BTO Research Report 561

Trends among breeding water birds during 1974–2009, along canals in British Waterways ownership

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EXECUTIVE SUMMARY

1 BTO has operated two long-running surveys designed to monitor population change among breeding birds along linear waterways in the UK. A territory-mapping survey, the Waterways Bird Survey (WBS) ran from 1974 to 2007, covering water birds only. A new scheme, the Waterways Breeding Bird Survey (WBBS), began in 1998 and is ongoing. WBBS covers all bird species and its sites are mainly randomly selected. It uses transect methods similar to those of the BTO/JNCC/RSPB Breeding Bird Survey (BBS), which monitors birds more generally across the countryside.

2 With now 12 years of WBBS data, it has recently become possible to calculate joint WBS/WBBS indices of change. These indices are available for up to 25 species of water bird and cover periods beginning as early as 1974. Indices for waterways breeding birds help to assess conservation priorities at species level and, when combined into a multi-species indicator, provide a headline summary of bird population trends in this unique habitat.

3 Species trends derived from national WBS and WBBS data provide clear evidence of rapid population change, for example for the demise of a number of species formerly associated with lowland wet meadows, including Snipe, Redshank and Yellow Wagtail, and the rise in introduced geese. For the most abundant species it is possible to divide the sample, for example by region or waterway type, to investigate population change in more detail.

4 The present report investigates the subsample of WBS and WBBS sites that are under the ownership of British Waterways. These are all canals or river navigations in England or Wales, representing a high proportion of such sites in those countries. Using data from those sites alone, there are sufficient data to provide population indices for 14 bird species over the recent 25-year period.

5 Species trends are generally very similar between British Waterways sites and all sites in England & Wales. Increases appeared to be weaker on British Waterways sites than elsewhere in England & Wales for Canada Goose, which has long been abundant on canals, and stronger for Reed Warbler, for which canals may represent a secondary habitat. Increases of Mallard and Coot also appear to be steeper on British Waterways sites than elsewhere. Decrease for Lapwing, Sedge Warbler and Pied Wagtail appeared to be stronger on British Waterways canals than on other waterways in England & Wales; joint CBC/BBS trends show increase for Pied Wagtail in the countryside as a whole.

6 The present investigation of our data for British Waterways sites has been limited to a single range of years and a consequently a relatively small number of species. Some further options for exploring bird population trends on British Waterways sites are presented. These include compiling a multi-species breeding-bird indicator as a guide to waterway management.

1 INTRODUCTION

Rivers and canals are components of the countryside that are rich in birds, vulnerable to rapid large-scale change, and not covered well by general monitoring programmes. It is important, therefore, that the populations of breeding birds along linear waters are studied using dedicated surveys. Detailed data collection for breeding birds, alongside habitat recording, can help direct the conservation of wildlife along rivers and canals.

Since 1974, BTO has run two separate annual schemes that have these aims: WBS and WBBS, as discussed below. After an overlap period from 1998 to 2007, WBBS has now taken over from WBS as the main way by which breeding birds of linear waterways are monitored in the UK. The results feed into species conservation and can also help assess the value for wildlife of waterway stretches or catchments.

1.1 The Waterways Bird Survey (WBS)

The Waterways Bird Survey (WBS) began in 1974 and closed after the 2007 season. BTO volunteers conducted mapping censuses alongside linear waters, both rivers and canals, with the aim of monitoring bird population change in these important yet vulnerable habitats throughout the UK. The primary role of the WBS has been to record population changes among species poorly represented in the BTO's other monitoring schemes, principally, in its first two decades, the Common Birds Census (CBC). Carter (1989), Marchant *et al.* (1990) and Newson *et al.* (2003) have provided overviews of the WBS and its results.

The territory-mapping method, as was used by both CBC and WBS, produces high-quality maps of the activity recorded for each bird species during the breeding season. These data can also be used to investigate, at a variety of spatial and temporal scales, the ways in which breeding birds use the habitats available to them. Since observers can choose their own survey sites, however, the resulting distribution of sites is non-random and is not necessarily a representative sample of the wider countryside. Because the mapping method is labour-intensive, surveys were relatively few in number. These problems, as they related to CBC, were all addressed by the introduction of a new scheme, the BTO/JNCC/RSPB Breeding Bird Survey (BBS).

BBS began in 1994 and is an ongoing programme that was introduced specifically to take over from CBC as the main way in which population changes of birds are measured in the wider countryside. The CBC ceased in 2000 after 39 years of operation, following a seven-year overlap period between BBS and CBC. Population trends of common and widespread UK birds are now monitored by BBS index series, beginning in 1994, and by joint CBC/BBS trends, most of which date from 1966 (Baillie *et al.* 2010).

The WBS suffered the same disadvantages for bird population monitoring as the CBC did. In addition, WBS covered only a set list of waterside bird families and species, and so provides no information on the more widespread bird species as they occur in the waterside environment. These drawbacks were addressed by starting a new scheme in which BBS-style transect methods are applied to waterside surveys.

1.2 The Waterways Breeding Bird Survey (WBBS)

The BTO has been developing a Waterways Breeding Bird Survey (WBBS) since 1998, in conjunction with the Environment Agency's R&D programme. The overall aims of the project have been to:

- *supplement data from the BBS with counts from rivers and canals, thus maintaining or expanding the level of bird population monitoring currently available through BBS, and satisfying the needs of organisations with specific interests in ongoing long-term bird monitoring, such as JNCC and RSPB; and*

- *gather bird and bird–habitat data, relevant to nature conservation along waterways, that fulfil the requirements of the Environment Agency, and its sister organisations in Scotland and Northern Ireland, that have responsibilities specific to linear waters.*

After 12 years of successful operation, it is clear that WBBS is viable as a long-term survey and can provide results of major value for population monitoring. These supplement the data from BBS for the countryside as a whole, both as trends for individual species and as multi-species indicators for the waterside environment.

Long-term trends are now available that incorporate the results from both schemes to give a run of annual population monitoring since 1974. These were presented for the first time by Baillie *et al.* (2010), using data for the period to 2008 and updated to 2009 by Marchant *et al.* (2010). Trends for the more abundant species can be produced from subsets of the UK data, for example to investigate differences in trends by region or habitat type, although the scope for this is severely limited by sample sizes.

1.3 Aims of this report

The aims of this project have been:

- *to undertake an analysis of long-term breeding bird population trends on English and Welsh canals in British Waterways (BW) ownership, for common water bird species occurring in sufficient numbers, using Waterways Bird Survey and Waterways Breeding Bird Survey data; and*

- *to report the results of these analyses, comparing the results from British Waterways (BW) sites and those drawn from the full set of WBS/WBBS data, including rivers and canals, throughout England and Wales.*

This report describes the field methods of the two BTO projects for monitoring breeding birds along waterways, and presents the results of the relevant analyses of the joint WBS/WBBS trends. Plots are included of trends from BW sites in relation to the national trend and attention is drawn to cases where these may be different and to possible reasons underlying these differences.

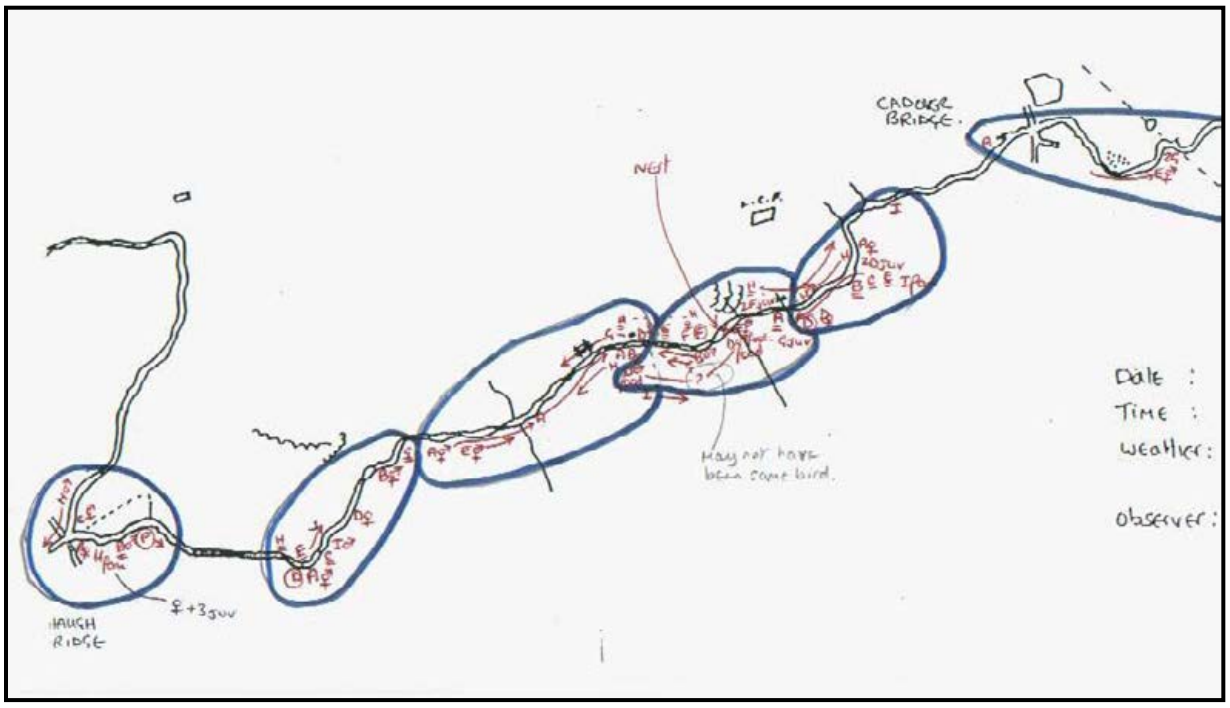
2 METHODS

2.1 Methods of the Waterways Bird Survey

Taylor (1982) and Marchant (1994) have described WBS procedures in full. The bird census method used was territory mapping, which produces an estimate of breeding pairs and a map of breeding territories for each species, stretch and year (see Figure 1). Details of the habitats available to the birds were also mapped. Plots were chosen by the observers themselves, under guidance from BTO staff, and were stretches typically 4–5 kilometres long that were of relatively easy access and of which at least one bank could be walked.

Observers were asked to make nine visits to their site each breeding season. WBS coverage was restricted to waterside specialist birds such as grebes, ducks, geese, swans, waders, and reedbed passerines. Compilation of visit data onto species maps was performed by the observers, many of whom began the process of assessing territory boundaries. To promote consistency through time and across the sample, final decisions on territory numbers at each site were made by a small number of trained staff at BTO HQ.

Figure 1. Example species map from the Waterways Bird Survey. The species is Grey Wagtail *Motacilla cinerea*.



