaw	28, (-9, 66), 46	-25, (-44, -6), 46	-19, (-49, 10), 36	.	.	.
Rook	8, (-31, 46), 41	-23, (-59, 13), 34	32, (-92, 156), 21	.	.	.
Carrion Crow	1, (-12, 14), 80	-1, (-18, 16), 75	-1, (-30, 28), 46	.	.	.
Starling	-2, (-68, 63), 57	9, (-21, 38), 59	-4, (-31, 24), 35	.	.	.
House Sparrow	4, (-26, 34), 40	10, (-7, 28), 41	10, (-32, 51), 22	.	.	.
Tree Sparrow	29, (n/a), 4	-23, (-137, 91), 5	-13, (-75, 48), 5	.	.	.
Chaffinch	0, (-9, 9), 84	2, (-8, 13), 84	15, (3, 28), 46	.	.	.
Greenfinch	-3, (-23, 18), 49	3, (-19, 25), 46	7, (-17, 30), 31	.	.	.
Goldfinch	-2, (-36, 31), 47	22, (-6, 50), 52	-18, (-48, 12), 31	.	.	.
Linnet	-32, (-60, -4), 24	-7, (-50, 35), 21	-41, (-73, -10), 13	.	.	.
Bullfinch	0, (-43, 43), 9	-17, (-53, 20), 10	-9, (-48, 30), 7	.	.	.
Yellowhammer	-7, (-36, 23), 29	-5, (-29, 18), 25	10, (-26, 45), 17	.	.	.
Reed Bunting	9, (-11, 29), 37	-20, (-42, 2), 32	9, (-19, 36), 20	6	-6	3

3.4.2 Comparison of random WBBS with other monitoring measures

Figure 2 shows a comparison of year-to-year percentage changes between the random WBBS stretches and the full WBS mapping sample. Each point represents a species covered by both WBBS and WBS, and all species represented are therefore waterbirds. Data are drawn from Table 5. The distance of each point from the line $y=x$ is a measure of the discrepancy between these two monitoring methods, for this species. Confidence intervals are not plotted. Since most of the percentage changes are not significantly different from zero, however, it is unlikely that many of the discrepancies between the methods are statistically significant. Nevertheless, the scatter of these points is informative as to the general nature of this comparison.

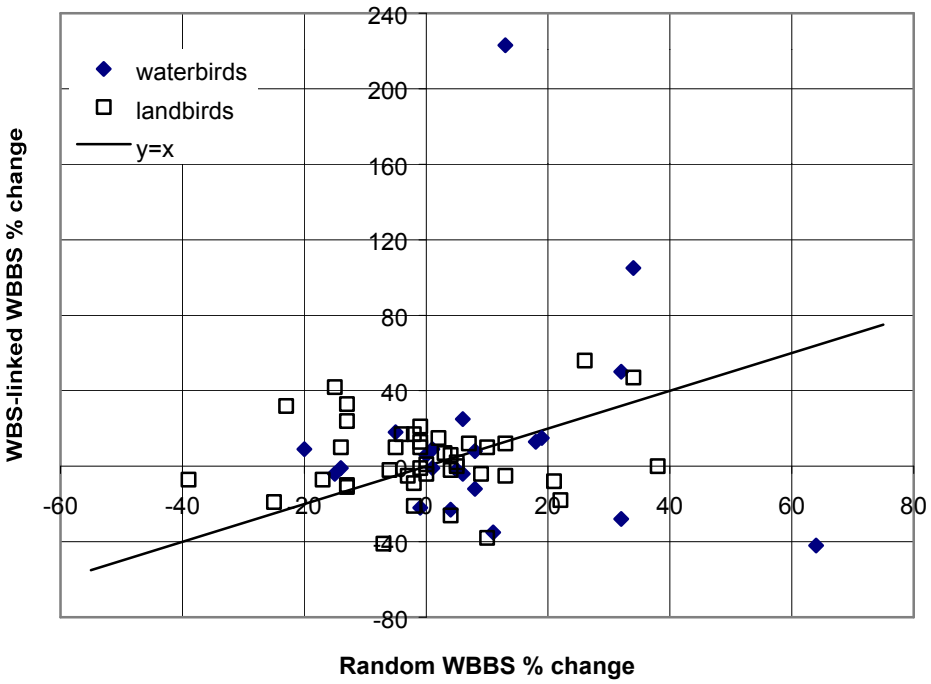
Figure 2. Comparison of percentage changes between random WBBS stretches and WBS mapping plots. All WBS species are included.



All points except one could be viewed as part of a cluster of points that lie approximately along the line indicated. The conspicuous exception is Greylag Goose in 1998–99, which decreased by 22% according to the WBS mapping survey but increased by 130% according to the random WBBS. The latter figure was drawn from only two WBBS plots, however (Table 5), too small a sample to give a reliable estimate of population change.

In Figure 3, a similar comparison is shown for the two main parts of the WBBS sample. Percentage changes are compared, for 1999–2000 only, between random sites and WBBS stretches surveyed because they were also covered by WBS mapping. Methods were identical between these two samples, which differ only in the distribution of sites. This Figure shows two conspicuous outliers to the main scatter of points along the line $y=x$., both for waterbirds. Black-headed Gull increased by 13% on the random sample but by 223% at WBS-linked sites. Lesser-Black-backed Gull increased by 64% according to the random sample but decreased by 42% at the WBS-linked sites.

Figure 3. **Comparison of percentage changes, 1999–2000, between random WBBS stretches and WBBS surveys carried out on WBS mapping plots. Species occurring on fewer than 10 stretches in either sample are omitted.**



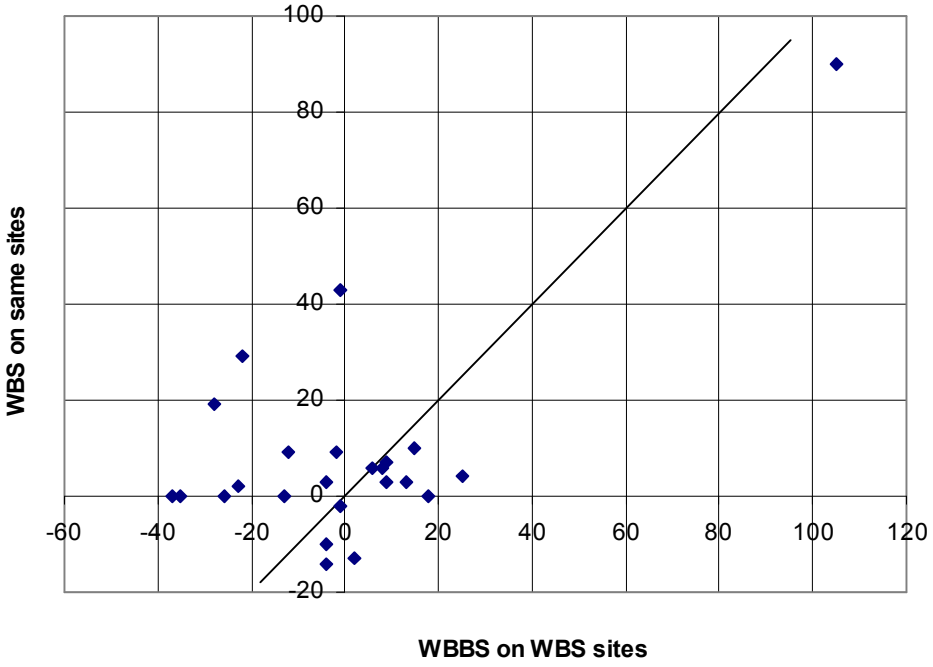
3.4.3 Comparison of WBBS and WBS change measures along the same waterway stretches

In Figure 4, a comparison is drawn between the percentage changes for 1999–2000 that were estimated from the WBS-linked section of the WBBS sample and from the mapping censuses conducted on 50 of the same plots. Data are again drawn from Table 5. A similar figure was presented previously by Marchant (2001).

