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The Value and Management of Wastewater Treatment Works for Breeding and Wintering Birds in Lowland Eastern England

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S.J. Gough, S. Gillings and J.A. Vickery

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Executive Summary

A volunteer survey of Anglian Water wastewater treatment works in eastern England provides information on their value for British birds. These islands of semi-natural habitat are important to both breeding and wintering birds. Surveys were conducted at 35 sites in the winter and 25 sites in the summer. There was a great deal of variation in the size of the water treatment works visited, from Lamport (0.2 hectares) to Marston (83.8 hectares).

We are grateful to volunteers from Anglian Water and the BTO's membership for their help with this survey, which took place in the 12 months from the autumn of 2001.

- In three winter visits and six summer visits observers assigned birds to the various available habitats using standard mapping techniques.

- Over the whole survey period, site species richness (*i.e.* total number of species on a given site) varied between nine species (Wymondham) and 81 species (Marston). There was a significant correlation in the species richness between the two seasons. Thus sites supporting the highest diversity of birds in summer also tended to support the highest diversity in winter

- Species richness increased with increasing size and habitat diversity within a site. However, there was no significant correlation between size of site and the number of habitat types. Thus, even on the smallest of sites, increased habitat diversity will have a positive influence upon species richness.

- Within the wider landscape, the only significant relationship with surrounding landcover was that, in both summer and winter, species richness on Anglian Water sites was greater in areas with larger amounts of urban cover nearby.

- Within individual sites, it was possible to identify associations between habitats and the birds they attracted. The three wagtail species (Pied, Grey and Yellow) together with Meadow Pipit, were all closely associated with damp or wet habitats, such as flood meadows, filter beds and tanks. They were also strongly associated with the presence of cut grass.

- For Robin, Blackbird, Dunnock and Song Thrush there were close associations with hedgerows, trees, scrub and grassland.

- Grey and Yellow Wagtail and Dunnock are all amber listed within the Birds of Conservation Concern (BoCC), whilst Song Thrush is red listed. Sympathetic management of grass, hedge and scrub habitat may be particularly valuable in terms of enhancing the number of individuals of species of high conservation concern.

- The generalist species, such as Starling, Carrion Crow and Magpie, were associated with a broader range of habitat types. These included the filter beds and tanks, cut grass, hedgerows and trees.

- The most frequently selected habitat was hedgerows, positively selected by 27 out of 40 species in both summer and winter. Scrub and cut grass were particularly important in the winter and cut grass, unspecified grass (i.e. cut or uncut) and scrub were important in summer. A full list of the associations between habitat and the species which use them is given in this paper.

- Species visiting water treatment works in the summer were compared with those species breeding in the wider countryside in the same region, using Breeding Bird Survey (BBS) data to identify species for which water treatment works may be particularly important. Pied

Wagtail was the most commonly occurring species on treatment works, although it did not appear in the top ten for BBS. Starling (amber listed BoCC) was ranked seventh most common on the treatment list, as opposed to tenth on the BBS list, and Dunnock (amber listed BoCC) was ranked ninth on the treatment list but was outside the top ten list for BBS.

- Comparing the 'treatment vs. countryside' rankings of birds which occur on the red and amber lists of Birds of Conservation Concern highlighted some other potentially important differences. Within the red list, Tree Sparrow, Corn Bunting, Marsh Tit and Willow Tit were all ranked higher on treatment works. Within the amber lists there were gains for House Martin and Grey Wagtail.

- The presence of several granivorous species on the BOCC red list on treatment works was encouraging. These included Linnet (11% of visits), Reed Bunting (9%), Yellowhammer (6%), House Sparrow (6%).

- The association of wagtails with wet or damp habitats has already been mentioned. Other species to benefit from the presence of wet or damp, often grassland, habitats were Snipe (present on 5% of visits), Lapwing (5%) and Redwing (5%). All of these are amber listed BoCC.

- Continued positive habitat management on Anglian Water sites is likely to benefit many bird species, particularly those foraging, roosting or nesting within woody habitats, such as hedgerows and scrub. Eighteen of the treatment works already contain scrub patches which are known to be particularly important for red listed Turtle Doves.

- The management of grassland is very important to many of the species that have been mentioned above. A mix of cut grass, for ground-foraging pipits, wagtails and thrushes and uncut grass to provide nest cover and seed resources for granivorous birds is recommended.

- Although modern wastewater treatment sites provide far less in the way of wetland habitat than did their predecessors, it may be possible to use tertiary treatment, in which water is finely filtered through reed beds and grass plots, at more sites. These flooded meadows were selected by many species throughout the year.

- A closer look at the data presented in this paper might reveal other ideas to support species of conservation concern. The red listed House Sparrow, for instance, might be encouraged to visit more than 5% of sites in the winter time, by providing more supplementary feeding. This would have benefits for other granivorous species. As another example, the presence of Willow Tit at 4% of winter visits and only 2% of summer visits might suggest that the provision of special Willow Tit nest boxes could be useful.

Conclusion

Although treatment works no longer provide extensive wetland habitats, they do provide areas of rough grass, scrub and hedgerows that are becoming increasingly rare in the wider countryside. Their value for birds can be maximised by enhancing habitat diversity, particularly where this includes areas of cut and uncut grass grassland alongside woody habitats, such as hedgerows or scrub. Sites that still include large areas of wet or damp grassland or meadows, or are particularly large, merit specific management plans.

1. INTRODUCTION

Capsule Modern wastewater treatment works can provide valuable pockets of semi-natural habitat for breeding and wintering birds.

Aims To assess the ornithological value of modern wastewater treatment works which are typically smaller and lack the lagoons and flooded meadows of traditional sewage farm.

Methods A volunteer survey of treatment works in eastern England, comprising three visits in the winter and six in the spring/summer to count all birds present on site.

Results Species richness was correlated with treatment work size, within-site habitat richness and the extent of urban habitat in the surrounding countryside. The most frequently encountered species were Woodpigeon, Pied Wagtail, Blackbird, Robin, Chaffinch, Wren, Blue Tit, Dunnock, Starling, Carrion Crow and Greenfinch. These, and many other less abundant species, tended to be most strongly associated either with damp habitats, often with areas of short grass, or woody habitats such as hedgerows and scrub.

Conclusion Although treatment works no longer provide extensive wetland habitats, they do provide areas of rough grass, scrub and hedgerows that are becoming increasingly rare in the wider countryside. Their value for birds can be maximised by enhancing habitat diversity, particularly where this includes areas of cut and uncut grass grassland alongside woody habitats, such as hedgerows or scrub. Sites that still include large areas of wet or damp grassland or meadows or are particularly large merit specific management plans.

There is a growing recognition of the value of urban or man-made habitats for fauna and flora in general (Owen 1991) and birds in particular (Jokimaki 1996, Marzluff & Sallabanks 1998, Cannon 1999, Mead 2000). A disproportionate percentage of certain birds species are found in urban areas, including some listed as threatened by government or conservation organisations (e.g. Gibbons *et al.* 1996, Cannon 1999, Mead 2000, Mason 2000). For example, a large scale habitat survey of birds across Britain found that human settlements held more than 20% of Blackbirds *Turdus merula* and Song Thrushes *T. philomelos* (Gregory & Baillie 1998). Built habitats may also provide source populations for nationally declining species such as House Sparrow *Passer domesticus* (Summers-Smith 1999).