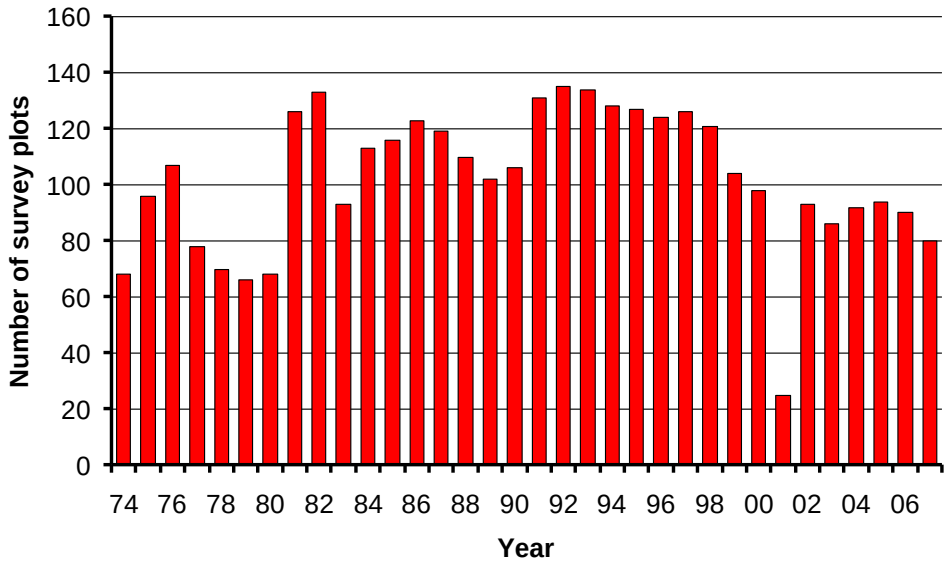
A grand total of 526 different WBS sites were covered in the UK (Table 1), with three more in the Republic of Ireland, and around 3,480 surveys were conducted. Many surveys were very long running: 106 sites provided data for more than 10 years, 32 for more than 20 years, and eight for more than 30 of the survey's 34 years.

Table 1. **Numbers of WBS plots surveyed, by country and type. UK totals include three fast river stretches on the Isle of Man. 'Slow' rivers have a gradient of <5 m/km and generally lie in a broad valley, and 'fast' rivers have a gradient of >5 m/km. The overall mean length of plots was 4.6 km, and 2,407 km were surveyed in one or more years.**

Waterway type	England	Wales	Scotland	N Ireland	UK total
Fast rivers	73	12	29	4	121
Slow rivers	227	14	21	11	273
Canals	90	1	4		95
Mixed or other types	33	1	1	2	37
Total	**423**	**28**	**55**	**17**	**526**

A maximum annual total of 135 WBS returns was received in 1992 (Figure 2). The number of surveys conducted began to fall after the introduction of WBBS in 1998 and reached a low point of just 25 surveys in 2001, when all survey fieldwork was limited by the outbreak of FMD.

Figure 2. **Numbers of WBS mapping plots surveyed during 1974–2007.**



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 up to 25 species that occur on at least 15 or so plots in each year, where number of territories can be modelled as a function of year and site (e.g. Newson *et al.* 2003).

2.2 Methods of the Waterways Breeding Bird Survey

The WBBS, which began in 1998 and replaced WBS after the 2007 season, is a two-visit transect survey based closely on BBS methodology.

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

2.2.1 Selection of sites for coverage

The following procedure was used to select waterways randomly. First, we made a list of all tetrads (2x2-km national grid squares, bounded by the even-numbered grid lines) in the UK (omitting only those where the southwestern 1-km square held no land), and ranked them in random order. Next, beginning at the top of the list, we examined each tetrad on the Ordnance Survey 1:25,000 map, discarding those without a waterway running through them, until the required number of tetrads with waterways was identified. 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 waterway to select from within the square. Third, we assigned each selected tetrad by BTO region and gave it a regional priority ranking based on the original random numbering.

The number of tetrads selected for possible WBBS coverage was initially 263. The total was increased to 511 in 2002 and to 529 in 2004.

A clear definition was required of the water bodies that formed the population being sampled. There were questions, for example, over whether waterways best described as ditches or drains, as opposed to rivers and canals, should be included in the survey. For rivers, a policy was needed on whether headwaters should be excluded and how this could be achieved, and on whether broad or tidal stretches should be included. For the purpose of the WBBS, therefore, a waterway was defined as any double blue line, with shaded in-fill, on the Ordnance Survey (OS) 1:25,000 Pathfinder/Explorer/Outdoor Leisure map series. Single blue lines, typically minor headwaters and drainage ditches, were ignored, as were all non-linear water features, or linear features less than 500 metres in total length. 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 'NTL' on the OS maps; no upper width limit was applied, and thus river stretches were sometimes tens of metres in width.

No stratification was employed in creating the sample, since it was not required to meet the aims of survey's initial phases. Stratification could be applied to WBBS results and plot selection in the future, however, for example on the basis of waterway type, RHS data, water quality, waterbird density or observer density, with the aim of either reducing the variance of the results or making more efficient use of the available volunteer manpower.

For each selected random waterway, an A4-sized map was prepared showing the boundaries of the random tetrad (positioned roughly centrally) and the selected waterway. The waterway was picked out with a highlighter pen, typically for several kilometres in both directions beyond the tetrad boundary. These maps were sorted by BTO region and sent to the relevant BTO Regional Representative (the RR), whose job it was to match each site with an observer. Sites were referred to by the grid reference of the southwestern 1-km square of the selected tetrad.

Start and end points of the actual 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 a large majority of cases, and a survey route set up that could be followed on a long-term basis.

Aside from the random stretches, determined on the basis described above, the WBBS sample has also, since 1999, included a substantial number of non-random stretches that were chosen because there are WBS mapping data available for the same sites. The latter are referred to in this report as 'WBS-linked' stretches. They differ from the random stretches in their geographical distribution and, having been freely selected by the observers, may perhaps be biased towards places that are richer in breeding birds.

Surveys at sites falling into neither of these categories, listed as 'other non-random stretches', are not encouraged but have been included in the data set where available. The canal sites selected for their fishing seasons in 1998 are included in this 'other' category,

2.2.2 WBBS fieldwork methods

The BBS method had already proved to be enjoyable, popular with observers, and well suited to its purpose. The original outlook for WBBS was as a direct extension to that scheme and, when WBBS was set up, modifications to BBS procedures were 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, April–June – thus ideally one visits between 1 April and 15 May and a second between 16 May and 30 June (www.bto.org/bbs). 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. Some details of the design of forms were altered in minor ways between 1998 and 2000 but, once established, the field methods of WBBS have been kept constant. Forms for 1998–99 are each appended to the reports from WBBS for those seasons (Marchant & Gregory 1999, Marchant & Noble 2000). These contain full details of fieldwork methods and recording.

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's section length, whereas in BBS they are 200 metres;*
- *transects are not fixed at 2 km, as BBS transects are, 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 extra information to be recorded about the waterway itself.*

Other aspects of fieldwork and analysis are identical. WBBS follows BBS in having a reference 1-km square for each survey site, even though the nominal reference may miss the actual survey by 2–3 km.

As on 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. Observers coded the main features of up to three habitat types per 500-m 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 used widely in BTO surveys.

Within each region, BTO RRs seek volunteer observers to cover as many of their selected sites as possible, beginning at priority 1 and working down the list. RRs distributed survey packs and collected completed forms for return to BTO HQ.

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 efficiencies also for analysts in using this method. Importantly, its random sampling design ensures that the results are representative of the waterway habitat.

2.2.3 Coverage achieved by WBBS in 1998–2009

Table 2 shows the numbers of WBBS stretches surveyed, by country within the UK, according to the class of survey, to the end of 2009. WBBS observers surveyed 395 different waterway stretches in England & Wales during the 12-year period. Coverage in Northern Ireland, by contrast, was intermittent and at a very low level.

Table 2. Numbers of WBBS stretches surveyed during 1998–2009, by country and selection type.

Selection type	England	Wales	Scotland	N Ireland	UK total
Selected but not covered	52	7	95	30	184
Random sites covered	199	45	96	5	345
WBS-linked stretches	106	4	11		121
Other non-random stretches	40	1	1	5	47
Total stretches covered	**345**	**50**	**108**	**10**	**513**

The 529 random stretches selected are mapped in Figure 3 with green and red symbols. The pattern of their distribution follows from the area-based method of selection which, since 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 barely represented in the sample since, by chance, just two of the tetrads selected there contained a waterway.

Of the random stretches selected, 184 have not yet been surveyed (shown by red dots in Figure 3). These sites are mainly in Scotland and Northern Ireland, where potential observers are fewest, but some sites in England and Wales are also still awaiting cover. The regional pattern of the sites not yet covered reflects topography, with some upland sites being difficult to access, the distribution of potential observers, and the efficiency of regional organisation for the survey.

The geographical distribution of the 121 WBS-linked stretches is also shown in Figure 3. These sites are mainly in England, with four in Wales and 11 in Scotland (Table 2). Within England there has traditionally been strong participation by the Lancaster & District Bird Watching Society and the Sheffield Bird Study Group, who each began their contributions with pilot studies for WBS in 1973.

Figure 3. **Distribution of WBBS stretches. Random stretches that have been covered at least once during 1998–2009 are shown as green squares and those not yet surveyed as red dots. WBS-linked stretches surveyed are shown as yellow triangles.**