The points are mostly relatively close to the origin, indicating that rather little change was detected among these species by either method. The single notable exception was Sand Martin, for which large but similar percentage changes were estimated (+90% from mapping and +105% from transects). Mallard, the species for which the sample was the largest, also showed very similar estimates between the two survey methods (-1%, -2%).

In this comparison, the geographical distribution of the sites was non-random, but was the same between the two samples. Because of the requirement for complete 500-metre sections for the WBBS, the lengths of waterway surveyed were often different between WBS and WBBS surveys. Survey method, however, was the only important difference between these samples. Observers were the same in almost all cases.

Figure 4. **Comparison of WBBS and WBS change measures for waterbirds along the same waterway stretches. The line indicates the expected one-to-one relationship.**



3.5 Relationships between WBBS and RHS data

Table 6 compares the significant relationships between WBBS data for canals collected during 1998 and selected habitat variables, identified in a previous study by Marchant *et al*. (1996), with the equivalent relationships identified in the current analysis, which used WBBS data collected over the period 1998–2000 from a much wider variety of natural and artificial watercourses.

The results indicate that several of the relationships between species abundance during 1998 and canal habitat features still hold when the sample size is extended to include subsequent breeding seasons and other habitat types. In addition, significant relationships have also been identified between the selected habitat variables and a number of additional species. The much larger number of relationships found by the present study may simply be a result of larger sample sizes, or may stem from the inclusion of a much wider range of habitat types in the current data set.

Table 6. **Significant correlations between waterbird numbers and RHS features in WBBS 500-metre sections. Results from the current analysis are compared with those obtained from canals in 1998 (from Marchant *et al.* 1999). Species and habitat features not included in the current analysis are omitted here from the results presented for 1998. Species names in bold text are those for which similar results were obtained in the two studies.**

RHS feature	Direction of correlation	Species and sample	
		Canal stretches (selected for investigation of fishing seasons) surveyed in 1998	Random UK waterways, of all types, surveyed during 1998–2000
Water width	+ve	Curlew, Sedge Warbler, **Reed Warbler**	Mute Swan, Coot, Oystercatcher, Lapwing, Sand Martin, **Reed Warbler**, Reed Bunting
	-ve	Moorhen	Curlew
Extent of bankside trees	+ve	Moorhen	Canada Goose, Goosander, Kingfisher, Grey Wagtail, Dipper
	-ve	–	Oystercatcher, Lapwing, Common Sandpiper, Yellow Wagtail, Reed Warbler, Sedge Warbler, Reed Bunting
Extent of improved grassland	+ve	Yellow Wagtail, **Reed Bunting**	Mute Swan, **Reed Bunting**
	-ve	–	Sedge Warbler
Extent of tilled land	+ve	**Reed Warbler**	Canada Goose, Mallard, Moorhen, Yellow Wagtail, **Reed Warbler**, Sedge Warbler, Reed Bunting
	-ve	–	Oystercatcher, Lapwing, Common Sandpiper, Curlew, Grey Wagtail, Pied Wagtail, Dipper
Extent of urban/suburban development	+ve	**Mallard**	Mute Swan, **Mallard**, Moorhen, Coot
	-ve	Reed Bunting	Goosander, Oystercatcher, Lapwing, Common Sandpiper, Curlew

Several of the habitat variables used in the current study demonstrated significant relationships with the abundance of a large number of different species. The relationships identified for the five habitat variables that demonstrated significant correlations with the highest numbers of individual species' counts are presented in Table 7.

Table 7. RHS features showing the highest numbers of monotonic correlations with WBBS bird counts, from UK waterways selected randomly and surveyed during 1998–2000.

RHS feature	Direction of correlation	Species
Extent of emergent vegetation	+ve	Mute Swan, Canada Goose, Mallard, Lapwing, Moorhen, Sand Martin, Yellow Wagtail, Reed Warbler, Sedge Warbler, Reed Bunting
	-ve	Coot, Oystercatcher, Common Sandpiper, Curlew, Grey Wagtail, Pied Wagtail, Dipper
Presence of unvegetated bars	+ve	Goosander, Oystercatcher, Common Sandpiper, Curlew, Grey Wagtail, Pied Wagtail, Dipper
	-ve	Mute Swan, Canada Goose, Mallard, Coot, Moorhen, Lapwing, Yellow Wagtail, Reed Warbler, Sedge Warbler, Reed Bunting
Altitude	+ve	Oystercatcher, Common Sandpiper, Curlew, Pied Wagtail, Dipper
	-ve	Mute Swan, Canada Goose, Mallard, Moorhen, Coot, Kingfisher, Sand Martin, Yellow Wagtail, Reed Warbler, Sedge Warbler, Reed Bunting
Presence of cascades and/or rapids	+ve	Oystercatcher, Common Sandpiper, Curlew, Grey Wagtail, Pied Wagtail, Dipper
	-ve	Mute Swan, Canada Goose, Mallard, Coot, Moorhen, Lapwing, Sand Martin, Yellow Wagtail, Sedge Warbler, Reed Bunting
Extent of bedrock as channel material	+ve	Oystercatcher, Common Sandpiper, Curlew, Grey Wagtail, Dipper
	-ve	Mute Swan, Canada Goose, Mallard, Coot, Moorhen, Lapwing, Sand Martin, Yellow Wagtail, Reed Warbler, Sedge Warbler, Reed Bunting

Table 8 summarises all significant relationships between WBBS counts and RHS variables identified for a subset of species for which the WBBS potentially provides a relatively better measure of abundance than either the CBC or the BBS. All species included are therefore found predominantly, though not necessarily exclusively, in riparian habitats. The results for the Grey Wagtail may be of particular interest as the most recent analysis of WBS data (Baillie *et al*. 2002) indicated that this species has declined at a moderate rate along Britain's waterways (by an estimated 41% over the 24-year period 1974–99).

Table 8. **Significant correlations between RHS variables and counts of selected waterbird species. Species selected are those for which surveys along waterways are likely to provide a better measure of long-term population change than CBC and BBS (Marchant *et al.* 1996, with the addition of Canada Goose). Little Grebe, for which the WBBS sample size was small, is omitted. See Appendix 2a for RHS variable definitions.**