Wastewater treatment works (previously known as sewage works or farms) provide some of the most valuable artificial habitats for birds throughout the year in Britain (e.g. Simms 1975, Fuller & Glue 1980) and abroad (e.g. Knight 1997, Knight *et al.* 2001). The present study was designed to describe the seasonal patterns in bird communities at wastewater treatment works in lowland eastern England and relate these to the habitat characteristics of the sites themselves and to the nature of the habitat and bird community in the surrounding landscape.

Historically, treatment works have been recognised as valuable bird sites and many of the pioneer studies on inland wader migration were made at old style ‘sewage farms’ (Boyd 1957, Fuller & Glue 1980). The shallow lagoon systems associated with the sewage farms often supported high densities of species such as Ringed Plover *Charadrius hiaticula*, Common Sandpiper *Actitis hypoleucos*, Redshank *Tringa totanus* and Dunlin *Calidris alpina* (Moyes 1974). Irrigation plots, effluent lagoons and sludge beds, with shallow water or bare mud, provided good feeding sites for waders and passerines. Farms with a grass meadow cycle were important sites for wintering waders such as Lapwing *Vanellus vanellus* and Snipe *Galinago gallinago* as well as passerines such as Fieldfare *Turdus pilaris*, Redwing *T. iliacus* and Starling *Sturnus vulgaris* and species like Black-headed Gull *Larus ridibundus*, (e.g. Milne 1956, Parr 1963). In the 1950s and 60s most sites supported a range of breeding birds associated with wet or damp habitats, e.g. Moorhen *Gallinula chloropus*, Pied Wagtail

Motacilla alba and Reed Bunting *Emberiza schoeniclus* and many supported breeding Mallard *Anas platyrhynchos*, Sedge Warbler *Acrocephalus schoenobaenus* and Yellow Wagtail *Motacilla flava*.

Wastewater treatment in Britain has changed markedly, as a result of increasing population pressures and rising standards of public health and pollution control. The field lagoon rotation system, typical of sewage farms in the past, were huge by comparison with most contemporary works and size was undoubtedly one of the key factors relating to their ornithological value. A variety of systems now operate, most of them very unlike sewage farms of the past in terms of the habitats available for birds. The biggest change has been the reduction in the extent of wetland habitat. Nevertheless, there are still opportunities for birdlife on present day wastewater treatment works, especially where they create habitat that is otherwise scarce in the surrounding landscape. Even small areas of semi natural or marginal habitat, such as waste ground, scrub and hedgerows, can provide valuable feeding and nesting sites for a range of species. Previous work has also highlighted the value of man-made features for birds e.g. percolating filters and tertiary treatment, especially by surface irrigation (Fuller & Glue 1980, 1981). Similarly, pump-houses and buildings provide nest sites for hirundines, thrushes, wagtails, Starlings and House Sparrow.

Thus, although the ornithological potential of modern wastewater treatment sites works is relatively restricted compared to the old sewage farm systems, they can still represent valuable sites for birds (Fuller & Glue 1980). This may be particularly true in the light of habitat degradation in the wider countryside through, for example, the intensification of farming practices (Chamberlain *et al.* 2000) and loss or degradation of woodland habitats (Fuller 1995, Vanhinsbergh *et al.* 2001, Gregory *et al.* 2002). Despite the increasing recognition of the value of urban habitats for birds, our knowledge about the nature of these communities and the factors determining their density and diversity remains poor.

The present study had four main aims, first, to describe the bird community of treatment works in an area of lowland England in winter and summer; second, to relate the nature of these bird communities to site characteristics including size, the nature and diversity of habitats within the site and the nature of the surrounding landscape; third, to determine the extent to which the breeding bird community reflected that of the surrounding countryside, and, finally; to use this information as a basis for management recommendations, designed to enhance the value of treatment works for birds in winter and summer.

2. METHODS

2.1 Study Area and Site Selection

The study area in lowland England was that covered by Anglian Water (Figure 1), the company providing water and wastewater treatment services in eastern England (http://www.anglianwater.co.uk/). This represents a largely farmland and urban area extending from Lincolnshire in the north to Essex in the south and from Northamptonshire in the west to Norfolk and Suffolk in the east. Volunteer observers were able to choose any site from a complete list of over 1000 wastewater treatment works within the Anglian Water region.

2.2 Bird and Habitat Recording

Birds were recorded on nine survey visits, three in winter and six in summer. Winter visits were made between 1 October and 15 November 2001 (visit one), 16 November and 31 December 2001 (visit two) and 1 January and 28 February 2002 (visit three), with a minimum of ten days between each visit. Summer visits were carried out monthly between 1 April and 30 September 2002. Summer visits were made before 11:00 hours and winter visits between 10:00 and 15:00 hours, to coincide with peak bird activity and, in winter, to avoid roosting movements in the morning and evening. Observers were asked to walk to within 50 m of every part of the site and record all the birds encountered, either by sight or sound, on site maps using a standard mapping technique (Bibby *et al.* 2000). Birds flying over, such as gulls were not recorded unless they were actively using the air space for hunting. In a few cases, at the smaller sites observers were able to record birds accurately from the perimeter fence but at most sites access had to be arranged.

In addition, an initial visit was made to map habitats in late summer/autumn 2001 prior to the first bird survey. Observers were asked to record the presence of all habitats within and including the boundary of the treatment works. This included semi-natural habitats such as hedgerow, scrub and wet meadows, as well as the installations themselves, e.g. pump-houses and rotary filters (see Appendix 1 for complete list of habitats recorded).

3. ANALYSIS

3.1 Factors Influencing Species Richness on Site

Two habitat-related factors were considered likely to be important in determining the abundance and diversity of birds present on wastewater treatment works. First, the habitat diversity of the treatment works site itself – a site comprising a diversity of habitat types will provide feeding and nesting habitat for a wider range of species in summer and winter. Second, the nature of the surrounding environment – whether it is surrounded by a woodland, farmland or urban landscape will determine the potential bird community available to use the site.

The habitat diversity of a site was quantified as the number of habitat types that were present on the site (Appendix 1). Diversity was calculated in this way because areas of individual habitat types were not available and, since many habitats differ in their geometry from linear (e.g. hedges) to two-dimensional (e.g. filterbeds), making direct comparisons were difficult. Landscape context was quantified using data from the Centre for Ecology and Hydrology's *Countryside Survey 2000* (Haines-Young *et al*. 2000). The latter provides estimates of the percentage landcover of various habitat types in 1-km squares throughout Britain. Landcover data were extracted for the nine (three by three) 1-km squares centred on each treatment works. Data were used to derive the area (ha) of woodland, grassland, arable farmland and urban landcover in this 3 km × 3 km square.

3.2 Seasonal Trends in Use of Treatment Works

Use of sites will be seasonal for some species that are either winter or summer visitors to Britain. However, residents may also show seasonal patterns of occurrence or abundance on treatment works. The percentage of sites reporting each species on each winter visit or each spring/summer month was plotted. Percentage occupancy may mask large changes in abundance so the mean number of individuals per visit, across sites, was also calculated. These measures of species occurrence were used to examine seasonal patterns in the use of treatment works by different resident and migrant species.