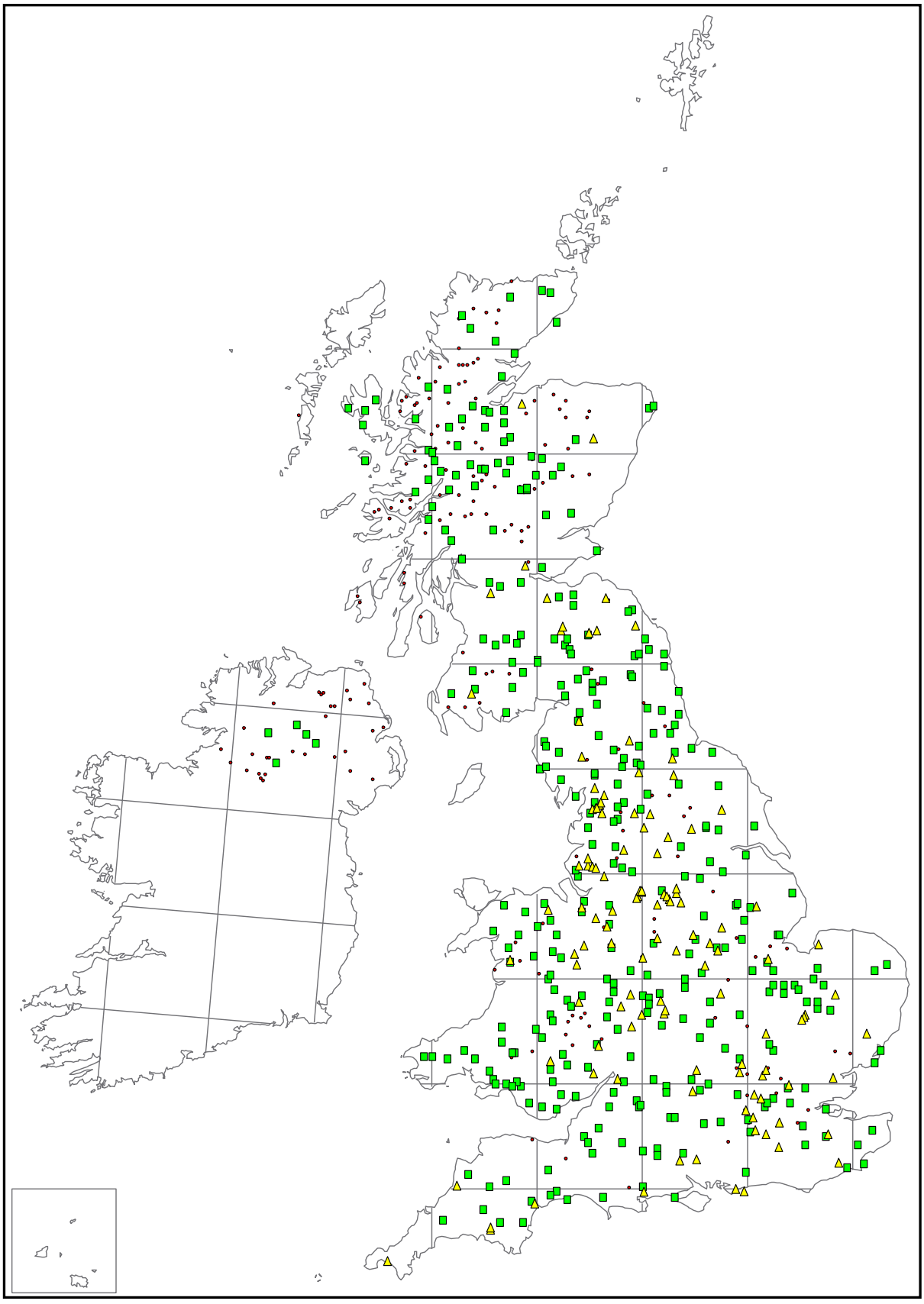


Table 3. Numbers of WBBS surveys during 1998–2009, by year and class of stretch.

Year	Random stretches	WBS-linked	Other non-random	Total stretches	Total 500-m sections	Mean length of stretch (km)
1998	108	20	40	168	1,124	3.35
1999	117	68	1	186	1,261	3.39
2000	110	65	1	176	1,205	3.42
2001	24	27	0	51	380	3.73
2002	162	66	0	228	1,515	3.32
2003	198	64	0	262	1,703	3.25
2004	219	68	0	287	1,863	3.25
2005	231	68	2	301	1,977	3.28
2006	226	65	4	295	1,968	3.34
2007	213	57	0	270	1,770	3.28
2008	201	74	1	276	1,843	3.34
2009	200	82	1	283	1,887	3.33
Total survey-years	2,009	724	50	2,783	18,496	3.32

The annual samples of WBBS stretches surveyed are explored further in Table 3. The survey has been surveying about 900 km of waterway annually in recent seasons. It has proved difficult to increase the sample of random stretches using the present set of selected sites, since many are difficult to access. The 1998 sample included 60 canal stretches that had been chosen non-randomly on the basis of the fishing seasons in operation there. Some of these were also in the random sample or were also WBS plots. The 40 plots that did not also fall into either the random or the WBS category were dropped from the survey in subsequent seasons. WBS observers were asked to contribute WBBS data also from their stretches, beginning in 1999, and many conducted both surveys on their stretches until 2007. The number of WBS-linked stretches increased markedly in 1999 and again in 2008, when WBS itself ceased operation and observers were asked to transfer to WBBS. Most surveys since 1999 have been repeat surveys at stretches already covered, and can therefore contribute to models of population change.

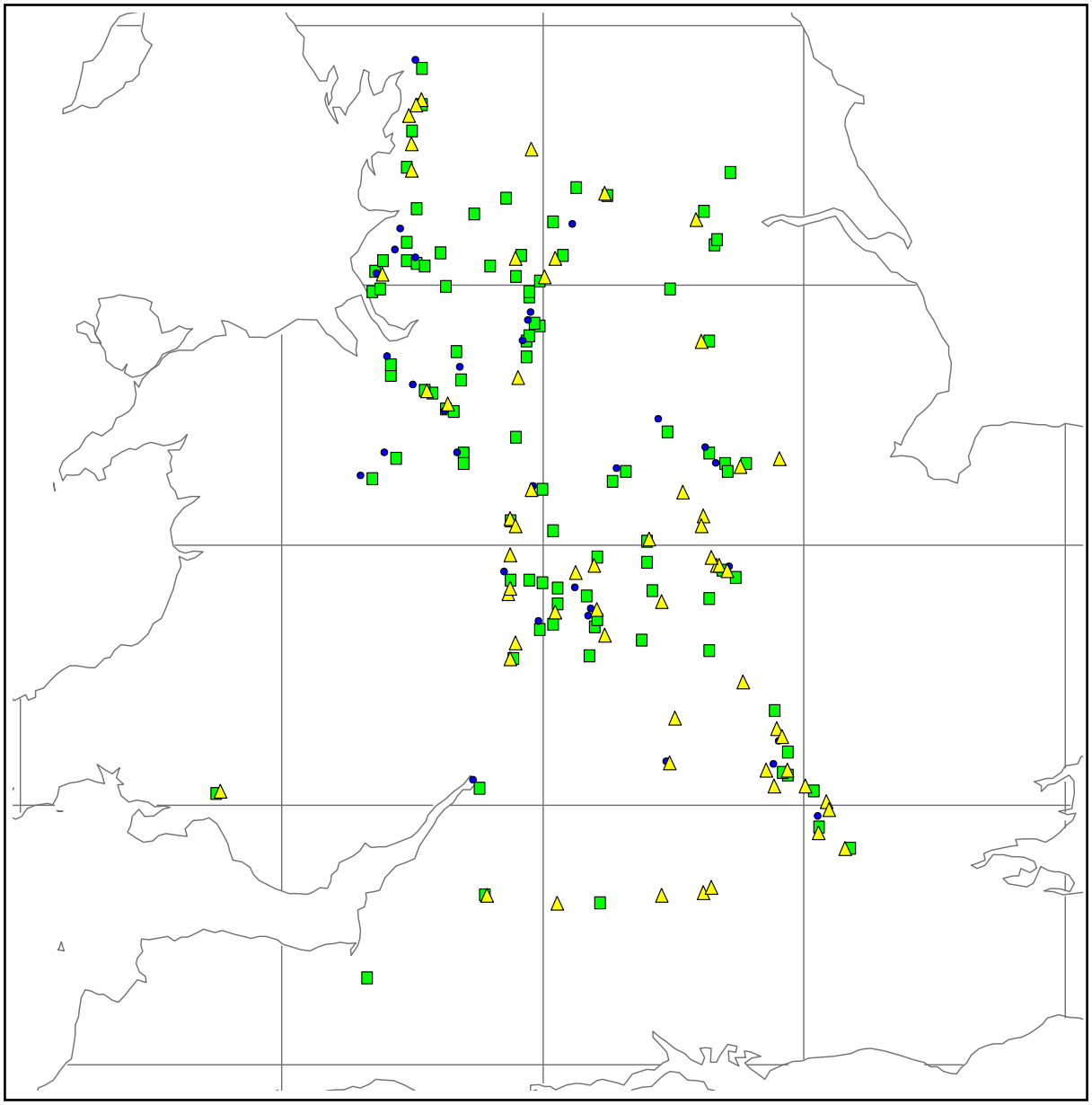
Only 24 random stretches and 27 WBS-linked ones were surveyed in 2001, when FMD imposed severe restrictions on access to the countryside, representing just 29% of the coverage in the previous year. These sites were concentrated in the English Midlands and the north of Scotland, these being areas where access generally was curtailed to a lesser degree than elsewhere (Marchant *et al.* 2002). The 2001 WBBS sample is thus rather different in character from the samples in other years.

2.3 Sites under British Waterways ownership

The full lists of WBS and WBBS sites were sent to BW for them to identify the sites under their ownership. Sites considered relevant to the current study were all canals, in either England or Wales, and under BW ownership. Although BW owns the great majority of English and Welsh canals, there were WBS sites on eight canals that were not within BW ownership. In total, 94 WBS and 95 WBBS sites were relevant to the study. Within these lists of sites, 33 WBS sites also appeared in the WBBS sample: for some of these both surveys were conducted in some of the years, whereas in others the observer conducted WBS originally but switched to WBBS without an overlap. All the relevant sites are mapped in Figure 4.

The distribution of canals in England & Wales, avoiding high ground and forming routes linking major population centres, is clearly shown in the distribution of sites included in the study.

Figure 4. **Distribution of WBS and WBBS sites on BW-owned canals in England & Wales. WBS sites also in the WBBS sample are shown as blue dots, and others as yellow triangles. WBBS stretches surveyed are shown as green squares.**



2.4 Trend analysis from WBS/WBBS and WBBS data

For WBS the number of apparently occupied territories along the stretch of waterway was taken as the count unit. For WBBS, counts are provided by 500-m section but, because the individual WBBS transect sections cannot be treated as independent, it is necessary for statistical reasons to combine these into a single count for each whole survey. We used the sum of the counts across the transect sections for each stretch of waterway in the analysis: counts were first summed across the four distance bands and the higher of the counts across the two visits at the level of each transect section being summed for use in the analysis. The procedure we have used for finding a single count differs from that standardly employed for BBS analyses, where counts are summed across both sections and distance bands and the higher of these overall sums across the two visits enters the calculations.

The WBS and WBBS data sets were combined for the calculation of joint trends. Because the nature of WBBS and WBS coverage in 2001 had been so different from the other years, 2001 data were not used at all in these calculations.

Annual population changes were produced using a full site-by-year log-linear GLM with Poisson error terms. Only waterway stretches that were surveyed in two or more of the years of interest were included in the analysis. Waterway stretches with zero counts for a species in all years were not included in the model: this does not affect the model's estimates of annual effects, but leads to more conservative estimation of the standard errors. Counts were corrected to account for overdispersion, with adjustments being made to the standard errors.

To account for the varying length of WBBS survey stretches, the log of the number of transect sections within each waterway stretch was used as an offset variable in the model (Stokes *et al.* 2003). In this case, the offset variable serves to normalise the fitted cell means to a per-section basis, since it is the total count of birds across the whole stretch that is used in the model, not the individual transect section counts. The offset for WBS sites was set to unity.