Species	RHS variable	
	Correlated +vely	Correlated –vely
Mute Swan	emergepres2, flocat2, gravpeb, habmodsc, igrass, owater2, pctbare, scrub, silt, subpres2, tallhb, urbdev, weirpres, width	alt, boil2, bough2, brypres2, casrap, cwoodeb2, matisle2, moor, noperflo, pctcliff, pctcomplex, pctsimple, riffpres, rock, run, unvegbar, vegbar, vegpres
Canada Goose	algpres2, bridgepres, emergepres2, flocat2, habmodsc, owater2, pctsimple, sand, scrub, subpres2, tilled, tree, weirpres	alt, boil2, bothreinf, brypres2, casrap, matisle2, noperflo, riffpres, rock, rpast, run, slope2, unvegbar, vegpres
Goosander	bough2, depth2, flocat2, ravpeb, pctcliff, pctsimple, poached, run, tree, unvegbar, vegbar	bothreinf, bridgepres, floatpres2, pctbare, urbdev
Common Sandpiper	algpres2, alt, casrap, exprock, riffpres, rock, rpast, unvegbar	blmwood, bothreinf, bough2, cwoodeb2, emergepres2, floatpres2, flocat2, gravpeb, habmodsc, pctcomplex, pctsimple, scrub, silt, subpres2, tilled, tree, urbdev, weirpres
Kingfisher	blmwood, flocat2, glide, pctsimple, poached, tree, weirpres	alt, boil2, exprock, moor, rpast, slope2
Sand Martin	bough2, depth2, emergepres2, flocat2, glide, gravpeb, pctcliff, pctsimple, poached, rpast, sand, scrub, silt, subpres2, vegbar, wetland, width	alt, bridgepres, brypres2, casrap, exprock, floatpres2, matisle2, pctcomplex, rock, slope2, vegpres
Grey Wagtail	blmwood, bothreinf, bridgepres, brypres2, casrap, pctbare, pctsimple, riffpres, rock, run, scrub, tree, unvegbar, weirpres	emergepres2, floatpres2, noperflo, silt, subpres2, tilled
Dipper	alt, bothreinf, brypres2, casrap, matisle2, poached, riffpres, rock, run, slope2, tree, unvegbar, vegpres, weirpres	depth2, emergepres2, floatpres2, flocat2, habmodsc, silt, subpres2, tallhb, tilled
Reed Warbler	emergepres2, floatpres2, habmodsc, owater2, silt, subpres2, tallhb, tilled, width	alt, blmwood, boil2, bothreinf, bough2, brypres2, cwoodeb2, gravpeb, pctcliff, pctcomplex, pctsimple, riffpres, rock, rpast, sand, scrub, tree, unvegbar, vegbar, vegpres, weirpres

4 DISCUSSION

4.1 Progress in 2000

The year 2000 was a successful season for WBBS in that the objectives of Phase 2 were met in full. It was disappointing that there was a 7% fall in the number of WBBS stretches covered, to 172 from 184 in 1999, but plans have been laid to reverse this decline in 2002–03. The number of repeat WBS surveys also fell, from 98 in 1999 to 84 in 2000.

RHS surveys were matched to 605 WBBS sections, 68% of the 889 sections in the total WBBS random sample. A large random sample of matched data was therefore available for analysis.

4.2 Comparisons of monitoring results

Investigations of the way in which monitoring results compare between different samples of waterways surveys began in Phase 2 of this project, and we report here on the first two year-to-year comparisons. With only three seasons' results in total, it is not possible yet to separate effects that stem from differences between monitoring methods from those that are simply due to chance. The results and discussion here must therefore be treated as preliminary.

As the number of seasons for which data are available increases and the number of random WBBS sites grows during Phase 3 of the project, so the conclusions that can be drawn from the various comparisons will become clearer. Seven overlap years were allowed between BBS and CBC to investigate possible differences in monitoring results between those schemes, to which WBBS and WBS make a close parallel. In the WBBS–WBS study, however, we are collecting data from individual study sites using both survey methods – a dimension that was not available during the BBS–CBC calibration.

A possible future course for BTO's long-term monitoring of waterbird populations would be to terminate the mapping WBS and divert all available effort towards an ongoing WBBS programme. To ensure that the existing 27-year run of monitoring results from WBS for waterbirds would not be lost, it would be important to calibrate changes as measured by WBBS and WBS. WBBS could then effectively continue the run of monitoring data for waterbirds, much as BBS continues the trend collected, until 2000, by the CBC.

An efficient way of managing a changeover between WBS mapping and WBBS transects might be to allow existing WBS observers to contribute to the WBBS results (perhaps with some regional weighting of their data to allow for the lack of random selection for these sites), at least until these observers drop out of the scheme. For such a strategy to work, we would need to know whether there were any systematic differences in monitoring results between these two groups of WBBS sites. The results of this analysis could be used retrospectively to provide appropriate weighting to the WBS results since 1974, therefore maximising the representativeness of long-term monitoring for the UK as a whole.

We take the first steps towards these comparisons in this report. Initial results confirm that confidence intervals around individual WBBS percentage changes are relatively wide, and therefore that more years' data will be required if sufficiently precise answers to our questions are to be obtained.

The largest discrepancies, those for Greylag Goose, Black-headed Gull and Lesser Black-backed Gull (Figures 2 & 3), demonstrate the importance of an adequate sample size, particularly for species that, because they occur in flocks, may differ widely in numbers between surveys depending on whether or not the flock was observed. In some cases, it may be appropriate to treat flocking species separately for analysis of population trends, as is done for five wader species in BBS results (Noble *et al*. 2001).

Where results from WBS mapping and WBBS transects are being compared, it should be borne in mind that the units of the results from these two schemes are subtly different. Mapping surveys set out to count territorial males: non-territorial birds are mostly excluded, as are territorial birds for which insufficient evidence of a territory was obtained. WBBS transects, on the other hand, count all individuals, whether or not they are territorial on site. Different trends would therefore be expected to emerge where the proportion of the total population that breeds varies between years.

4.3 Prediction of bird numbers from RHS data

This report demonstrates and amplifies the potential for linking bird counts from WBBS surveys with RHS data. This is a highly complex subject area, however, given the large number of RHS variables that might be important to particular populations of birds. Much of the work we have done in matching RHS and WBBS sites and in extracting and manipulating RHS variables is a necessary preliminary to a full analysis of these data, although we do not attempt that analysis here.

Our previous report on this topic (Marchant *et al*. 1999) drew on 334 RHS surveys, all for canals that had been selected to form a paired sample of sites with and without a close season for fishing. This sample was geographically limited to England and Wales, with sites especially concentrated in the Midlands. In the present study, we extend this approach to a larger sample of sites (605), covering the full range of WBBS waterway types, including all types of rivers as well as canals, and restricted to those sites selected randomly rather than being hand-picked.

Despite the differences in the nature and size of the two datasets, several of the relationships identified in the previous WBBS were also identified in the current report (Table 6). Reed Warbler numbers displayed a significant positive correlation with waterway width in both studies, and the relationships identified between Reed Bunting abundance and improved grassland, Reed Warbler abundance and tilled land, and Mallard abundance and the extent of urbanised areas all persisted in the current study. Curlew, on the other hand, was related positively to water width on the canals studied in 1998, but negatively in the present random sample. This discrepancy may stem from the low variability in the width of canals, or from the inclusion of upland regions within the enlarged current sample.

In comparison with the previous study (Marchant *et al.* 1998), a much larger number of species demonstrated significant relationships between abundance and the habitat variables tested in the present study. It is possible that the increased number of significant relationships identified in the current study is a result of increased statistical power due to the larger sample size used. In addition, using measures of mean abundance over a period of several years may reduce the amount of statistical 'noise' produced by annual fluctuations in abundance caused by factors such as winter weather conditions. Alternatively, the 'additional' species, for which relationships were identified only in the present study, may not be well represented in canal habitats, and sample sizes may therefore again have been too small to identify a significant relationship with

the habitat variables listed in Table 6. This may be particularly true for relatively scarce species such as Goosander, Oystercatcher, Lapwing, Common Sandpiper and Dipper.

Tables 7 and 8 indicate that, even after significance levels had been adjusted to allow for the potential problems of performing multiple tests, a large number of significant relationships between species abundance and RHS habitat variables were detectable. One of the problems faced when interpreting the results of multiple analyses involving single dependent variables such as these, is that many of the habitat variables used are likely to be significantly correlated with each other, and also with additional, untested variables. Thus, correlations that are detected may have no genuine biological significance. Further, more detailed analysis, involving multivariate techniques such as stepwise regressions, may help to increase the probability of identifying the major factors influencing abundance by controlling for the interdependence of the habitat variables.