3.3 Habitat Selection Within Treatment Works

Simple measures of habitat selection were calculated using Jacob's (Jacob 1974) selection index, $D = (r - p) / (r + p - 2rp)$, where r is the proportion of times a habitat was occupied by a species, and p the proportional availability of the habitat. Since habitats differed in their geometry (linear versus two dimensional) and size, each site was simply scored (1 or 0) for the presence or absence respectively of each habitat type. On each site, the score was multiplied by the number of times the site was visited (separately for winter and summer), and this figure summed across sites. This gave an index of total availability in terms of the number of visits on which a habitat type was present. In the same way, habitat use was scored to give the total number of visits on which each habitat type was occupied by each bird species. Jacob's D was calculated for winter and summer separately since a different suite of species was present and since habitat selection may differ seasonally for resident species. Presence rather than abundance was used to reduce problems of differences in size of habitat patches within and between sites.

3.4 Avian Communities on Treatment Works and the Surrounding Countryside

Data from the British Trust for Ornithology/Joint Nature Conservation Committee/Royal Society for the Protection of Birds (BTO/JNCC/RSPB) Breeding Bird Survey (BBS) was used to investigate whether the breeding bird community of wastewater treatment works simply reflected that of the surrounding countryside or was distinct from it in some way e.g. certain species were over or under represented. The BBS is Britain's national breeding bird monitoring scheme and involves surveys of breeding birds in randomly selected 1-km squares throughout Britain (Raven *et al.* 2002). The bird community of the Anglian Water region was quantified using data from 420 BBS survey squares that were surveyed within this region between 1994 and 2001. The list of species reported from BBS was compared with the list reported from May and June visits to treatment works (directly comparable with the BBS survey period). Initially, species present on only BBS or only on treatment sites were identified. Species present on both BBS squares and treatment sites were considered further. Occupancy on treatment works was simply the percentage of works surveyed in May-June that were occupied by each species, ranked from one (most widespread). On BBS squares, the percentage of squares occupied in each year was calculated and ranked, and an average rank calculated across years. This was done on an annual basis, rather than summing occupancy, because some species are sporadic in their occurrence and their prevalence would be overestimated and hence incomparable with the single year of data from the treatment works. Ranks were calculated rather than directly comparing occupancy because the smaller size of treatment works (compared to the 100 ha squares) would inevitably mean that fewer individuals would be sampled and thus a lower absolute occupancy expected by chance.

4. RESULTS

A total of 35 sites were surveyed, giving wide geographic coverage throughout the Anglian Water region (Figure 1). Nineteen of these received all nine visits, 32 received all three winter visits and 19 received all six summer visits (ten sites received no summer visits). Thus, total coverage in winter was 100 sites × visits, and in summer, 133 sites × visits.

4.1 Species Richness

Treatment works were highly variable in terms of the nature of avian communities they supported. Site species richness (i.e. total number of species on a given site) over the whole survey period varied from nine species (Wymondham) to 81 (Marston, Table 1). Similar differences were apparent when summer and winter species richness were considered separately. In winter, species richness varied from five to 81 species, and in summer from ten to 42 species (note that Marston, the site with highest winter species richness, was not surveyed in the summer). For sites that were visited in winter and summer, species richness in each season was significantly correlated (n = 25, r_s = 0.70, P < 0.0001). Species richness was accumulated over a series of visits. On average, individual visits yielded between 2.7 and 49.0 species in winter and between 4.5 and 22.2 species in summer (Table 1).

The extent and diversity of habitats on the site was an important factor influencing species richness. The latter was positively correlated with site area in winter (r_s = 0.54, P < 0.001), summer (r_s = 0.60, P < 0.01) and all seasons (r_s = 0.54, P < 0.001). Species richness was significantly positively correlated with the number of habitat types present on the site (range seven to 20) in winter (n = 35, r_s = 0.56, P < 0.001), summer (n = 25, r_s = 0.40, P < 0.05) and across all visits (n = 35, r_s = 0.36, P < 0.05, Figure 2). Importantly, site area and habitat richness were not significantly correlated (r_s = 0.14, P <0.5 n/s) so large sites did not have more habitat types. This was supported by the fact that a generalised linear model (Dobson 1990) showed that both area ($_1$ = 104.4, P < 0.0001) and habitat richness ($^2_1$ = 8.5, P < 0.005) explained significant variation in species richness (Table 2)

Landscape context in the surrounding 3 km × 3 km square varied considerably between sites (Figure 3). Woodland cover varied from 0% to 32%, grass cover from 9% to 42%, arable cover from 18% to 79% and urban cover from 3% to 40%. The analysis of species richness on an individual site in relation to the percentage cover of each of these four surrounding landscape types was run with and without the Marston site. This particular site was exceptional in terms of species richness (70% higher than the next best site) and site area (170% higher than the next largest site). Winter species richness was not significantly correlated with percentage cover of any of wood, grass, arable or urban habitat in the surrounding landscape. Summer species richness and total species richness were not significantly correlated with either wood or grass cover, although a negative relationship with arable cover approached significance. Species richness in both time periods was, however, significantly positively correlated with urban landcover, especially after excluding Marston (Summer: n = 25, r_s = 0.42, P < 0.05; Total: n = 34, r_s = 0.47, P < 0.005, Figure 4). It may be that a combination of site factors (e.g. habitat diversity and area) overrode any landscape context effects for the Marston site.

Generalised linear models (logit link and Poission errors) showed that site area explained most of the variation in species richness, followed by on-site habitat richness, then surrounding urban landcover and arable landcover. Neither grass nor wood in the surrounding landscape explained significant variation in species richness. Sequential test indicated that on-site habitat richness, together with surrounding arable and urban landscape features, were important in addition to site area. The model explaining most variation included area, urban landcover and on-site habitat richness (Table 2).

4.2 Bird Habitat Relationships Within Wastewater Treatment Sites

The habitat preferences of a number of the more commonly occurring species and/or those of particular interest (e.g. rare or declining species such as Yellow Wagtail) were considered in three 'functional groups'. The latter were defined largely by diet/foraging technique and habitat association as in previous studies (e.g. Atkinson *et al.* 2002, Henderson *et al.* in press). Three groups were considered (Figure 5); species of open ground, feeding on small surface dwelling invertebrates (pipits and wagtails); species associated with hedgerows and other 'woody habitats' (thrushes and robins) and; generalist species (Starling and corvids).

The preferences shown by these groups of species were largely as would be predicted from their ecology. Thus, the three wagtail species, Pied, Grey *Motacilla cinerea* and Yellow, and Meadow Pipit *Anthus pratensis* were all closely associated with damp or wet habitats such as flooded meadows, filter beds and tanks, as well as cut, and occasionally uncut, grass (Figure 5a). The 'hedgerow species'; Robin *Erithacus rubecula*, Blackbird, Dunnock *Prunella modularis* and Song Thrush, were closely associated with the woody habitats present including hedgerows, trees (isolated or as treelines or small plantations) and scrub, as well as 'unspecified' grassy habitats (Figure 5b). The generalist species, Starling, Rook *Corvus frugilegus*, Carrion Crow *C. corone* and Magpie *Pica pica*, as predicted, were associated with a broader range of habitat types, including the filter beds and tanks, cut grass, hedgerows and trees.