Confidence limits were calculated using bootstraps with 199 samples and are presented at the 85% level in charts and analysed at the 95% level. Population indices and bootstraps were smoothed using the TPSPLINE procedure in SAS and population change estimates were based on these smoothed indices. The time series analysed omitted the first and last years of the study to avoid any extreme effects of smoothing at the two ends of the study period. The period considered was the 25 years from 1985 to 2009, with the time-series analysis therefore running from 1986 up to 2008. The percentage change was calculated from the smoothed index values, and the change was considered statistically significant where the bootstrapped 95% confidence intervals for the years under comparison did not overlap zero. If the change was negative and over 25% this was flagged up as an 'alert'. Decreases of more than 50% were flagged as 'high alerts'.

Population indices were calculated for BW sites and for England and Wales together. Joint indices were available for a maximum of 25 species, which were the ones with sufficient WBS data. Species displayed in the trend graphs presented in this report are those where the GLMs converged and where there were sufficient data to produce bootstrapped confidence intervals. Using the most recent 25-year period of the survey enabled a larger cohort of species to be analysed than would have been possible with a longer run of years. When all years from 1974 were included, the smaller samples for earlier years resulted in problems with bootstrapping for a number of species.

2.4.1 Weighting system employed in the model

Originally the random selection of WBBS sites was intended to provide a representative sample of the waterways in the UK. Had all the selected stretches been surveyed, the results would indeed have provided this representativeness, but in fact only 65% of the random stretches were surveyed, and some of these only in a single year.

To counteract any bias in uptake by observers and hence coverage of the UK, counts were weighted to account for differences in sampling effort among Government Office Regions (GORs). Weighting was based on the proportion of those randomly selected sites that were actually surveyed by observers in each of the regions. GORs were chosen as the regional level to ensure there was a sufficient sample size in each of the regions to work out a weighting factor: BTO regions, for example, produced sample sizes that were too small. It was hoped that, after correcting the bias in observer coverage using the weights, the population trends would more accurately reflect the true picture in the UK.

Generally, WBBS sites in the south and east of England have low weights in the GLM relative to sites in the north, especially Scotland.

The weights for the non-random WBBS sites were calculated in the following way. We assumed, as for the weighting of random sites, that the regional distribution of the randomly selected sites was a good representation of the UK distribution of waterways so the ideal regional distribution of the WBS-linked sites would be in exact proportion to that of the number of randomly selected sites. Weightings were calculated as the ratio of the "ideal" and observed distribution of non-random sites. These are below unity for oversampled regions and above unity in Scotland and other regions where waterways are plentiful but observers few.

For WBS sites the weighting is based on the method used for weighting the WBS-linked sites. The proportion of WBS sites of the total number of WBBS sites was the basis by which the weightings were calculated and the weightings for these and the WBS-linked sites were then scaled up to the random WBBS level using the mean random WBBS weighting.

3 RESULTS

3.1 WBS/WBBS data collection for birds

Twenty-five bird species have enough data to provide a long-term joint WBS/WBBS population index for the UK (Appendices 1 & 2). Of these 25 species, the models ran for only 14 once the sample was restricted to BW canals. These species are listed in Table 4, together with their mean annual total counts of birds (territories or individual birds) and the mean annual number of sites on which the species was recorded. Figures are also given for England & Wales: these include those for the BW sites, with the additional sites being mostly along rivers.

Table 4. Species for which joint WBS/WBBS indices for the recent 25-year period could be calculated for British Waterways sites, with their mean annual sample sizes on BW sites and at all sites in England & Wales.

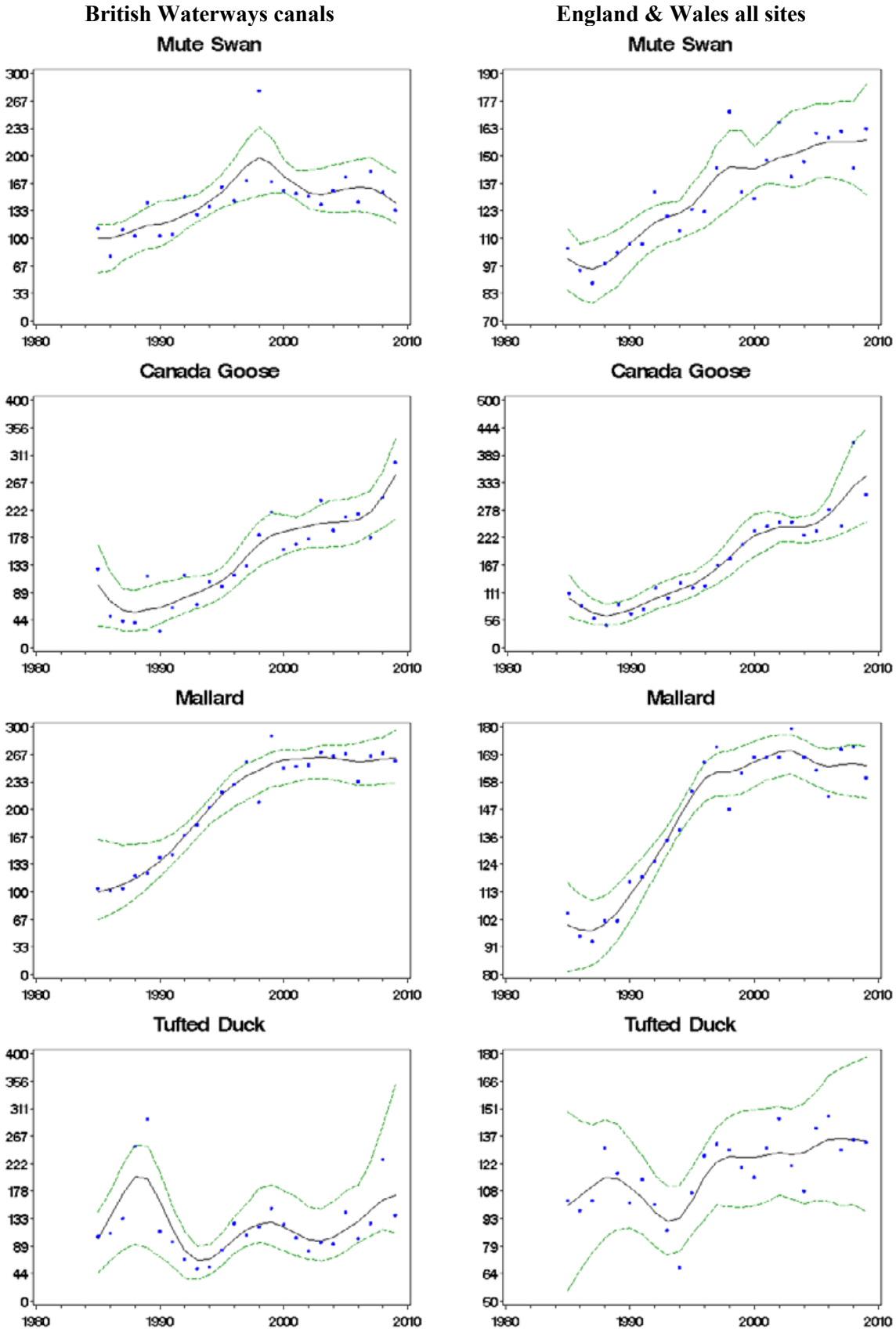
Species	British Waterways		England & Wales	
	Mean annual count of birds	Mean annual number of sites	Mean annual count of birds	Mean annual number of sites
Mute Swan	84.6	21.9	459.4	86.0
Canada Goose	199.3	18.5	633.2	66.5
Mallard	1,084.9	34.9	3,998.7	161.8
Tufted Duck	25.1	6.7	267.4	38.6
Moorhen	403.2	34.6	1,186.2	130.2
Coot	201.4	19.6	630.6	68.3
Lapwing	90.6	15.1	401.4	59.8
Kingfisher	15.1	10.8	538.5	59.7
Whitethroat	131.5	24.8	489.0	87.9
Sedge Warbler	140.4	18.4	1,015.3	71.0
Reed Warbler	80.4	12.0	318.1	44.3
Grey Wagtail	20.8	10.6	393.1	89.0
Pied Wagtail	38.1	17.6	429.2	102.4
Reed Bunting	114.8	22.3	511.4	84.5

3.2 Trends and alerts for waterways birds on British Waterways sites

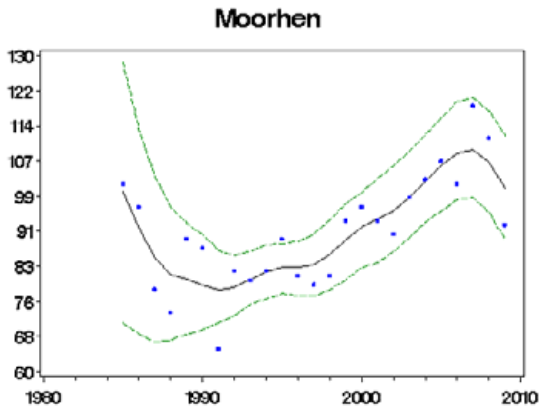
Smoothed WBS/WBBS index trends for waterways birds on BW sites are shown in Figure 5 together with, for comparison, the trends for all sites in England & Wales. These cover only the 14 species for which a joint WBS/WBBS index will run on the restricted BW sample of plots. Equivalent plots for the UK and England, covering the full range of species available, are presented in Appendix 1.

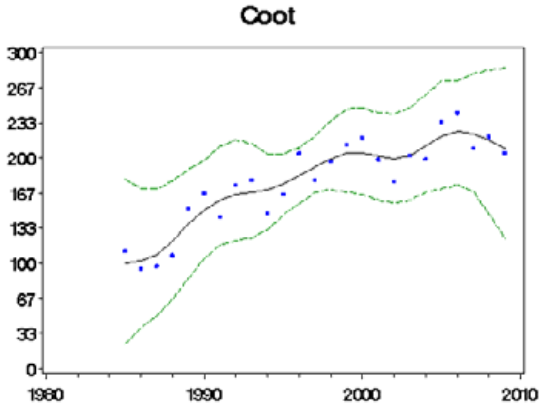
Summarised trends and alerts for the same subset of waterways birds for the period 1986–2008 are presented in Table 5, again for BW sites and for England & Wales. Equivalent data for the UK and England, covering the full range of species available, are presented in Appendix 2. These figures (from Marchant *et al.* 2010) update those published previously for the years to 2007 (Baillie *et al.* 2010).