Despite these caveats, the results presented in Tables 7 and 8 group the species clearly into two main ecotypes, suggesting that many of the correlations found do indeed have biological significance. The first ecotype includes Curlew, Oystercatcher, Common Sandpiper, Dipper and Pied and Grey Wagtails. These species are generally more abundant at relatively higher altitudes, where rock, rapids and unvegetated bars are more prevalent, and emergent vegetation generally absent. The second ecotype comprises the wildfowl species included in the study (with the exception of Goosander), together with Lapwing, Kingfisher, Sand Martin, Yellow Wagtail, Sedge Warbler, Reed Warbler and Reed Bunting. These species are more abundant in lowland areas where channels are wider and both vegetation and human modification of watercourses more prevalent. Variables measured by the RHS therefore have the potential to predict the relative abundance of groups of species, although the present analysis does not allow us to determine whether the observed relationships are causal, or whether the same factors are responsible for the relative abundance of each of the individual species within the group.

Sand Martin has additional associations with sand and cliffs, in accordance with its known requirements for nesting. Reed Warbler occurs at well-vegetated sites, but avoids wooded areas and rocky or sandy substrates. Goosander, a diving duck that is relatively wary of people, differs from the other waterfowl in its associations and favours waterway stretches with deeper runs, avoiding floating vegetation, bridges, and urban development. As well as separating the species into groups, therefore, the results for many of the species reflect their individual requirements. It is likely that a multivariate approach would allow more complex models to be built. Such models could enable detailed predictions to be made about waterbird communities on the basis of RHS data, and would also allow the habitat requirements of these waterbirds to be described more precisely.

Each WBBS site consists, on average, of six 500m transect sections. In the analyses of WBBS and RHS data carried out here, we have chosen to ignore the problem of non-independence of transect sections, which may have contributed to the number of apparently significant associations. There are several important reasons for this. Firstly, because the length of each transect section (500m) is much larger than the territory size of many of the species monitored, the problem of non-independence may not apply to many of the RHS variables considered. Secondly, we have used measures of bird abundance at each transect section that are averaged across years, hence minimising temporal autocorrelation. And thirdly, because this is a preliminary analysis intended to assess the potential of RHS data to predict bird abundance as measured by the WBBS, we wanted to take a more inclusive approach and not miss potentially important habitat variables. The aim is to identify associations that might turn out to be important predictors once further modeling of a much larger data set is carried out, and one of the aims of

the current WBBS programme is to increase the size of the random sample from just over a hundred sites to at least 300 sites. We have also been conservative in assessing the importance of associations with RHS variables by applying the Bonferroni approach to reporting significance.

4.4 Future developments

The 2001 field season had been intended to mark the beginning of Phase 3 of WBBS, in which the size of the random sample is scheduled to double. Access restrictions imposed following the outbreak of Foot and Mouth Disease in February 2001, which were still fully in place in most parts of the UK well into the spring, considerably reduced the number of surveys undertaken in 2001 (Marchant *et al.* 2002).

Further efforts are currently being made to increase the numbers of random plots surveyed in 2002 and 2003. It is intended that the sample of linked RHS sites will also be increased during this period.

ACKNOWLEDGEMENTS

The launch of WBBS was funded in collaboration with the Environment Agency's R&D programme. We also acknowledge the financial support of Anglian Water, British Waterways, Northumbrian Water, Essex & Suffolk Water, Severn Trent Water, Thames Water and Welsh Water. BBS is funded jointly by the BTO, JNCC (on behalf of English Nature, Scottish Natural Heritage, the Countryside Council for Wales and the Environment and Heritage Service in Northern Ireland), and the RSPB.

The BTO's work relies heavily on volunteers. It is gratifying that, in a period when BBS grew and CBC and WBS continued to be well supported, BTO volunteers also found time to survey such a large sample of WBBS plots. We are very grateful to all observers who have contributed WBBS data, and to the BTO's Regional Representatives and others who assisted with finding volunteers and forwarding paperwork.

We acknowledge the help of the following Environment Agency staff during the course of this project (since 1998): Geraldine Daly, Alastair Driver, Andrew Heaton, Marc Naura, Helena Parsons, Paul Raven, Martin Smalls, Adrian Taylor and Mark White. Dr Steve Ormerod of the School of Biosciences at Cardiff University has also provided valuable advice and guidance. At BTO HQ in Thetford, Nick Carter, Jackie Coker, Richard Gregory, Vivien Hiom, Angie Raven, Angela Rickard, Sam Rider, Fiona Sanderson, Jen Smart, Susan Waghorn and Jane Wells have all assisted at various stages of the project. Host Data Services Ltd of Watford input the bulk of the WBBS data from the observers' field sheets.

Figure 1 was produced using the program DMAP, with thanks to Alan Morton.

REFERENCES

Baillie, S.R., H.Q.P. Crick, D.E. Balmer, L.P. Beaven, I.S. Downie, S.N. Freeman, D.I. Leech, J.H. Marchant, D.G. Noble, M.J. Raven, A.P. Simpkin, R.M. Thewlis & C.V. Wernham. 2002. *Breeding birds in the wider countryside: their conservation status 2001.* Research Report 278. British Trust for Ornithology, Thetford. (www.bto.org/birdtrends)

BTO. 2000. *Breeding Bird Survey 2000 instructions*. British Trust for Ornithology, Thetford.

Carter, S.P. 1989. The Waterways Bird Survey of the British Trust for Ornithology: an overview. *Regulated Rivers: Research & Management* 4: 191–197.

Crick, H.Q.P. 1992. A bird-habitat coding system for use in Britain and Ireland incorporating aspects of land-management and human activity. *Bird Study* 39: 1–12.

Langston, R.H.W., J.H. Marchant & R.D. Gregory. 1997. Waterways Bird Survey: evaluation of population monitoring and appraisal of future requirements. Pp 282–289 in: P.J. Boon & D.L. Howell (eds), *Freshwater Quality: defining the indefinable?* The Stationery Office, Edinburgh.

Marchant, J.H. 1994. *Guidelines for territory analysis on Waterways Bird Survey species maps*. British Trust for Ornithology, Thetford.

Marchant, J.H. 2000. Waterways Breeding Bird Survey progress. *BTO News* 226: 8.

Marchant, J. 2001. Waterways bird surveys – latest results, and a new challenge. *BTO News* 236: 8–10.

Marchant, J., & D. Balmer. 1994. Waterways Bird Survey: 1992–1993 population changes. *BTO News* 191: 8–10.

Marchant, J., & P. Beaven. 2000. Yellow Wagtails sinking – Waterways Bird Survey's latest population trends. *BTO News* 231: 12–13.

Marchant, J.H., & R.D. Gregory. 1999. *Waterways Breeding Bird Survey Pilot Survey 1998: adaptation of BBS census methods to rivers and canals.* R&D Technical Report W205. Environment Agency, Bristol.

Marchant, J.H. & D.G. Noble. 2000. *Waterways Breeding Bird Survey: progress report for 1998-99.* BTO Research Report 241. British Trust for Ornithology, Thetford.

Marchant, J.H., R. Hudson, S.P. Carter & P.A. Whittington. 1990. *Population trends in British breeding birds.* British Trust for Ornithology, Tring.

Marchant, J.H., R. Langston & R.D. Gregory. 1996. *The Waterways Bird Survey: an evaluation and appraisal of its future role*. R&D Technical Report W22. Environment Agency, Bristol.

Marchant, J.H., R.D. Gregory, D.E. Balmer, S.J. Gough & A.M. Wilson. 1999. *A comparison of breeding bird numbers along canals with and without a close season for fishing.* R&D Technical Report W193. Environment Agency, Bristol.

Marchant, J.H., D.G. Noble & L.P. Beaven. 2002. *Waterways Breeding Bird Survey: progress report for 2000–01.* Research Report 292. British Trust for Ornithology, Thetford.