The number of species showing positive, negative or neutral selection indices (winter and summer) for 27 habitat types is shown in Table 3. The habitats associated with the greatest number of species were very similar in both summer and winter. Hedgerows were the most frequently selected (27 of 40 species showed positive selection indices in summer and winter). This was followed by scrub and cut grass in winter (17 species) and cut grass, 'unspecified' grass and scrub in summer (19, 18 and 17 species respectively). Other important habitats in winter (those for which > 10 species showed a positive selection index) were flooded meadow, filter beds, tanks uncut grass, plantations and ruderal vegetation. In summer important habitats were filter beds, tanks, plantations, and ruderal vegetation (Table 3).

4.3 Avian Communities on Treatment Works and the Surrounding Countryside

Occupancy in the region based on BBS squares ranged from 0.24% (i.e. one square) for localised species such as Fulmar, *Fulmaris glacialis*, to 99.8% for Woodpigeon *Columba palumbus*. Comparing the most widespread species on BBS squares with the most widespread species on treatment works showed considerable overlap: seven of the ten species were the same (Table 4). In the region as a whole, Skylark *Alauda arvensis* was ranked fourth most widespread and Pheasant *Phasianus colchicus* eighth most widespread. In comparison, these species were 50th and 29th respectively on treatment works. Comparing all species, 112 species were recorded on the region's BBS squares but not on treatment works. There were no cases of the opposite.

For the 70 species recorded on both BBS squares and treatment works, rank occupancy was correlated (Figure 6) but many species were under-reported on treatment works (e.g. open farmland species such as Skylark). There were some notable gains, particularly Pied and Grey Wagtail, both associated with wet/damp and grassy habitats. Pied Wagtail was ranked most widespread on treatment works (96% of works) compared to only 29th in the region as a whole (43-57% of BBS squares). Similarly, Grey Wagtail fell just outside the top ten, being 16th most widespread species on treatment (40% of works) but only 69th most widespread species in the region (1-3% of BBS squares).

A comparison of prevalence of those species on the Red and Amber lists of Birds of Conservation Concern (Gregory *et al.* 2002) is given in Table 5. There are clearly some 'gains' and losses'. Amongst the Red list species, the open farmland species Skylark, Yellowhammer and Linnet are under-represented on treatment works. In contrast, the farmland/scrub species Tree Sparrow *Passer montanus*, Corn Bunting *Miliaria calandra*, Marsh Tit *Parus palustris* and Willow Tit *P. montanus* were all ranked higher on treatment works. However, in each case they were only present on one to two sites and the ranking was high due to many tied ranks. Of the Amber list species, Cuckoo and Mistle Thrush were under-represented on treatment works. Five amber list species 'gains' on treatment works were still only present on one to two treatment works (Table 5). Of the remainder, notable gains were Lapwing which was 33rd most prevalent species on treatment works compared to

43rd on squares. However, percentage occupancy was lower on treatment works. Treatment works also provide a good foraging habitat for the Amber listed aerial feeder, House Martin *Delichon urbica*. Overall, Grey Wagtail showed the greatest difference in rank, and percentage occupancy (Table 5).

5. DISCUSSION

The results of this study suggest that, whilst the density and diversity of bird species present at wastewater treatment works varies considerably between sites, these artificial habitats can support relatively rich bird communities. More than 20 species were recorded at 11 sites in winter and 16 sites in summer. One exceptionally large site (Marston, 83.8ha) supported more than 80 species in winter. In general, the bird community of these treatment works reflected that of the eastern region of England. Those species common in the wider countryside within the Anglian Water region (as recorded through the BTO/JNCC/RSPB Breeding Bird Survey) were also those generally most frequently encountered at treatment sites. There was a tendency for species typical of more arable habitats, including Red and Amber listed species of conservation concern (e.g. Skylark) to be less widespread at wastewater treatment works whilst those associated with short grass and damp habitats, such as pipits and wagtails, were more abundant at these sites than the region overall.

Three factors were identified as having an important influence on the species richness of treatment works. The most important factor was the area of the site, with bigger sites predictably supporting more species. The only landscape factor influencing species richness was the extent of nearby urban habitat. This may reflect the fact that species adapted to exploit urban environments are also likely to be those that might find suitable nesting and foraging sites in and around treatment works. In general, arable and grassland habitats tend to support fewer more specialist bird species than urban habitats, where the community is comprised of a larger number of generalist species (Mead 2000). The third factor determining site species richness was the diversity of habitats within the site. Importantly, this was not simply a result of larger sites having more habitats since these two factors were not correlated.

The key role of habitat diversity in determining species richness of bird communities is well documented in a range of natural and semi-natural habitats including farmland (e.g. Chamberlain *et al.* 1999, Robinson *et al.* 2001, Atkinson *et al.* 2002) and woodland landscapes (e.g. Fuller 1995, Donald *et al.* 1997, 1998, Vanhinsbergh *et al.* 2001). A wider variety of habitat types will provide foraging and breeding habitat for a larger number of individual species throughout the year (e.g. Benton *et al*. 2003). This is particularly important with respect to managing wastewater treatment works in order to maximise their value for birds. Although high habitat diversity is more readily achievable on large sites, the results of this study show that, even small treatment works with a good range of habitats can support diverse bird communities. For instance, Heckington at only 1.2 ha contained 17 habitat types and yielded 28 species, and many sites of 1-2 ha supported good numbers of habitats and bird species.

The ten most frequently encountered birds of wastewater treatment sites were Pied Wagtail, Blackbird, Woodpigeon, Chaffinch *Fringilla coelebs*, Robin, Wren *Troglodytes troglodytes*, Blue Tit *Parus caeruleus*, Starling, Dunnock and Greenfinch *Carduelis chloris*. These fall into three groups; first those associated with damp habitats and open, often short grass - the pipits and wagtails; second those species associated with woody habitats such as hedgerows and scrub – thrushes and wrens and to a lesser extent the finches and tits, and finally generalist species – Starling and corvids. Within these species Starling (at 41% of visits) is Red listed under the Birds of Conservation Concern (BoCC), having declined by >50% in the last 25 years, Dunnock (at 45% of visits) is Amber listed having declined by 25-49 % in the last 25 years.

In addition, several granivorous passerines that are Red listed BoCC (having declined by >50% in the last 25 years), occurred at more than 5% of sites e.g. Linnet *Carduelis cannabina* (11%), Reed Bunting *Emberiza schoeniclus* (9%), Yellowhammer (6%), House Sparrow (6%). Similarly, a number of Amber listed BoCC (having declined by 25-49% in the last 25 years), associated with wet or damp, often grassland habitats, were present at 5% or more sites, e.g. Grey Wagtail (46%), Yellow Wagtail (6% of summer visits) Snipe (5%), Lapwing (5%) and Redwing (5%). The Amber listed Meadow Pipit was common and associated with dry grassy habitats (20% of visits). Wastewater treatment works also provide good foraging for aerial feeders and two amber listed hirundines, Swallow (19%

of summer visits) and House Martin (11% of summer sites), were frequently present. The latter are, of course, summer migrants but these sites also frequently supported the Amber listed winter migrants such as the Fieldfare and Redwing (both at 10% of winter visits). These figures highlight the fact that wastewater treatment works can frequently support, albeit in relatively small numbers, many species of bird that are declining in the wider countryside. The two key semi-natural habitats with which most of these species were associated (Figure 5 and Table 5) were 'woody' features such as hedges and scrub and damp/wet or dry grassland.