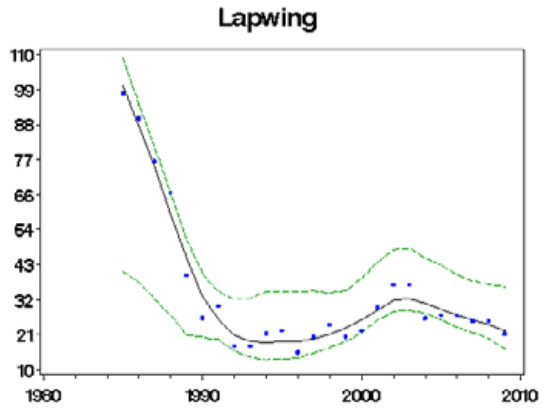
Figure 5. **Smoothed WBS/WBBS joint trends with 85% bootstrapped confidence intervals. Dots are the unsmoothed values of annual indices. Datum level (100) is the value of the smoothed trend in the first year of the run.**

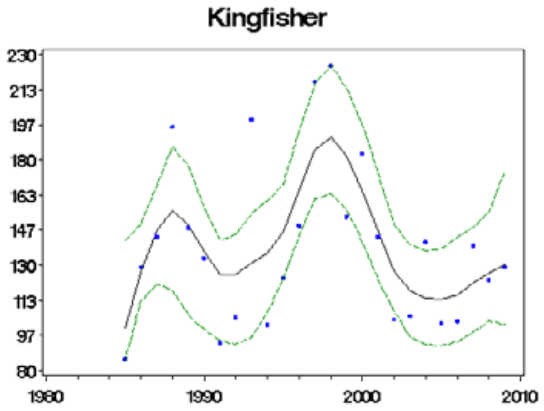


British Waterways canals

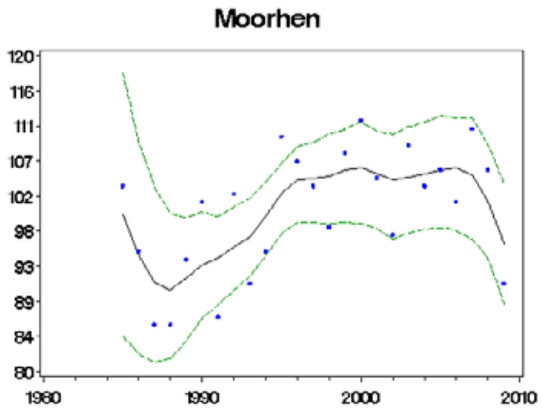


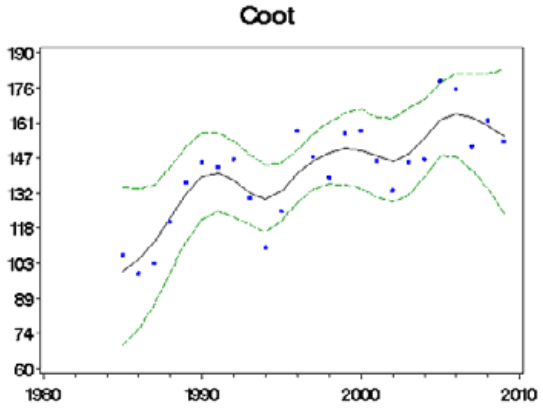


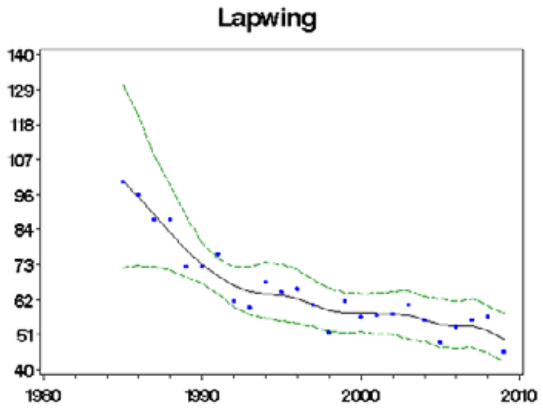


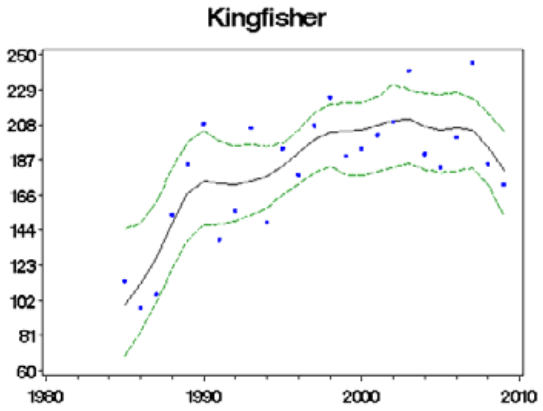


England & Wales all sites

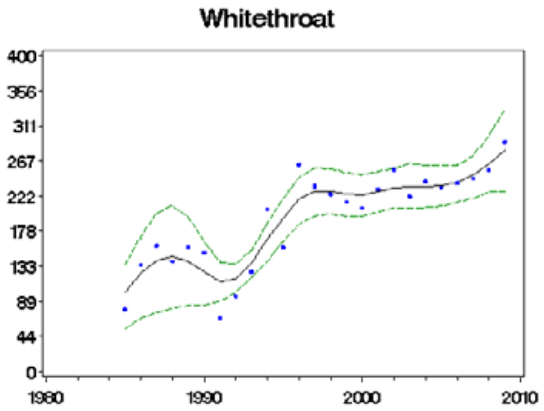


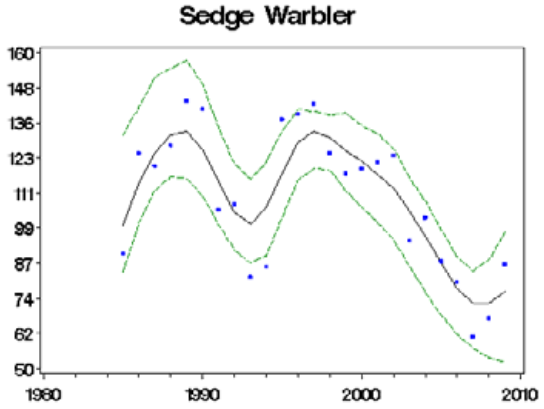


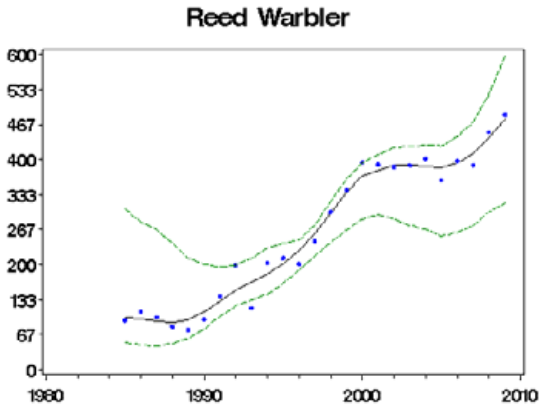


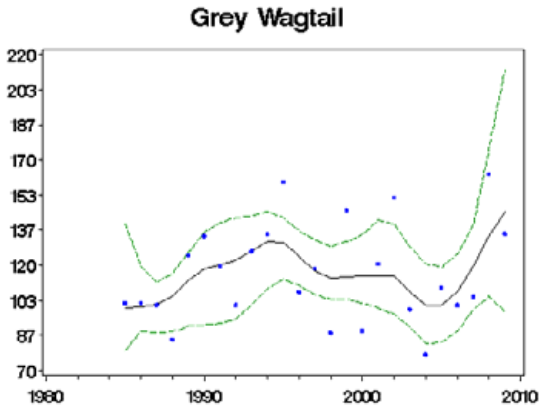


British Waterways canals

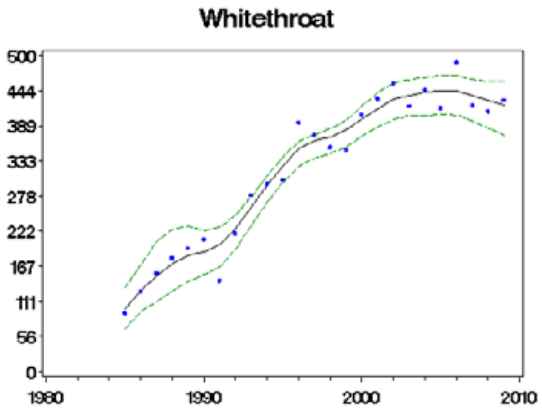


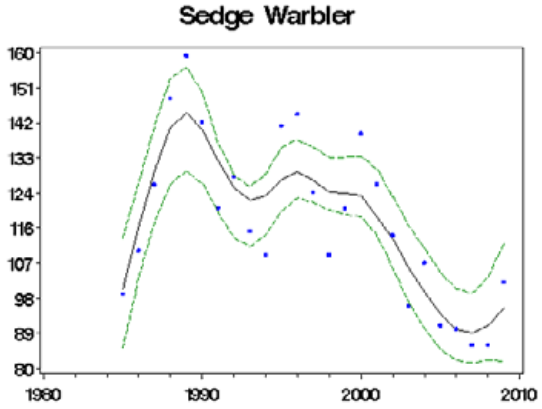


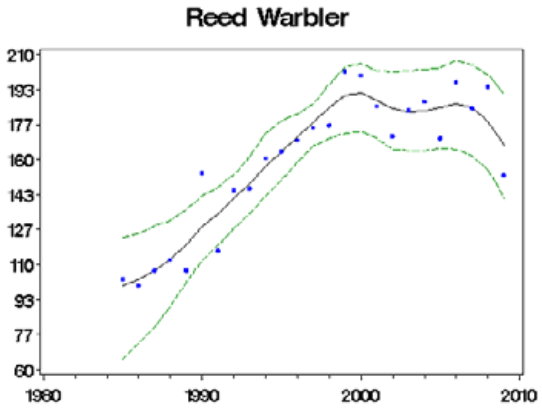


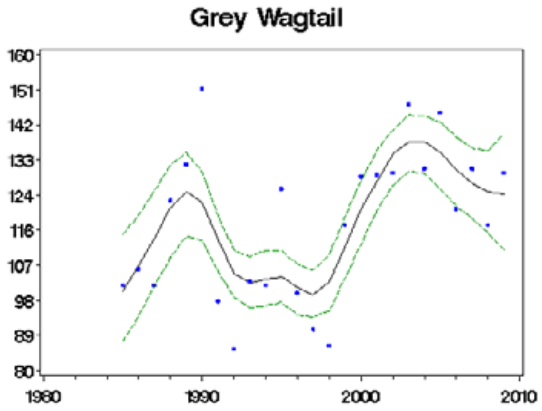


England & Wales all sites

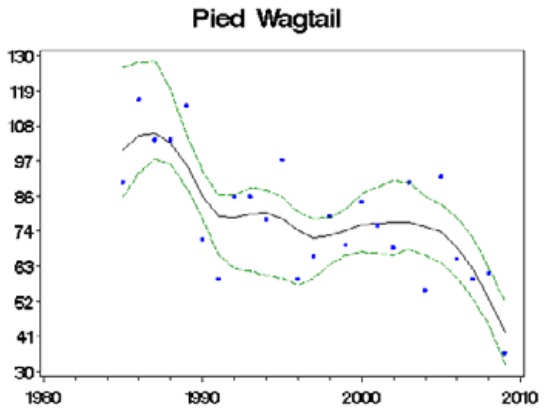


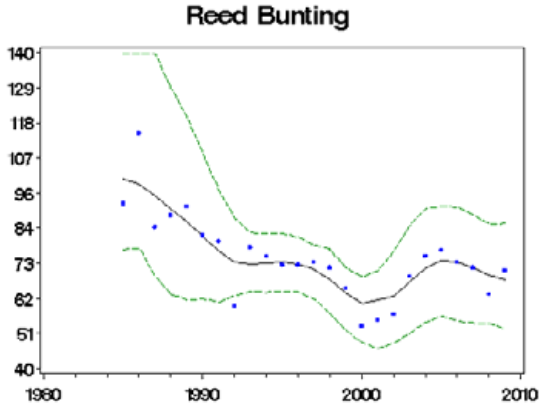




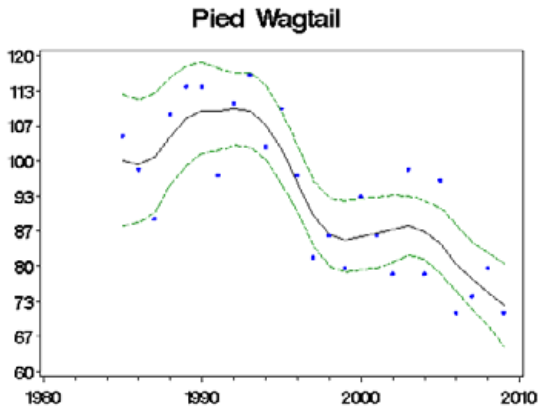


British Waterways canals





England & Wales all sites



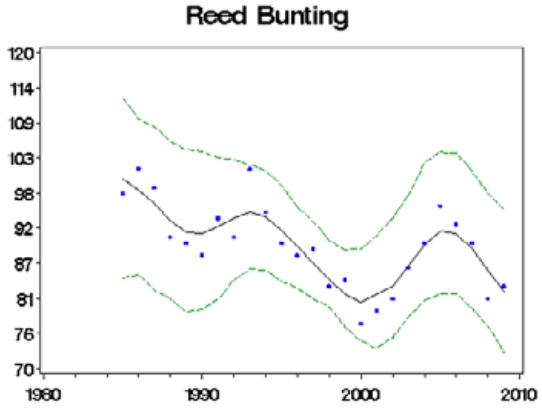


Table 5. Trends and alerts for waterways birds, 1986–2008.

Species	Period	No of yrs	British Waterways canals			England & Wales all sites		
			Population change	Direction of significant change	Alert	Population change	Direction of significant change	Alert
Mute Swan	1986–2008	22	+53%	+		+62%		
	1998–2008	10	–22%			+8%		
	2003–2008	5	+1%			+4%		
Canada Goose	1986–2008	22	+227%	+		+296%	+	
	1998–2008	10	+46%			+77%	+	
	2003–2008	5	+22%	+		+34%		
Mallard	1986–2008	22	+152%	+		+69%	+	
	1998–2008	10	+5%			+2%		
	2003–2008	5	–1%			–3%		
Tufted Duck	1986–2008	22	+19%			+29%		
	1998–2008	10	+31%			+7%		
	2003–2008	5	+68%	+		+6%		
Moorhen	1986–2008	22	+15%			+7%		
	1998–2008	10	+24%	+		–3%		
	2003–2008	5	+8%			–3%		
Coot	1986–2008	22	+113%			+53%	+	
	1998–2008	10	+9%			+7%		
	2003–2008	5	+7%			+8%		
Lapwing	1986–2008	22	–72%			–45%	–	>25
	1998–2008	10	+15%			–11%		
	2003–2008	5	–25%	–	>25	–8%		
Kingfisher	1986–2008	22	0%			+74%	+	
	1998–2008	10	–34%	–	>25	–4%		
	2003–2008	5	+7%			–8%		
Whitethroat	1986–2008	22	+111%	+		+235%	+	
	1998–2008	10	+15%			+15%	+	
	2003–2008	5	+13%			–2%		
Sedge Warbler	1986–2008	22	–36%	–	>25	–21%	–	
	1998–2008	10	–44%	–	>25	–27%	–	>25
	2003–2008	5	–30%	–	>25	–14%	–	
Reed Warbler	1986–2008	22	+356%			+73%	+	
	1998–2008	10	+48%	+		–4%		
	2003–2008	5	+14%			–3%		
Grey Wagtail	1986–2008	22	+33%			+18%		
	1998–2008	10	+17%			+22%	+	
	2003–2008	5	+25%			–9%	–	
Pied Wagtail	1986–2008	22	–49%	–	>25	–24%	–	
	1998–2008	10	–27%	–	>25	–13%	–	
	2003–2008	5	–31%	–	>25	–14%	–	
Reed Bunting	1986–2008	22	–29%			–13%		
	1998–2008	10	+2%			+2%		
	2003–2008	5	+3%			–1%		

4 DISCUSSION

4.1 Long-term changes in breeding bird populations along UK waterways

Together, the WBS and its successor, the ongoing WBBS, provide a history of population changes for breeding water birds along UK waterways since 1974. Full details, currently to 2008, are presented in the BTO's BirdTrends web pages (www.bto.org/birdtrends), which are updated annually to include each new season's data (Baillie *et al*. 2010).

The summarised results of joint WBS/WBBS indices for the UK are presented in Appendix 2. These cover standard reporting periods (five, ten and 25 years, and the maximum that can be calculated) that BTO has agreed with JNCC. Reporting periods omit the first and last years of the full index run (1974 and 2009), although index data are estimated for these years. Statistically significant decreases of more than 25% over any of these periods raise 'BTO alerts', with changes greater than a 50% decline raising high alerts.

Three species (Lapwing, Redshank and Yellow Wagtail) raise high alerts at the UK scale because their population size has at least halved over the recent 25-year period. A fourth species (Snipe) would also fall into this category except that it has become extinct over wide areas of lowland Britain and indices can no longer be reliably calculated. The decline for Yellow Wagtail is so severe that the 50% criterion is easily met, even over the 10-year period, while a decrease of 47% is estimated for the recent five-year period. Two further species (Pied Wagtail and Reed Bunting) raise high alerts for the 33-year period only and have shown little change in population in recent years.

In contrast to these decreases, there are significant increases of 100% or more for four species (Greylag Goose, Canada Goose, Mallard and Whitethroat). The first three of these have benefited from widespread introductions. The presence of non-native Canada Geese in large numbers in urban sites raises widespread concerns about public health and safety. Many Mallards on urban waterways are resident birds with plumage indicating a partly domestic origin and are largely dependent for food on the public. The sharp increase in Whitethroats over the longer periods represents a partial recovery after a severe population crash in 1968, linked to West African drought.

Many, but not all of the significant changes are also evident when changes are estimated for England alone (Appendix 2).

Graphs of joint WBS/WBBS index trends for the UK for the period 1974–2009 are presented in Appendix 1. Snipe is included here. The graphs highlight that the pattern of change has in many cases been non-linear. Increases among ducks and geese and decreases among the waders are the most obvious changes at the level of taxonomic groups. The waders recorded are mostly nesting in wet meadows in river floodplains and have suffered from habitat change brought about by such factors as drainage and increased grazing pressure.