Noble, D.G., M.J. Raven & S.R. Baillie. 2001. *The Breeding Bird Survey 2000*. BTO Research Report 265. British Trust for Ornithology & RSPB, Thetford.

Raven, P.J., P. Fox, M. Everard, N.T.H. Holmes & F.H. Dawson. 1997. River Habitat Survey: a new system for classifying rivers according to their habitat quality. Pp 215–234 in: P.J. Boon & D.L. Howell (eds), *Freshwater Quality: defining the indefinable?* The Stationery Office, Edinburgh.

Rushton, S.P., D. Hill & S.P. Carter. 1994. The abundance of river corridor birds in relation to their habitats: a modelling approach. *Journal of Applied Ecology* 31: 313–328.

Taylor, K. 1982. *BTO Waterways Bird Survey instructions*. British Trust for Ornithology, Tring.

Appendix 1. Waterway stretches covered by WBBS 1998–2000, ordered by nominal 1-km grid square, together with the limiting grid references, number of 500-metre sections covered in each year of coverage and the class of survey (random, WBS or other).

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
Random sites				**98**	**99**	**00**
.H4050	Many Burns River	H381495	H504513	–	6	–
.H5688	Glenlark River	H574871	H592889	–	6	6
.H6680	Ballinderry River	unknown	unknown	–	3	–
NC2634	Maldie Burn	NC252352	NC239340	4	4	4
NC3422	River Cassley	NC344226	NC368203	6	6	–
NG1846	Hamra River	NG187480	NG199463	–	4	4
NG4454	River Romesdal	NG440543	NG460549	–	–	10
NG9406	Allt Coire Sgoireadail	NG952068	NG974088	–	8	8
NG9804	Allt Coire nan Eiricheallach	NG998032	NG993054	5	5	5
NH1428	Allt a' Choire Dhomhain	NH144269	NH156302	6	–	–
NH3648	Allt Cam Ban	NH362497	NH357500	2	1	1
NH6614	River Findhorn	NH665140	NH705170	10	10	10
NH6632	River Nairn	NH684349	NH674320	10	10	10
NH6644	River Ness (non-tidal part)	NH664444	NH642413	5	8	8
NH9200	Am Beanaidh	NH923039	NH917099	–	10	10
NJ3416	Water of Buchat	NJ323189	NJ393157	–	10	–
NK0446	South Ugie Water	NK015472	NK056485	–	9	–
NM9478	Dubh Lighe	NM966787	NM932799	–	6	9
NN0096	River Kingie	NN042978	NN000964	10	10	10
NN0686	Allt a' Cham Dhoire	NN040863	NN064873	6	–	–
NN1620	Allt an Stacain	NN153213	NN162218	–	4	–
NN2082	River Spean	NN183837	NN208814	9	9	–
NN3872	Allt Feith Thuill	NN400731	NN372711	3	7	7
NN4488	Allt Coire Ardair	NN466887	NN440883	6	6	6
NN4888	Allt a' Chrannaig	NN484872	NN488885	3	3	3
NN6094	River Spey	NN640941	NN596938	10	10	10
NN6884	Unnamed, feeds into aqueduct	NN687855	NN681870	3	–	–
NN7296	Milton Burn	NN744988	NN719956	10	10	10
NO0644	Buckny Burn/Lunan Burn	NO090455	NO066480	–	10	10
NO1282	Baddoch Burn	NO137834	NO129820	5	5	5
NO2090	River Dee	NO213920	NO201908	4	4	4
NO3046	Dean Water	NO339479	NO286459	–	7	7
NO5410	Kenly Water	NO538113	NO553122	4	4	–
NS6826	River Ayr	NS682263	NS715281	–	–	10
NS7822	Duneaton Water	NS781226	NS814213	10	10	10
NS8230	Douglas Water	NS828300	NS840319	5	5	5
NS8280	Bonny Water	NS823803	NS793789	8	8	8
NS9804	Crook Burn	NS973063	NS984039	6	6	6

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
NT8452	Blackadder Water	NT857543	NT825529	10	10	–
NT9010	River Alwin	NT911108	NT926082	7	–	–
NT9412	Shank Burn	NT973153	NT952137	6	6	6
NU1812	River Aln	NU186138	NU215125	9	9	9
NX1674	Cross Water of Luce	NX180772	NX192742	10	–	–
NY0604	River Bleng	NY077033	NY099032	4	4	–
NY5076	Black Lyne	NY515784	NY496733	6	–	–
NY5084	Kershope Burn	NY483828	NY521848	10	10	10
NY5464	King Water	NY557668	NY527641	3	–	–
NY6086	Lewis Burn	NY631887	NY623874	–	4	4
NY7020	Hilton Beck	NY710200	NY719207	–	–	3
NY8012	River Belah	NY800124	NY819123	–	–	6
NZ2436	River Wear	NZ259374	NZ243361	2	4	–
NZ2818	River Skerne	NZ302193	NZ291207	6	6	–
NZ2844	River Wear	NZ284448	NZ302466	–	7	–
NZ6418	Skelton Beck	NZ659201	NZ668215	5	–	–
SD3406	Leeds & Liverpool Canal	SD365069	SD369092	–	–	6
SD7012	Eagley Brook	SD727123	SD712134	4	4	4
SD7466	River Wenning	SD746673	SD715676	8	8	8
SD7488	Clough River	SD764902	SD718906	–	–	10
SD8804	Rochdale Canal	SD885079	SD893038	10	10	10
SD9664	River Wharfe	SE004633	SD981659	–	8	8
SE0278	River Cover	SE045808	SE023791	6	6	6
SE3288	River Swale	SE320895	SE337880	8	8	8
SE3800	Dove & Dearne Navigation	SE411022	SE395012	4	4	4
SE9620	New River Ancholme	SE972164	SE974209	–	–	9
SH7032	Afon Eden	SH703321	SH700328	–	–	2
SH9424	Afon Eiddew	SH963244	SH947250	4	4	4
SJ1006	Afon Banwy neu Einion	SJ107068	SJ117078	3	–	–
SJ1228	Afon Iwrch	SJ134266	SJ126300	7	7	7
SJ2022	Afon Tanat	SJ185240	SJ226240	10	10	10
SJ4066	Shropshire Union Canal	SJ415667	SJ399669	–	10	10
SJ4276	Manchester Ship Canal	SJ476777	SJ451773	5	5	5
SJ6402	River Severn	SJ636042	SJ673034	8	8	–
SJ6654	River Weaver	SJ650523	SJ662552	10	10	6
SJ8610	Shropshire Union Canal	SJ849142	SJ875102	10	10	10
SK0206	Cannock Extension Canal	SK021069	SK019045	5	–	–
SK0836	River Dove	SK102374	SK104346	–	–	10
SK1686	River Noe	SK168846	SK152864	8	7	7
SK5662	River Maun	SK569638	SK601649	4	4	4
SK8874	Fossdyke Navigation	SK909749	SK880745	6	6	6
SK9458	River Brant	SK943600	SK940583	4	4	4
SN6456	Afon Teifi	SN646561	SN660569	–	5	5
SN6802	Lower Clydach River	SN684026	SN687045	5	5	5
SN7400	River Clydach	SN741010	SS738972	9	9	9