Patches of woody habitats, such as hedgerows provide food, shelter and nest cover for birds and the decline of this habitat in the wider countryside has been well documented (O'Connor 1987, Parish *et al*. 1994, 1995, Barr *et al*. 1995, Macdonald & Johnson 1995, Jobin *et al*. 2001). These 'woody' habitats are common features of treatment works and in this study 35 works surveyed contained hedgerows (Appendix 1). Areas of scrub serve a similar role and are also now relatively rare in the wider countryside with little provision made for the creation or management of scrub for birds, or other wildlife, within current Agri-environment schemes (Vickery *et al*. in press). Eighteen of the treatment works contained scrub patches (Appendix 1). The latter are particularly important for breeding Nightingales *Luscinia megarhynchos* (Wilson *et al*. 2002) and Turtle Doves *Streptopelia turtur* (Browne & Aebischer 2001), both species of high conservation concern (Gregory *et al*. 2002).

Areas of short grass, managed perhaps by cutting or mowing but without chemical fertilisers or herbicides, frequently attract small insectivorous wagtails and pipits. This habitat is likely to provide good foraging for these birds that feed visually on surface dwelling invertebrates (Vickery *et al.* 2001). Much of the agriculturally managed grassland in lowland England has become increasingly unsuitable as nesting or foraging habitat for many bird species (Vickery *et al.* 2001). Thus, wastewater treatment works with areas of 'rough' (as opposed to intensively managed) grassland provide a valuable foraging and nesting habitat that is, therefore, becoming increasingly scarce elsewhere. It seems likely that maintaining some cut and some uncut areas of grass would maximise the value of this habitat for foraging and nesting birds. Taller, more structurally complex, grass swards tend to support more abundant and species rich invertebrate communities than short, regularly cut grass swards (Morris 2000) as well as providing potential nesting cover. In contrast, invertebrates are often more readily accessible to ground feeding species, such as pipits and wagtails, in short swards (Vickery *et al.* 2001). Allowing some grass to set seed will also provide a food resource for a number of granivorous finches and buntings (Wilson *et al.* 1999).

Modern wastewater treatment works do, undoubtedly, provide much poorer habitat for bird species associated with wet or damp habitats, that were present on the traditional sewage farms. However they still contain artificial 'wet' habitats in the form of rotary filter beds, tanks and lagoons and these were important 'habitats' in terms of the number of species with which they were associated. There may be further scope for enhancing habitats through wider adoption of tertiary treatment in which water is finally filtered through reed beds and grass plots providing the modern 'flooded meadows' of this study which were selected by many species throughout the year.

In addition to within-site habitat changes, changes to the surrounding landscape may have affected the nature of the bird community on treatment works. Declines of some species in the wider countryside may have simply reduced the 'pool' of birds available to utilise these sites. For example, in the past, large numbers of Yellow Wagtails were recorded using filter beds and other natural and man-made damp habitats for foraging (Fuller & Glue 1978). In the current survey they were recorded at only eight sites in summer, almost certainly reflecting the national decline in their population size in Britain (Nelson *et al.* 2003).

The lack of large areas of wetland habitat almost certainly explains why, unlike in the past, these sites are no longer markedly relatively more valuable for birds in winter than summer. Most of the wintering birds were waders or waterfowl and thus dependent on these wet habitats. With the exception of Mallard, which was encountered on 25% of winter visits, waders and waterfowl were relatively scarce (though, as already mentioned, declining species such as Lapwing, Redshank, Snipe and Green Sandpiper *Tringa ochropus* were still recorded at >5% of sites). The value of these sites now lies, to a much greater extent, in the fact that they provide pockets of semi-natural habitat that is becoming increasingly rare elsewhere in the wider, particularly agricultural, landscapes.

There are a number of recommendations that arise from the work presented here with respect to managing wastewater treatment works to maximise their value for birds. First, enhancing habitat diversity at any site will increase the range of species supported at that site. The two most valuable habitats that could be created and managed at any site are grassland and hedge/scrub. Creating and maintaining a combination of areas of grassland, ideally with some cut and some uncut patches, and some woody habitats, such as hedgerows or scrub, will provide a diversity of nesting and foraging habitats for a range of species throughout the year. Special attention should be paid to two 'types' of site. First, those that include areas of wet or damp grassland/meadow and, second, those that are particularly large sites. The former are particularly valuable for 'wetland birds' and the latter in terms of the abundance and range of species that can, potentially be supported. In these cases it would be worth developing tailor-made management plans.

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Table 1 Species richness on individual water treatment works sites. Separate summaries are given over the three winter visits, the six summer visits, and across all nine visits. For winter and summer, the mean species richness per visits is given along with the total species richness across all visits in the period. Note that ten sites were not visited in the summer and the 'All Totals' for these species are given in italics.

Site	Winter		Summer		All
	Mean	Total	Mean	Total	Total
Aylsham	11.3	19	not visited		*19*
Bedford	21.7	31	22.2	40	46
Brampton	5.3	10	not visited		*10*
Brandon	16	26	16.8	29	38
Briston	11.3	19	not visited		*19*
Brixworth	13.7	19	not visited		*19*
Broadholme	20.3	32	21.2	39	48
Bury St Edmunds	6	10	7.2	15	19
Diss	19.5	25	18	18	32
Duxford	7.7	14	9.8	25	28
East Harling	7	12	7.8	21	24
Fakenham	11	20	9.8	29	32
Framlingham	8	14	11.3	24	25
Great Hockham	3.7	8	7.5	16	17
Heckington	11.7	14	14.7	27	28
Hollowell	15.3	24	not visited		*24*
Ingoldisthorpe	4	7	4.5	15	19
Kings Lynn	16	26	17.2	41	48
Lakenheath	10	10	6.5	10	13
Lamport	5.3	10	not visited		*10*
Long Buckby	19.3	29	not visited		*29*
Marston	49	81	not visited		*81*
Martin	13.3	16	10.7	17	20
Oundle	5.7	11	8	22	26
Rowston	11	14	9.2	15	19
Sandy	2.7	5	11.7	25	25
Sawston	17	25	11.8	28	35
Soham	8	8	9.2	18	20
St Ives	11	18	not visited		*18*
St Neots	16.7	25	18.3	42	44
Stowmarket	17	27	21.5	27	38
Tuddenham	9	15	9.2	22	24
Wickham Market	8	13	11.3	24	27
Woodbridge	9	13	12	24	27
Wymondham	6.3	9	not visited		*9*

Table 2 Results of generalised linear models relating species richness to habitat characteristics of wastewater treatment works and their surroundings. df = degrees of freedom. Π^2_1 is a test of the significant contribution of the last variable listed to reducing deviance. Superscript symbols represent tests of significance: 1 symbol = P < 0.05, 2 symbol = P < 0.01, 3 symbol = P < 0.001, and + and - represent positive and negative relationships respectively.