A much wider range of species can be indexed for five- and nine-year periods using WBBS data alone for 1998–2009. These additional species were not covered by WBS and data from waterways for earlier years are therefore lacking.

4.2 Population change on British Waterways sites

Owing to the much-reduced sample of sites, only 14 species provide a joint WBS/WBBS index from BW canal sites alone. The species are mainly those associated with still water and exclude those associated with mainly riverine habitats, such as fast-flowing water, shingle bars, eroding banks, oxbows and water meadows. The available results are presented in Figure 5 and Table 5.

The graphs in Figure 5 show that the parallels between trends on BW canal sites and in England & Wales as a whole are very strong. This similarity is quite surprising, given the fact that British Waterways sites are largely concentrated into the Midlands and Northwest, and that many species are likely to exhibit some regional variation in population trends. In limiting the sample to BW sites (ca 20% of the total), some divergence in trends would also be expected by chance, due to the relatively small number of sites reporting species such as Tufted Duck, Kingfisher, Grey Wagtail and Reed Warbler. This suggests that the main factors at work are strong, broad-scale drivers of change, such as those responsible for the rapid expansion of Canada Geese throughout the UK, or the steep declines in Lapwings from agricultural as well as wetland habitats. Some differences are apparent, however, that are worthy of comment and perhaps also of further investigation.

Canada Goose has shown a slightly less steep increase than was recorded elsewhere in England & Wales: the species is numerous on the BW sites, however (Table 4). It is possible that the observed pattern results from expansion from preferred canal sides into less-favoured riverine habitats, but the differences between the trends are very small. Population changes of Mallard, Coot and Moorhen, however, are more positive on BW sites than elsewhere (Table 5). The Mallards that are increasing on canals are likely to be mainly domestic-type birds, which gather on urban and suburban waterways and are fed by members of the public, and the overall trend revealed by BBS surveys, an increase of 33% in England between 1995 and 2008, is consistent with these results. Coot and Moorhen show quite similar trends, both between BW and all sites and between species, although the increase in Coots has been more sustained than for Moorhen. Relative densities of both species along stretches did not differ between BW and all sites.

The other duck included in the list is the Tufted Duck, although it was found on an average of fewer than seven BW sites per year (Table 4). This species prefers larger bodies of water, whether standing or moving, and many of the BW waterway stretches may be less suitable. In fact, population trends are broadly similar, both showing moderate and continuing increases (Figure 5).

Although Mute Swans have shown similar increases on British Waterway sites, as well as elsewhere, over the longer term, the results suggest a decline of this species on BW sites in the early 2000s which is not apparent over the most recent five-year period. We have no explanation for this pattern.

Decreases of Lapwing and Pied Wagtail have apparently been stronger on canals than on other waterways in England & Wales (Table 5, Figure 5). The Pied Wagtail decrease along waterways is of unknown cause, and conflicts with the strong increase detected by CBC and BBS in the wider countryside (Baillie *et al.* 2010). The pattern of declines in Lapwings, like those for Reed Bunting, are likely to be more strongly associated with changes in adjacent agricultural land use than in habitat features of the waterways themselves.

We are able to compare population trends in three species commonly associated with reed beds – Reed Warbler, Sedge Warbler and Reed Bunting – although the second and third of these are also commonly found in other habitats, particularly wet scrub and arable farmland, respectively. The increase in Reed Warblers has been much stronger on canals than on other waterways in England & Wales, although bird densities appear similar. The difference may result from birds moving more onto canals, where narrow fringing reed beds may be a secondary habitat for them, as populations in more extensive reed beds expand. Sedge Warbler show roughly parallel population trends, of fluctuating declines, on BW sites and on other waterways in England & Wales. The fluctuations in Sedge Warbler numbers have previously been linked to the variation in West African rainfall and its effects on habitat quality when birds arrive there for the winter (Baillie *et al.* 2010). Population trends for Reed Buntings were also broadly parallel on BW sites and elsewhere, both showing the longer-term declines that have been associated with changes in farmland (loss of winter stubbles for feeding, changes in cropping patterns) but also some evidence of recovery in more recent years. Any differences, or similarities, in trends for this species, which moves widely across agricultural habitats during the winter, are more likely to be due to regional differences in changes on farmland.