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
SO1204	Afon Rhymni	SO120059	SO138040	–	10	10
SO2230	Grwyne Fawr	SO229309	SO247293	–	6	–
SO4618	Afon Mynwy	SO477174	SO468200	–	10	10
SO6466	River Teme	SO629686	SO656691	7	7	7
SO6680	River Rea	SO662821	SO668787	9	9	9
SO7098	River Severn	SO722975	SJ707004	8	8	8
SO7454	River Teme	SO746563	SO758544	6	6	6
SO8004	River Frome	SO784057	SO808046	7	6	–
SO8628	River Severn	SO867304	SO844279	6	–	–
SP6002	River Thame	SP612027	SP605017	4	4	4
SP6260	Grand Union Canal	SP626619	SP630602	4	4	4
SS5204	River Lew	SS533057	SS539043	–	4	4
SS6810	River Taw	SS682115	SS685099	10	10	10
ST0280	Afon Elai	ST034824	ST039811	6	6	6
ST0820	River Tone	ST078203	ST084221	5	5	5
ST1600	River Otter	ST160012	ST170018	3	3	3
ST4646	River Axe	ST475475	ST452490	–	–	7
ST5660	River Chew	ST572617	ST584629	5	5	5
ST7846	River Frome	ST784462	ST787476	5	5	–
ST9480	River Avon	ST953800	ST960805	2	2	–
ST9682	River Avon	ST960831	ST977820	6	6	–
ST9804	River Allen	ST996040	ST990060	4	4	4
ST9838	River Wylye	ST948400	ST975395	–	–	5
SU1234	River Avon	SU127354	SU129330	6	6	6
SU2470	River Kennet	SU240700	SU253703	–	3	–
SU2870	River Kennet	SU280715	SU299710	5	5	5
SU5296	River Thames/Isis	SU539989	SU505971	10	10	10
SU5664	River Enborne	SU567648	SU557633	4	4	4
SU7266	River Loddon	SU743677	SU734663	4	–	4
SU9618	River Rother	SU961197	SU980190	–	6	6
SU9868	Virginia Water (outflow)	SU977686	SU987678	3	–	–
SX0872	River Camel	SX082742	SX065715	–	10	10
SX4682	River Lyd	SX478835	SX454834	5	5	5
SY1096	River Otter	SY112983	SY093960	7	6	6
SY2692	River Axe	SY262955	SY260922	5	5	5
SY6094	River Frome	SY606960	SY617955	–	–	3
TF0210	River Gwash	TF040107	TF028106	–	–	2
TF6002	Relief Channel	TF602038	TF601032	1	1	–
TF6412	River Nar	TF640133	TF663136	5	5	–
TL1840	River Ivel	TL182402	TL184429	5	–	–
TL2234	River Ivel	TL222369	TL223377	2	2	2
TL2296	King's Dike (Drain)	TL250965	TL222965	6	6	6
TL3288	Forty Foot or Vermuden's Drain	TL345879	TL315880	6	6	6
TL3296	Twenty Foot River (Drain)	TL324969	TL352989	8	7	7
TL6480	Mildenhall Drain	TL655813	TL650827	3	3	3

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
TL7672	River Lark	TL731739	TL762728	7	7	7
TM1822	Landermere	TM489239	TM497238	2	2	–
TM2434	Shotley Marshes	TM245361	TM252343	4	4	4
TQ0056	River Wey	TQ020569	TQ033571	5	5	5
TQ1480	River Brent	TQ146820	TQ146810	2	2	2
TQ1684	Grand Union Canal	TQ182836	TQ144843	10	10	10
TQ2288	River Brent	TQ240885	TQ241902	5	–	–
TQ5062	River Darent	TQ521617	TQ527627	3	3	3
TQ5244	River Medway	TQ529437	TQ542437	4	4	4
TQ5298	River Roding	TQ547996	TQ517981	8	8	8
TQ7252	River Medway	TQ740539	TQ704529	9	9	9
TQ7278	Cliffe Fleet	TQ744782	TQ746792	4	4	4
TQ9222	River Rother (non-tidal part)	TQ927243	TQ923227	3	3	3
TR0244	Great Stour	TR038449	TR032430	4	4	–
TR0826	New Sewer	TR058264	TR090273	7	7	7
TR1658	Great Stour	TR155590	TR163598	3	3	3
Non-random WBS sites				**98**	**99**	**00**
NH8350	River Nairn	NH806484	NH838507	–	9	8
NJ5117	River Don	NJ528173	NJ496181	–	9	9
NS5370	Forth & Clyde Canal	NS531704	NS563690	–	–	8
NS8696	River Devon	NS895961	NS863961	–	10	–
NT0765	Linhouse Water	NT068640	NT075660	–	7	7
NT5434	River Tweed	NT578346	NT528348	–	–	10
NY3748	River Caldew	NY371487	NY382516	–	7	7
NY8529	River Tees	NY857295	NY889283	–	10	10
SD4610	Leeds & Liverpool Canal	SD494104	SD453112	10	10	10
SD4617	Leeds & Liverpool Canal	SD461149	SD458193	10	10	10
SD5009	Leeds & Liverpool Canal	SD524093	SD494104	–	7	7
SD5064	River Lune	SD522648	SD482631	–	10	10
SD5284	Lancaster Canal	SD537831	SD520854	7	7	7
SD5308	Leeds & Liverpool Canal	SD540073	SD525092	–	5	5
SD5465	River Lune	SD545653	SD558673	–	5	5
SD5768	Rivers Wenning & Lune	SD585684	SD558673	–	6	–
SD5870	River Lune	SD571684	SD591721	–	–	5
SD6177	River Lune	SD611790	SD609750	–	8	–
SD8025	River Limy	SD810237	SD807266	–	–	6
SE1222	River Calder/Calder & Hebble Canal	SE135228	SE128224	–	2	2
SE2796	River Swale	SE291965	SE257974	–	10	10
SE4445	River Wharfe	SE440453	SE472447	–	10	10
SH7220	River Mawddach	SH718193	SH735223	–	7	7
SJ0868	River Clwyd	SJ092659	SJ082687	–	9	10
SJ4070	Shropshire Union Canal	SJ394706	SJ418719	–	6	6
SJ6452	Shropshire Union Canal	SJ629549	SJ638504	10	10	10
SJ6836	Shropshire Union Canal	SJ683347	SJ671389	–	–	9
SJ6967	Trent & Mersey Canal	SJ695671	SJ683689	5	5	5

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
SJ9279	Macclesfield Canal	SJ933779	SJ936814	8	8	–
SJ9586	Macclesfield Canal	SJ953860	SJ959880	–	5	5
SJ9785	Peak Forest Canal	SJ964882	SJ971859	–	5	5
SJ9786	River Goyt	SJ975867	SJ967883	–	5	5
SJ9822	Staffordshire & Worcs Canal	SJ995229	SJ971214	6	6	6
SK1883	River Noe	SK168846	SK204826	–	8	6
SK2181	River Derwent	SK205834	SK234806	–	10	10
SK2378	River Derwent	SK233806	SK240767	–	10	–
SK2476	River Derwent	SK244761	SK248727	–	8	8
SK3088	River Rivelin	SK322886	SK289871	–	7	7
SK4010	Erewash Canal	SK454471	SK469432	–	9	–
SK5715	River Soar	unknown	unknown	–	5	–
SK6236	Grantham Canal	SK639367	SK608368	8	8	8
SK6279	Chesterfield Canal	SK649808	SK611788	10	–	–
SK7351	River Trent	SK743515	SK767522	–	10	10
SO1024	River Usk	SO123234	SO095253	–	9	9
SO3780	River Clun	SO361805	SO387814	–	6	6
SO5112	River Monnow	SO495146	SO512122	–	10	10
SO5638	River Lugg	SO565372	SO556395	–	–	10
SO8687	Staffordshire & Worcestershire Canal	SO864855	SO862887	–	9	9
SO8757	Worcester & Birmingham Canal	SO865576	SO889577	5	5	5
SP1869	Stratford-upon-Avon Canal	SP187711	SP189671	8	8	–
SP4915	River Cherwell	SP484159	SP499151	–	–	10
SP7288	Grand Union Canal	SP727879	SP725901	10	10	10
SP9013	Grand Union Canal	SP933136	SP889140	–	10	10
SP9221	Grand Union Canal	SP929202	SP915230	8	8	8
SU4595	River Ock	SU473959	SU432963	–	10	10
SU9400	Alding Bourne/Lidsey Rife	SZ945999	SU958027	–	8	8
SX5363	River Plym	SX533637	SX569651	–	9	9
SX5365	River Meavy	SX527650	SX548669	–	10	10
SX9588	Exeter Canal	SX940894	SX963860	10	10	10
SY9999	River Stour	SZ004998	SY982994	–	6	6
TF1721	River Glen	TF201245	TF174210	–	10	–
TL1210	River Ver	TL123103	TL128084	–	4	4
TL1515	River Lea	TL140160	TL162145	–	7	7
TL1550	River Ivel	TL156519	TL156508	–	5	5
TL3701	River Lea/Lee Navigation	TL371018	TL375026	–	10	–
TL4963	River Cam	TL502644	TL487621	–	6	6
TL8187	River Little Ouse	TL817879	TL786869	–	8	8
TM1150	River Gipping	TM125491	TM113527	–	10	10
TQ0370	River Thames	TQ044695	TQ018721	–	10	10
TQ0492	Grand Union Canal	TQ062940	TQ044902	10	10	10
TQ0558	River Wey Navigation	TQ050578	TQ055586	–	2	2
TQ2865	River Wandle	TQ282651	TQ261687	–	9	9
Other non-random sites				**98**	**99**	**00**