Single variable models

Variable	df	deviance	Π^2_1
area	33	106.3	104.4^{+++}
habrich	33	138.3	72.4^{+++}
wood	33	210.7	0.0
grass	33	210.3	0.4
arable	33	202.4	8.3^{--}
urban	33	196.4	14.3^{+++}

Two variable models[1]

Variable	df	deviance	Π^2_1
area + habrich	32	97.8	8.5^{++}
area + arable	32	95.8	10.5^{++}
area + urban	32	83.6	22.7^{+++}

Three variable models[1]

Variable	df	deviance	Π^2_1
area + urban + habrich	31	75.0	8.6++
area + urban + arable	31	83.6	0.0

[1] effects of wood and grass were tested here too but there were no significant relationships.

Table 3 Summary of the number of species (40 most abundant species) showing negative, neutral or positive selection indices in winter and summer on different habitat types (see methods for the calculation of selection indices, see also figure 6).

Habitat	**Winter**			**Summer**		
	negative	**neutral**	**positive**	**negative**	**neutral**	**positive**
Built Features						
Road	37	2	1	35	3	2
Buildings	39	0	1	36	3	1
Chambers	40	0	0	40	0	0
Ditch	35	3	2	39	0	1
Filter bed	29	1	10	25	3	12
Settling ponds	30	1	9	37	1	2
Tanks	26	4	10	24	1	15
Semi natural habitats - dry						
Lagoon dry	30	1	9	36	0	4
Lagoon full	33	0	7	34	0	6
Cut grass	13	10	17	12	9	19
Uncut grass	23	4	13	32	2	6
Unspecified grass	26	4	10	18	4	18
Gravel	38	2	0	37	0	3
Hedgerow	12	1	27	12	1	27
Isolated trees	28	5	7	27	3	10
Pasture	40	0	0	40	0	0
Plantation	29	0	11	25	0	15
Scrub	21	2	17	20	3	17
Treeline	25	2	13	22	2	16
Semi natural habitats - wet						
Flooded meadow	28	0	12	31	1	8
Reedswamp	34	1	5	35	0	5
River	38	0	2	39	0	1
River bank	36	0	4	37	0	3
Ruderal vegetation	24	3	13	26	1	13
Stream	40	0	0	39	0	1
Unlabelled	23	6	11	16	8	16

Table 4 Top ten most widespread species in the AWG region and on treatment water sites (with % occupancy in brackets). These are the species that were recorded on most BBS squares or most visits to treatment works.

Rank	BBS squares		Treatment works	
1	Woodpigeon	(99%)	Pied Wagtail	(96%)
2	Blackbird	(96%)	Blackbird	(92%)
3	Chaffinch	(93%)	Woodpigeon	(92%)
4	Skylark	(90%)	Chaffinch	(88%)
5	Wren	(89%)	Robin	(84%)
6	Blue Tit	(86%)	Wren	(80%)
7	Carrion Crow	(85%)	Blue Tit	(64%)
8	Pheasant	(85%)	Starling	(64%)
9	Robin	(84%)	Dunnock	(52%)
10	Starling	(82%)	Greenfinch	(52%)

Table 5 Comparison of percentage occupancy of treatment works and BBS squares for Red and Amber listed Birds of Conservation Concern. *Diff* is the difference in rank of occupancy between the two surveys with positive values indicating greater occupancy on treatment works. Only species with ± 10 rank differences are shown.

A) Red list species

Species	**Treatment works**		**BBS squares**		**Diff**
	%sites	**rank**	**%squares**	**rank**	
Skylark	4%	50th	90%	4th	-46
Yellowhammer	8%	40th	77%	12th	-28
House Sparrow	12%	33rd	68%	17th	-16
Linnet	16%	30th	66%	18th	-12
Tree Sparrow	4%	50th	9%	60th	10
Corn Bunting	8%	40th	19%	51st	11
Marsh Tit	4%	50th	7%	63rd	13
Willow Tit	4%	50th	3%	67th	17

B) Amber list species

Species	**Treatment works**		**BBS squares**		**Diff**
	%sites	**rank**	**%squares**	**rank**	
Cuckoo	4%	50th	50%	28th	-22
Mistle Thrush	4%	50th	44%	33rd	-17
Green Woodpecker	16%	30th	30%	40th	10
Lapwing	12%	33rd	27%	43rd	10
Meadow Pipit	8%	40th	18%	52nd	12
Gadwall	4%	50th	3%	66th	16
Goldcrest	8%	40th	13%	58th	18
Snipe	4%	50th	2%	68th	18
House Martin	36%	19th	33%	38th	19
Oystercatcher	8%	40th	8%	62nd	22
Black-headed Gull	40%	16th	27%	42nd	26
Sand Martin	12%	33rd	5%	64th	31
Grey Wagtail	40%	16th	2%	69th	53

Figure 1 Map showing the Anglian Water region and the wastewater treatment sites surveyed for birds between October 2001 and September 2003. L=Lincoln, N=Northampton, C=Cambridge, I=Ipswich.