Another long-distance migrant, the Whitethroat, has shown a strong but partial recovery from problems caused by African droughts that began in the late 1960s. The pattern could be interpreted as a recovery that reached a plateau earlier on BW canals than in the general waterways sample, but the broad-scale increases are apparent in both sets of indices. This species generally occupies hedges and scrubby habitats and our results suggest that canal-side sites, filled first during the recovery period, may be preferred to sites by rivers.

Kingfishers commonly occupy slow-moving lowland canals and waterways, but the species is rare in the BW sample, and where present, numbers are very low. This may be due to the fact that BW canal sites are less likely to have the soft earth banks favoured by Kingfishers for nesting, which are more common by rivers. Given the small sample for Kingfishers on BW sites, differences in trends should be interpreted with caution. This species is well known to be especially susceptible to cold winters, so differences between the two trends may reflect regional differences in the impact of this factor. The most recent five-year increases on BW sites, relative to all sites, may be a positive result of mild winters, particularly in the more northerly parts of its range, and it will be interesting to see what the impact of the latest very cold winters will be on this species.

Only one species characteristic of fast-flowing waters; Grey Wagtail, is included in the list of 14 species. Trends over ten and 22 years are broadly similar between the BW and England & Wales samples, indicating modest increase. Over the past five years, however, numbers at the small number of BW sites have increased in contrast to modest declines elsewhere. Away from its favoured fast-flowing rivers, the species is closely associated with manmade structures along the waterway, such as locks and inflow channels. A high availability of aquatic invertebrates in the waterway and in adjacent habitats is also a requirement, so the increases on the BW sites are promising.

4.3 Options for further study

The present study has explored just some of the options for investigating bird trends on BW sites. The period has been shortened from the maximum 35 years to 25 years, to allow more species to be indexed using the joint WBS/WBBS protocol. Initial investigations indicate that index runs could be prepared for at least eight species over a longer period than the one we have used.

Only water birds have been included here, because only they were surveyed by WBS and thus have joint WBS/WBBS trends. WBBS alone can already produce ten-year trends, and these would cover a much wider range of species. It would be instructive to search for differences between BW sites and other waterways, and between BW sites and the wider countryside, for species that are not necessarily waterways specialists.

Trends presented in this report are at species level. Multi-species indicators have been developed from waterways bird surveys at national and regional level (Noble *et al.* 2008a, b). An indicator of bird populations along BW sites, prepared in a similar way but using only the relevant subset of data, may be a helpful tool for the future management of these sites.

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The BTO's work relies heavily on volunteers. We are very grateful to all observers who have contributed WBBS or WBS data, and to the BTO's Regional Representatives and others who assisted with finding volunteers and forwarding paperwork. Maps of sites were produced using the program DMAP, with thanks to Alan Morton.

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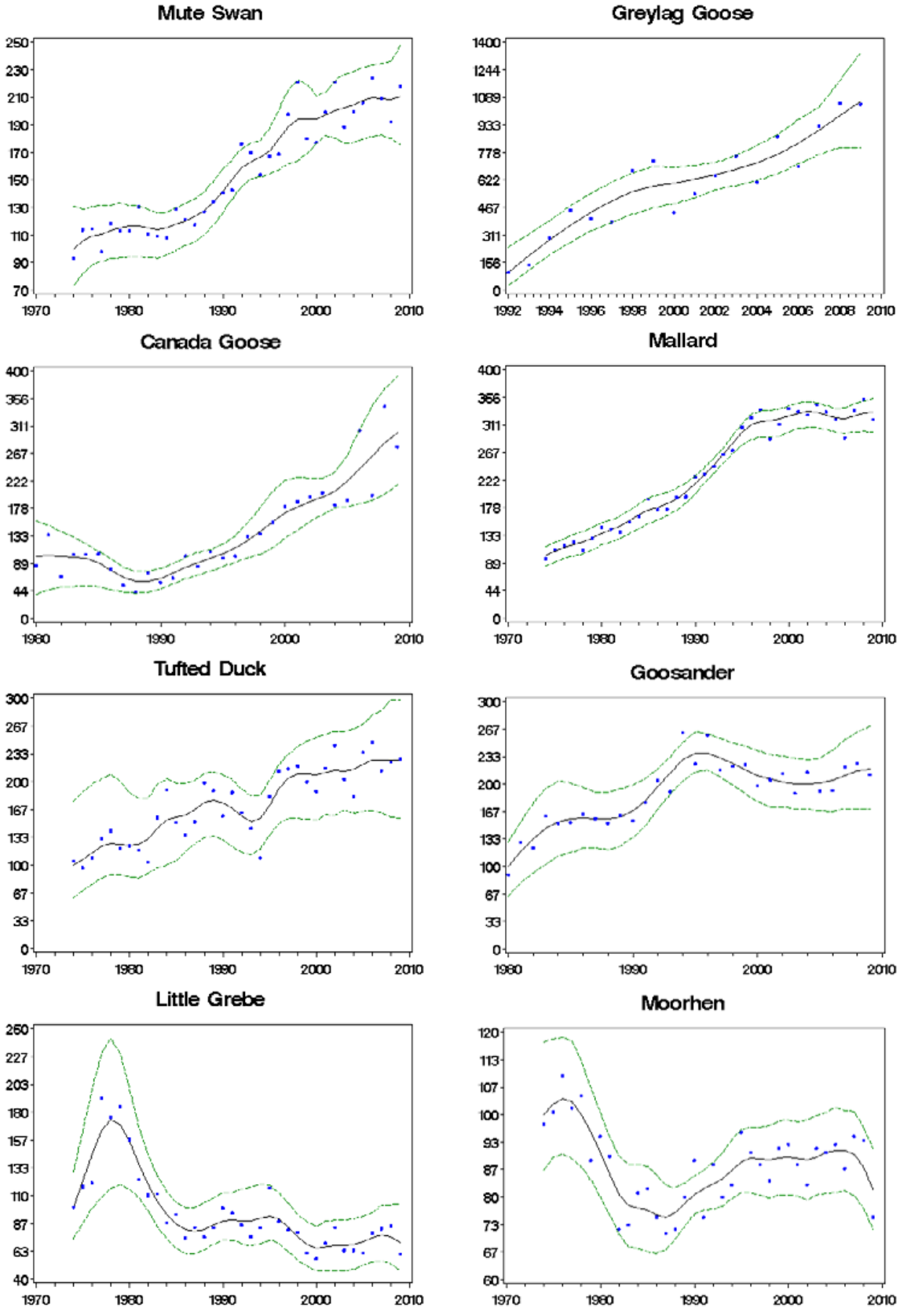
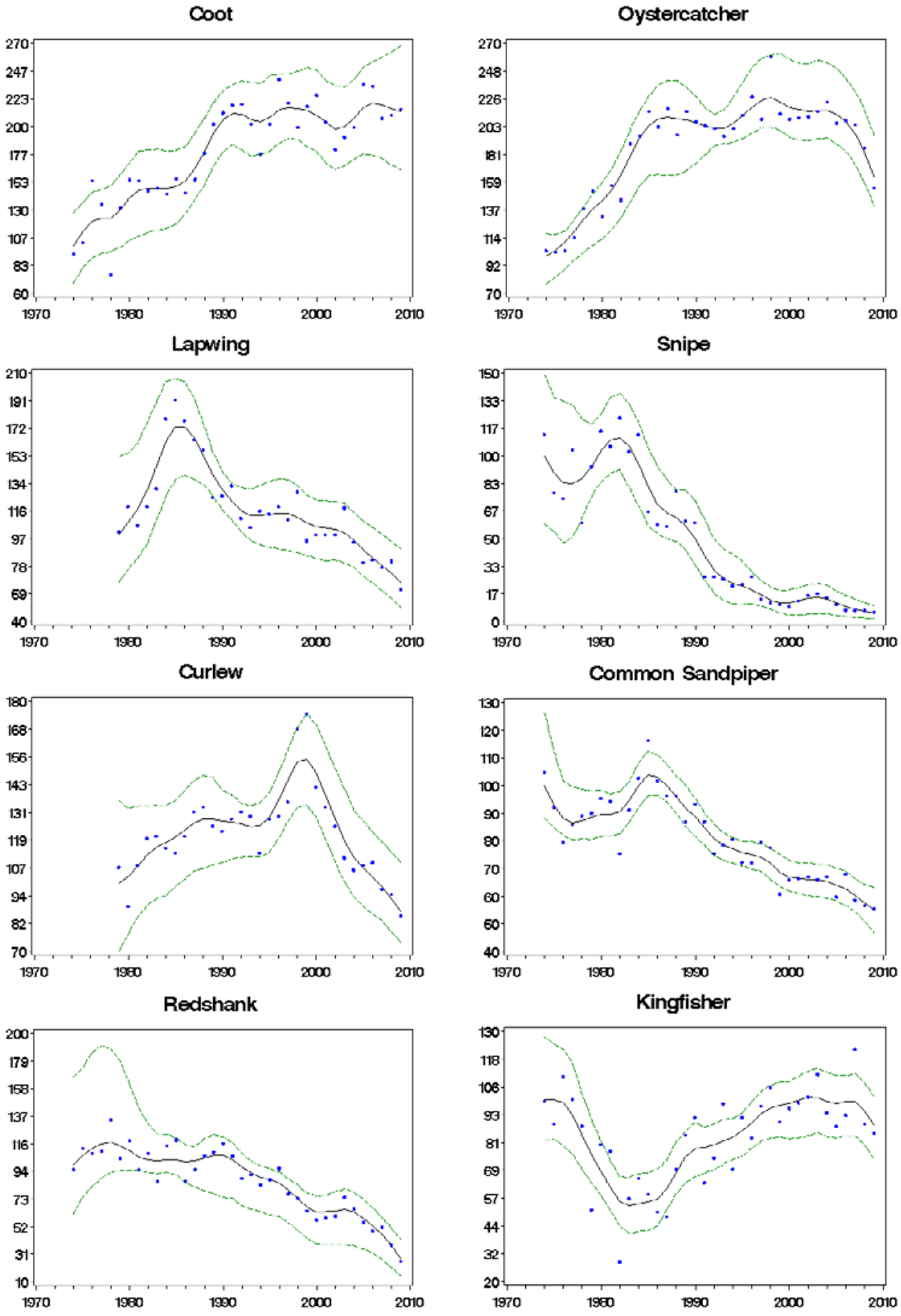
APPENDIX 1. Joint WBS/WBBS index trends for the UK, 1974–2009 (from Marchant *et al.* 2010).