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
SD4746	Lancaster Canal	SD487452	SD486488	10	–	–
SD5913	Leeds & Liverpool Canal	SD596168	SD599124	10	–	–
SD6100	Leigh Branch Canal	SD602018	SJ630996	8	8	8
SD8434	Leeds & Liverpool Canal	SD843365	SD845327	10	–	–
SD9012	Rochdale Canal	SD947182	SD917140	10	–	–
SD9702	Huddersfield Narrow Canal	SD984041	SD977025	4	–	–
SE0225	Rochdale Canal	SE015259	SE039245	7	–	–
SE0612	Huddersfield Narrow Canal	SE039119	SE079139	10	–	–
SE1138	Leeds & Liverpool Canal	SE107399	SE125384	5	–	–
SE2335	Leeds & Liverpool Canal	SE222368	SE238366	5	–	–
SE6029	Selby Canal	SE620320	SE585290	10	–	–
SE6416	New Junction Canal	SE634151	SE650184	7	–	–
SE6518	Knottingley & Goole Canal	SE648187	SE667193	4	–	–
SJ3398	Leeds & Liverpool Canal	SJ350994	SJ341969	10	–	–
SJ3699	Leeds & Liverpool Canal	SJ387981	SJ350994	10	–	–
SJ5659	Shropshire Union Canal	SJ553599	SJ581588	6	–	–
SJ6153	Llangollen Branch Canal	SJ621551	SJ617524	6	–	–
SJ6386	Bridgewater Canal	SJ669871	SJ625864	10	–	–
SJ6575	Trent & Mersey Canal	SJ644753	SJ666759	6	–	–
SJ6764	Middlewich Branch Canal	SJ689658	SJ679632	6	–	–
SJ7992	Bridgewater Canal	SJ784912	SJ796937	6	–	–
SJ7995	Bridgewater Canal	SJ762986	SJ799945	10	–	–
SJ8842	Trent & Mersey Canal	SJ881442	SJ885393	10	–	–
SJ9273	Macclesfield Canal	SJ930744	SJ925716	6	–	–
SJ9396	Peak Forest Canal	SJ935984	SJ944951	8	–	–
SJ9398	Ashton Canal (derelict)	SJ925976	SJ948985	6	–	–
SK2525	Trent & Mersey Canal	SK273274	SK238241	10	–	–
SK4644	Erewash Canal	SK454471	SK469431	10	–	–
SK4799	Sheffield & South Yorkshire Canal	SK468997	SE504001	7	–	–
SK6929	Grantham Canal	SK709292	SK676307	10	10	10
SN7305	Swansea Canal	SN752065	SN724041	6	–	–
SO7407	Gloucester & Sharpness Canal	SO737049	SO758093	10	–	–
SO8762	Droitwich Canal	SO868611	SO884627	5	–	–
SO9387	Dudley Canal	SO932892	SO953883	10	–	–
SP1581	Grand Union Canal	SP181804	SP144818	8	–	8
SP1996	Birmingham & Fazeley Canal	SP202984	SP186938	10	–	–
SP4083	Oxford Canal	SP382831	SP421822	10	–	–
SP6791	Grand Union Canal	SP695916	SP664927	8	–	–
SP8737	Grand Union Canal	SP869398	SP877372	6	–	–
ST0213	Grand Western Canal	ST023134	SS999131	10	–	–
ST3134	Bridgwater & Taunton Canal	ST301365	ST322325	10	–	–
ST7666	Kennet & Avon Canal	ST782657	ST755642	10	–	–
SU2063	Kennet & Avon Canal	SU224635	SU179618	10	–	–
SU8602	Chichester Canal	SU858036	SU842013	8	8	8
SU8953	Basingstoke Canal	SU809536	SU853527	9	–	–

Nominal 1-km reference	Waterway name	Start and end grid references		Number of 500-m sections surveyed, 1998–2000		
TL8094	River Wissey	TL807945	TL774962	–	10	10
TQ9427	Royal Military Canal	TQ958292	TQ938248	10	–	–

Appendix 2. RHS variables and bird species included in this analysis

(a) Codes for RHS habitat variables used in the analysis

Code	RHS habitat variable
alt	Altitude (m)
boil2	Presence of boils
cwoodeb2	Presence of coarse woody debris
flocat2	Flow category (higher scores = greater volume of water (cumecs))
glide	Presence of glides
habmodsc	Habitat modification score (higher scores = greater modifications of waterway)
matisle2	Presence of mature islands
bough2	Presence of overhanging boughs
run	Presence of runs
slope2	Gradient of channel
depth2	Depth of water
width	Width of water
riffpres	Presence of riffles
unvegbar	Presence of unvegetated bars
vegbar	Presence of vegetated bars
bothreinf	Presence of reinforcement ion both banks
blmwood	Presence of broad-leaved/mixed woodland within 50m
casrap	Presence of cascades and/or rapids
exprock	Presence of exposed rock/boulders
igrass	Presence of improved grassland within 50m
noperflo	Presence of areas of no perceptible downstream flow (e.g. pools, ponded reaches)
moor	Presence of moorland within 50m
bridgepres	Presence of bridges
weirpres	Presence of weirs
owater2	Presence of bodies of open water within 50m
poached	Presence of poached banks
rpast	Presence of rough pasture within 50m
scrub	Presence of scrub within 50m
tallhb	Presence of tall herbs within 50m
tilled	Presence of tilled land within 50m
tree	Extent of bank-side trees
urbdev	Presence of urban/developed land within 50m
wetland	Presence of wetland within 50m (marsh, bog)
pctcliff	Extent of river cliffs
pctbare	Extent of bare ground on banks
pctsimple	Extent of simple vegetation (2-3 species maximum) on banks

pctcomplex	Extent of complex vegetation (herbs, scrub and trees) on banks
rock	Extent of bedrock as channel material
gravpeb	Extent of gravel/pebbles as channel material
sand	Extent of sand as channel material
silt	Extent of silt as channel material
vegpres	Extent of channel vegetation
algpres2	Extent of algae in channel
brypres2	Extent of bryophytes/lichens in channel
floatpres2	Extent of floating vegetation in channel
emergepres2	Extent of emergent vegetation in channel
subpres2	Extent of submerged vegetation in channel