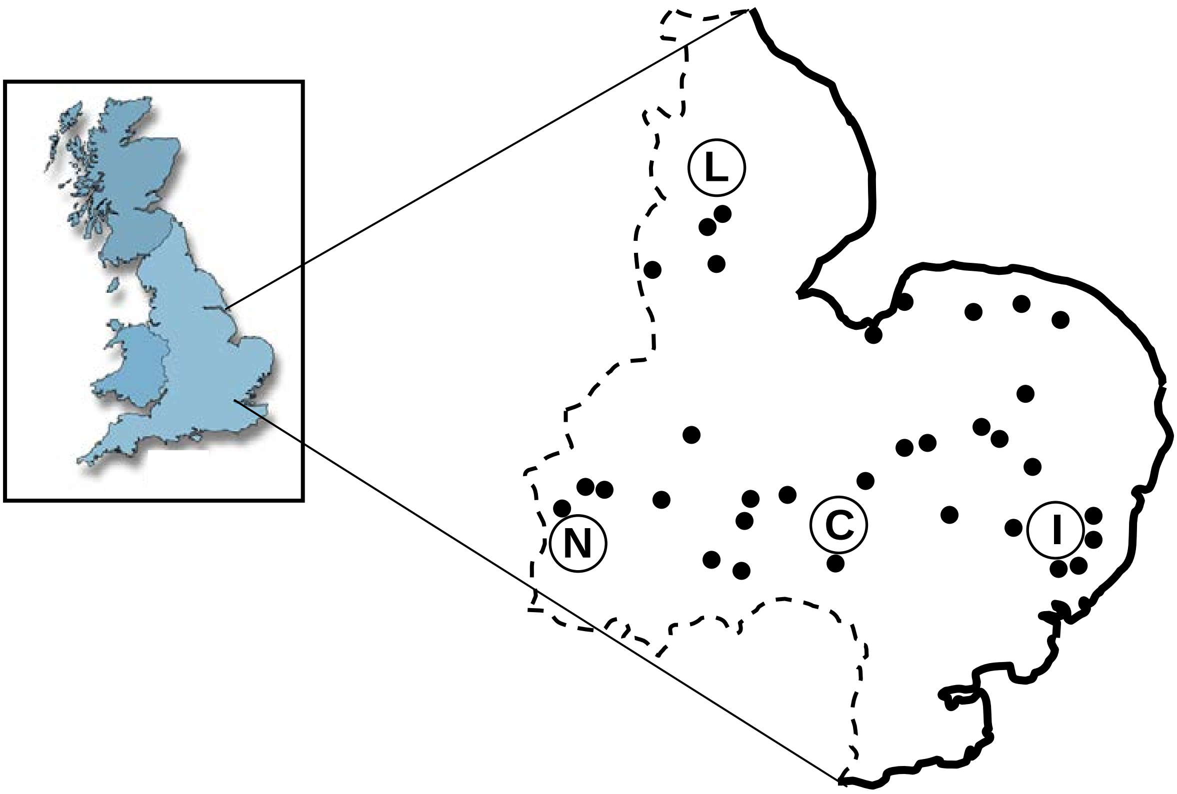


Figure 2 Scatter plot of habitat richness against species richness (total across all visits in summer and winter) at wastewater treatment sites in eastern England. Each point represents a single site.

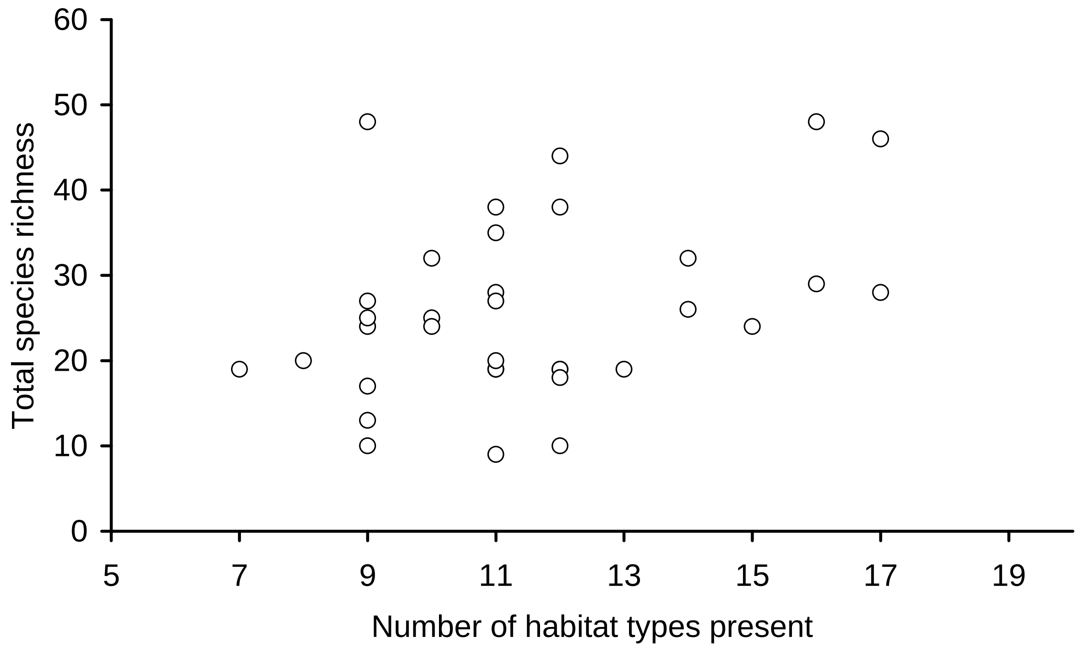


Figure 3 Landscape context of wastewater treatment sites in eastern England. Each column shows the area of urban, arable, grass or wooded cover in the 9 km^2 centred on the individual sites (from CS2000).

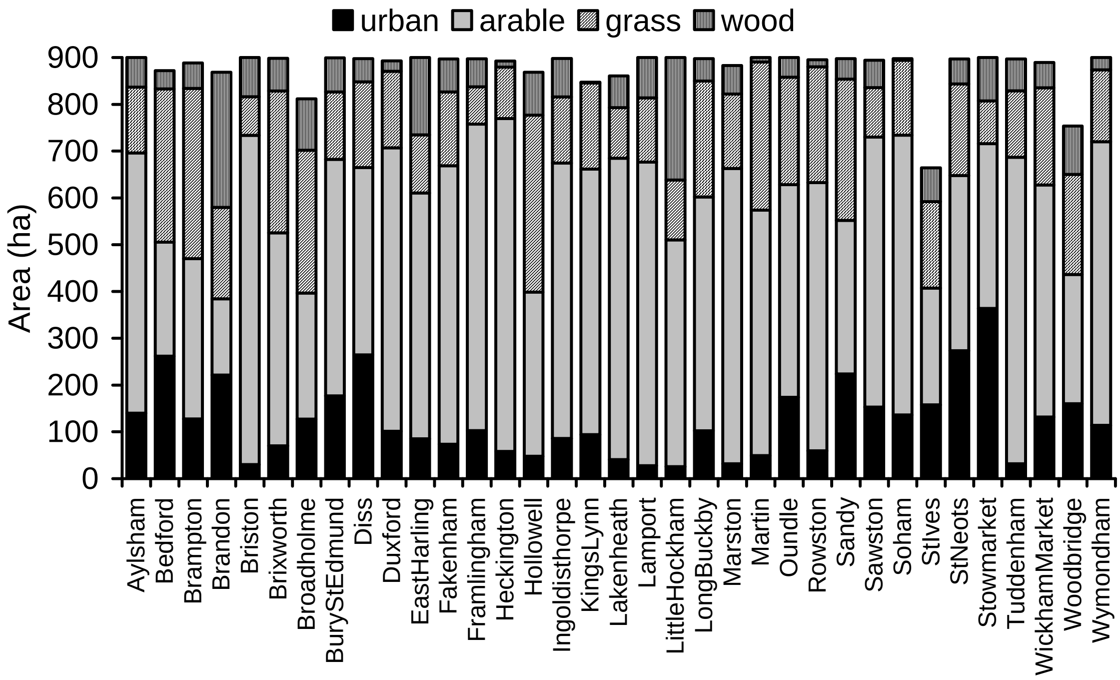


Figure 4 Scatter plot of %urban landcover in surrounding area against species richness on wastewater treatment works in eastern England (total across all visits in summer and winter). Note that the Marston site (solid dot) with exceptional species richness was excluded.