UK: smoothed WBS/WBBS joint trends with 85% bootstrapped confidence intervals. Dots are the unsmoothed values of annual indices. Datum level (100) is the value of the smoothed trend in the first year of the run.



UK: smoothed WBS/WBBS joint trends (continued)



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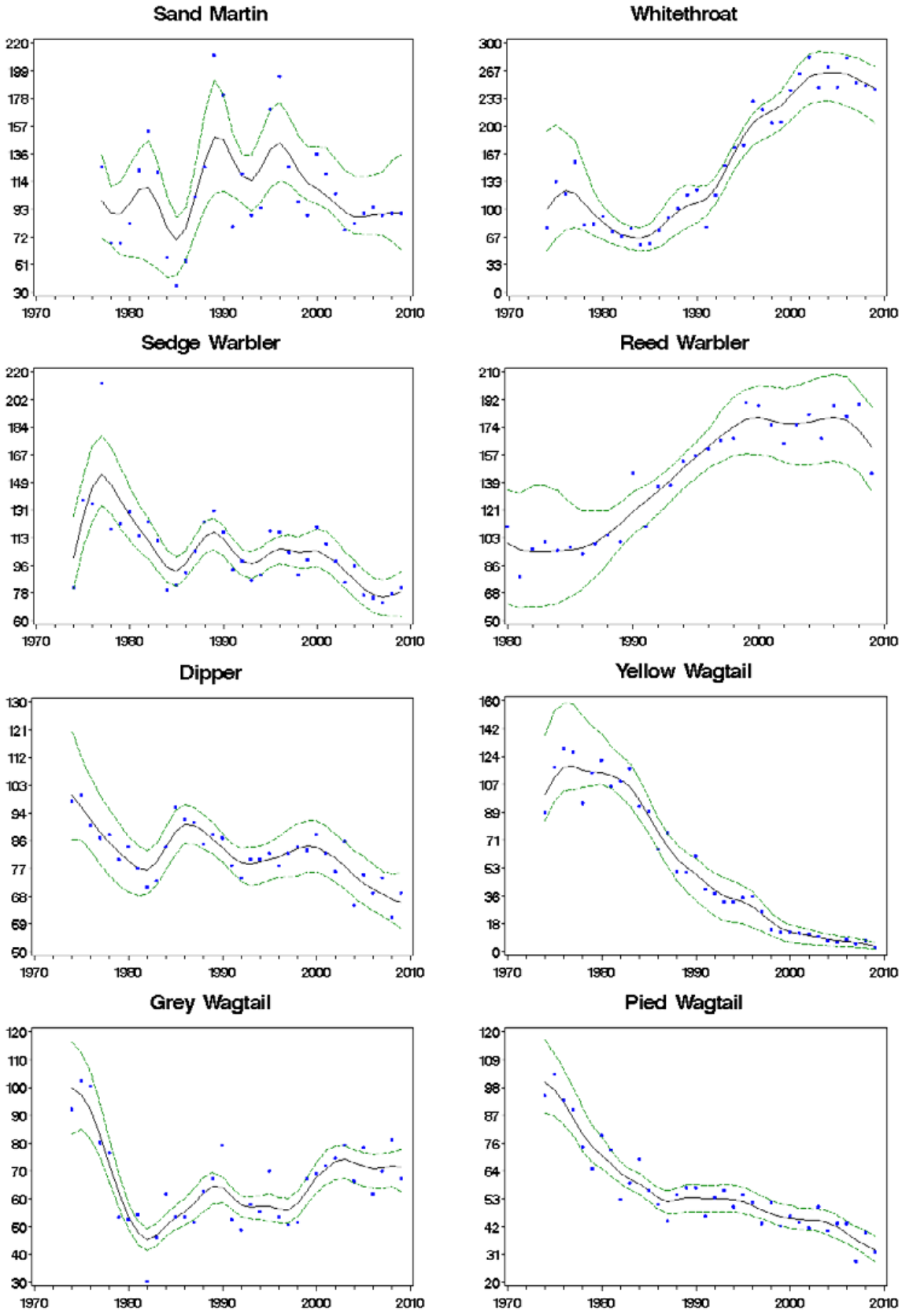
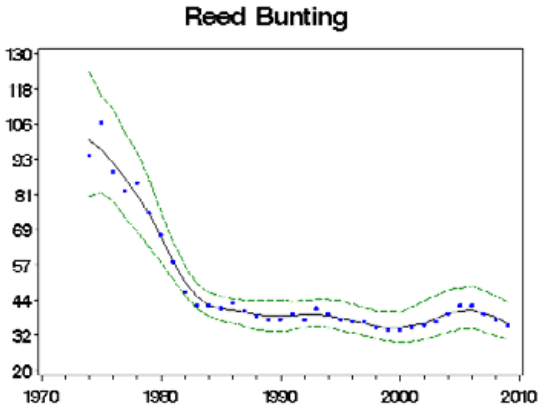


UK: smoothed WBS/WBBS joint trends (continued)



APPENDIX 2. National trends for breeding water birds as detected by joint WBS/WBBS indices (from Marchant *et al.* 2010).

Species	Period	Number of years	UK			England		
			Population change	Direction of significant change	Alert	Population change	Direction of significant change	Alert
Mute Swan	1975–2008	33	+98%	+		+125%	+	
	1983–2008	25	+83%	+		+87%	+	
	1998–2008	10	+7%			+4%		
	2003–2008	5	+3%			+3%		
Greylag Goose	1993–2008	15	+410%	+		+766%	+	
	1998–2008	10	+78%	+		+182%	+	
	2003–2008	5	+45%	+		+67%	+	
Canada Goose	1981–2008	27	+179%	+		+346%	+	
	1983–2008	25	+185%	+		+297%	+	
	1998–2008	10	+101%	+		+74%	+	
	2003–2008	5	+45%			+33%		
Mallard	1975–2008	33	+207%	+		+150%	+	
	1983–2008	25	+110%	+		+75%	+	
	1998–2008	10	+4%			+2%		
	2003–2008	5	–1%			–4%		
Tufted Duck	1975–2008	33	+111%			+143%		
	1983–2008	25	+57%			+66%		
	1998–2008	10	+8%			+8%		
	2003–2008	5	+6%			+5%		
Goosander	1981–2008	27	+82%	+		+62%		
	1983–2008	25	+47%			+26%		
	1998–2008	10	–4%			–14%		
	2003–2008	5	+7%			–6%		
Little Grebe	1975–2008	33	–39%			–14%		
	1983–2008	25	–28%			–15%		
	1998–2008	10	–1%			–2%		
	2003–2008	5	+10%			+12%		
Moorhen	1975–2008	33	–15%			–3%		
	1983–2008	25	+12%			+26%		
	1998–2008	10	–2%			–3%		
	2003–2008	5	–3%			–3%		
Coot	1975–2008	33	+92%	+		+99%	+	
	1983–2008	25	+45%			+46%		
	1998–2008	10	0%			+5%		
	2003–2008	5	+8%			+10%		
Oystercatcher	1975–2008	33	+74%	+		+124%	+	
	1983–2008	25	+1%			+32%	+	
	1998–2008	10	–20%	–		+4%		
	2003–2008	5	–16%	–		–8%		
Lapwing	1980–2008	28	–32%			+58%		
	1983–2008	25	–50%	–	>50	–5%		

Species	Period	Number of years	UK			England		
			Population change	Direction of significant change	Alert	Population change	Direction of significant change	Alert
	1998–2008	10	–34%	–	>25	–13%		
	2003–2008	5	–27%	–	>25	–10%	–	
Curlew	1980–2008	28	–10%			–8%		
	1983–2008	25	–19%			–20%		
	1998–2008	10	–39%	–	>25	–20%	–	
	2003–2008	5	–21%	–		–9%		
Common Sandpiper	1975–2008	33	–38%	–	>25	–36%	–	>25
	1983–2008	25	–39%	–	>25	–36%	–	>25
	1998–2008	10	–20%	–		–21%	–	
	2003–2008	5	–12%	–		+2%		
Redshank	1975–2008	33	–65%	–	>50	–50%	–	>25
	1983–2008	25	–63%	–	>50	–47%	–	>25
	1998–2008	10	–49%	–	>25	–31%	–	>25
	2003–2008	5	–42%	–	>25	–25%	–	>25
Kingfisher	1975–2008	33	–5%			–7%		
	1983–2008	25	+78%	+		+81%	+	
	1998–2008	10	–1%			–8%		
	2003–2008	5	–6%			–8%		
Sand Martin	1978–2008	30	0%			–2%		
	1983–2008	25	–8%			–13%		
	1998–2008	10	–26%			–30%	–	>25
	2003–2008	5	–1%			–7%		
Whitethroat	1975–2008	33	+119%			+174%		
	1983–2008	25	+280%	+		+306%	+	
	1998–2008	10	+15%	+		+17%	+	
	2003–2008	5	–5%			–2%		
Sedge Warbler	1975–2008	33	–40%	–	>25	–35%		
	1983–2008	25	–25%	–	>25	–32%	–	>25
	1998–2008	10	–27%	–	>25	–27%	–	>25
	2003–2008	5	–17%	–		–14%	–	
Reed Warbler	1981–2008	27	+80%	+		+36%		
	1983–2008	25	+83%	+		+45%		
	1998–2008	10	–1%			–8%		
	2003–2008	5	–2%			–3%		
Dipper	1975–2008	33	–31%	–	>25	–18%		
	1983–2008	25	–15%			+2%		
	1998–2008	10	–19%	–		–9%		
	2003–2008	5	–13%	–		–3%		
Yellow Wagtail	1975–2008	33	–96%	–	>50	–95%	–	>50
	1983–2008	25	–95%	–	>50	–95%	–	>50
	1998–2008	10	–74%	–	>50	–71%	–	>50
	2003–2008	5	–47%	–	>25	–46%	–	>25
Grey Wagtail	1975–2008	33	–26%	–	>25	–23%		
	1983–2008	25	+53%	+		+61%	+	
	1998–2008	10	+23%	+		+27%	+	

Species	Period	Number of years	UK			England		
			Population change	Direction of significant change	Alert	Population change	Direction of significant change	Alert
	2003–2008	5	–3%			–9%	–	
Pied Wagtail	1975–2008	33	–64%	–	>50	–56%	–	>50
	1983–2008	25	–43%	–	>25	–32%	–	>25
	1998–2008	10	–26%	–	>25	–11%	–	
	2003–2008	5	–22%	–		–13%	–	
Reed Bunting	1975–2008	33	–60%	–	>50	–49%	–	>25
	1983–2008	25	–16%			–7%		
	1998–2008	10	+8%			+6%		
	2003–2008	5	+1%			–2%		