(b) List of species (and their two-letter codes) included in the analysis of RHS data

CG	Canada Goose
CO	Coot
CS	Common Sandpiper
CU	Curlew
DI	Dipper
GD	Goosander
GL	Grey Wagtail
KF	Kingfisher
L.	Lapwing
MA	Mallard
MH	Moorhen
MS	Mute Swan
OC	Oystercatcher
PW	Pied Wagtail
RB	Reed Bunting
RW	Reed Warbler
SM	Sand Martin
SW	Sedge Warbler
YW	Yellow Wagtail

Appendix 3. RHS variables deleted or combined

(a) Sweep-up variables

i) Deleted irrelevant variables

Accreditation ID
Addit Channel Substrate 1
Addit Channel Substrate 2
Addit Channel Substrate 3
Alders
Animals
Area Name (Public Face boundaries)
Area Name (Water Monitoring boundaries)
Artificial Two-stage (L)
Artificial Two-Stage (R)
Bankfull Width
Banktop Height (97) (L)
Banktop Height (97) (R)
Bed Material at Site
Bed Visible
Comments
Composite (L)
Composite (R)
County
Dataset
Discrete Sand Deposits
Discrete Silt Deposits
Diseased Alders
Distance From Source
District Name
Downstream Site Number
Downstream Site Number of Yributary
Downstream Site Rank Difference
Drift Geology Number
Embanked (L)
Embanked (R)
Embanked Height (m) (L)
Embanked Height (m) (R)
Exposed Bankside roots
Ext Embankments (L)
Ext Embankments (R)
Fallen Trees
Floating Mats
Flow Sequence
Fords
Gentle (L)
Gentle (R)
Giant Hogweed
Grid Reference of Source
Habitat Modification Class
Height of Source

Himalayan Balsam
How?
HQA adjusted
HQA bank
HQA Channel Substrate
HQA Channel Vegetation
HQA Flow Type 95
HQA Land Use
HQA Point Bar
HQA Special Features
HQA Tree
HQA Vegetation
Hydrological Unit Number
Is Banktop Height Also Bankfull Height (R)
Is Banktop Height Also Bankfull Height (L)
ITE Land Use
Japanese Knotweed
Laminar Flow
Landscape Character Area
Landscape Natural Area
Land Management
Leap/Catchment
Location of Measurement
Major Impacts
Map Number
Mowing (L)
Mowing (R)
NCCdrift
NCCsolid
No Culverts
No Deflectors
No Intermediate Revetments
No Major Revetments
No Minor Revetments
No Nuisance Plants
No Other Intermediate Structures
No Other Major Structures
No Other Minor Structures
No Outfalls
No Sluices
State Other Recent Management
Other Nuisance
Other Structures
PCA1
PCA2
Region Public Face
Region Water Monitoring
Reinforced – Top Only (L)
Reinforced - Top Only (R)
Resectioned (L)
Resectioned (R)

Resectioning (L)
Resectioning (R)
Riparian Zone (L)
Riparian Zone (R)
Rock / Scree (L)
Rock / Scree (R)
Set Back Embankment (L)
Set Back Embankment (R)
Shading of Channel
Single Photo
Site Surveyed From
Solid Geology Code
Special Feature Photo
Spot Check 1
State Other Special Features
Steep (>45) (R)
Steep(>45) (L)
Step-pool
Survey Affected By Conditions?
Surveyor's Initials
Terraced Valley Floor
Time of survey
Trashline height (m)
Trashline Width (m)
Tributary
Underwater Tree Roots
Valley Form
Vertical + Toe (L)
Vertical + Toe (R)
Vertical/Undercut (L)
Vertical/Undercut (R)
Water Impounded By Dam?

ii) Deleted relevant variables

Artificial Channel – no entries
Channel Enhancement – no entries
Channel Form – no entries
Country – all entries 'UK'
Enhancement (L) – no entries
Enhancement (R) – no entries
Fen – all entries '0'
GQA90 – all entries'0'
GQABio – insufficiently variable
No Bridges (road &foot) – all data 'Missing'
No Other Artificial Features – all data 'Missing'
No Road Bridges – all data 'Missing'
No. Weirs – all data 'Missing'
Recent management – all '0' or '98'
Rifle-Pool – no entries

Scrub / Rough pasture (L) – no entries
Scrub / Rough pasture (R) – no entries
Static Flow – no entries
Water meadow - all entries '0'
Water Quality 85 – all entries '0'
Waterfall/Cascade - all entries '0'

iii) Combined variables

Left and right banks:

Highest value on either side used, therefore if "E" on either side then total = "E", if "P on either side then total = "P", etc. Same for categorical variables with numbers (e.g. Tree (L) and Tree(R)).

Broadleaf/Mixed Woodland
Coniferous Plantation
Improved Grassland
Moorland/Heath
Open Water
Orchard
Rough Pasture
Poached Bank
Scrub
Tilled Land
Tall Herbs
Trees
Urban Development
Wetland

Other variables:

- Natural and artificial open water combined as 'opwatr' (used maximum value). 'Open Water L' and 'Open Water R' categories combined to give 'opwatlr' (used maximum value). 'opwatr ' and 'opwatlr' combined as 'owater' (chose maximum value) as data were inconsistent.

- 'No. pools' converted to presence/absence, then combined with 'Pools' variable as the data in the two categories were inconsistent (used maximum value). Resulting variable combined with 'Marginal dead water' and 'Ponded reach' variables (used maximum value) to give category which indicated presence of areas with no perceptible flow – 'noperflo'.

- 'Reinforced toe only (L)' and 'Reinforced whole (L)' combined (used maximum value) and same for variables on R. Converted to present/absent (removed extensive category). L and R values then combined (used **minimum** value) to give category that denotes presence of reinforced banks if they occur on both sides of the river, but not if they only occur on one.

- Marsh and bog (fen excluded – no data) combined (used maximum value) and resultant

variable combined with wetland (combined L and R variable – see above) as data were inconsistent (used maximum value). Marsh and Bog also included as separate variables.

- 'Mown' and 'Weedcut' variables combined (used maximum value) and converted to presence/absence (extensive removed).

- Vegetated side, mid-channel and point bars combined (used maximum value) – converted to presence/absence as point bars was a count and the other two variables were scored as E/P/0. Unvegetated bars converted in same way.

- Cascades and rapids combined as 'casrap' (used maximum value).

- Exposed boulders and exposed bedrock combined as 'exprock' (used maximum value).

- Number of minor, intermediate and major bridges summed and converted to presence/absence measure 'bridgepres' (includes 'Culverts' – only 3 sites, two of which already had bridges).

- Number of minor, intermediate and major weirs summed and converted to presence or absence measure 'weirpres'.

- Small waterfalls and big waterfalls combined (used maximum value).

(b) Spot-check variables

i) Deleted variables

Left Bank Material
Right Bank Material
Left Bank Modification
Right Bank Modification
Left Bank Modification #2
Right Bank Modification #2
Left Bank Features (except 'cliff' data)
Right Bank Features (as above)
Land Use within 5m
Flow Type
Channel Modification
Channel Modification #2
Channel Features
Channel Features #2

ii) Combined variables

- Left bank top, left bank face, right bank top and right bank face vegetation structure combined to give overall vegetation structure (used maximum value).
- Floating-leaved vegetation and free-floating vegetation combined (used maximum value).
- Emergent reeds/sedges/rushes, emergent broad-leaved vegetation and amphibious vegetation combined (used maximum value).
- Submerged broad-leaved, linear-leaved and fine-leaved vegetation combined.