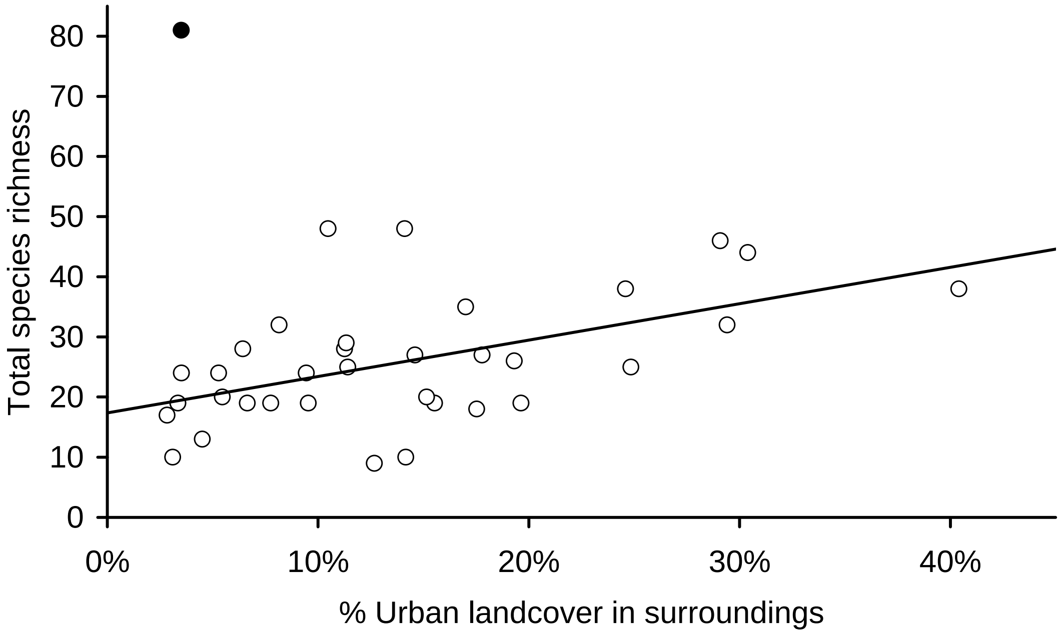
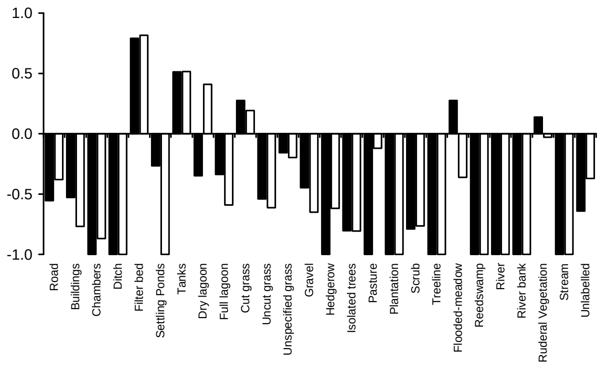


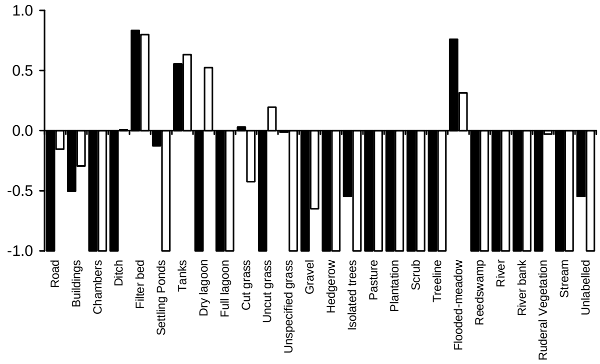
Figure 5 Selection for individual habitat types within wastewater treatment sites. This is based on an index of availability (the number of visits on which a habitat type was present) and habitat use (the total number of visits on which a habitat type was occupied) by each bird species. The selection index, Jacob's D, was calculated for winter (white) and summer (black).

a. Pipits and wagtails

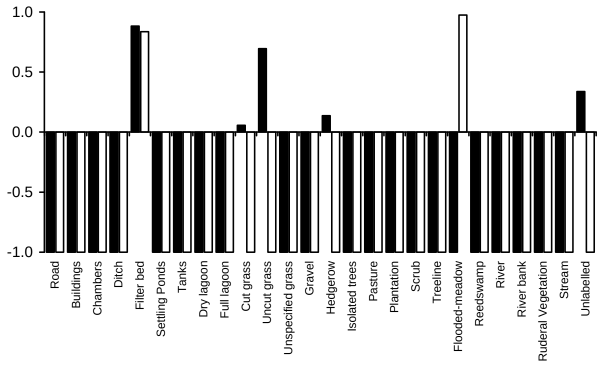
Pied Wagtail



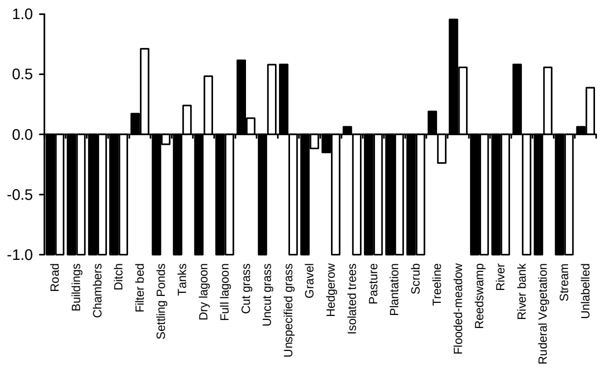
Grey Wagtail



Yellow Wagtail

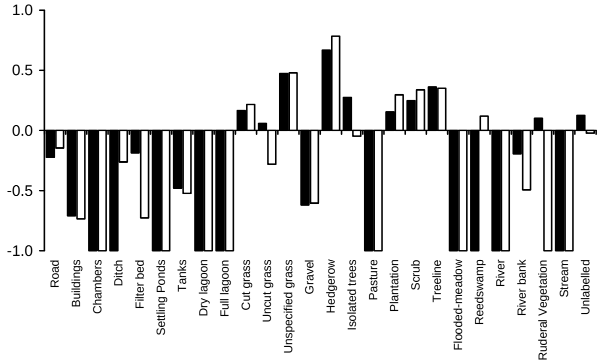


Meadow Pipit

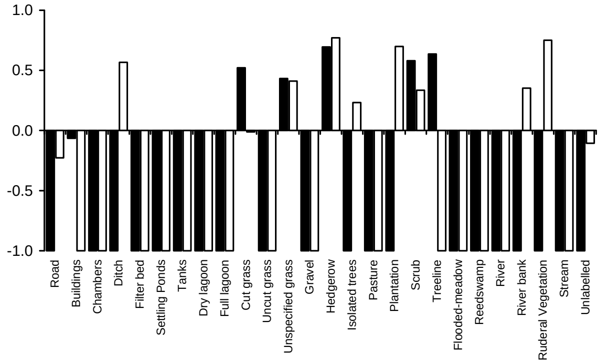


b Hedgerow species

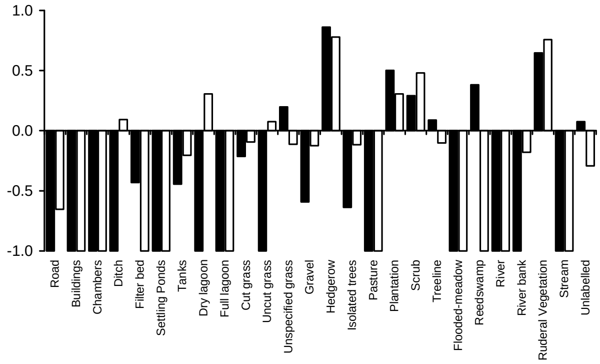
Blackbird



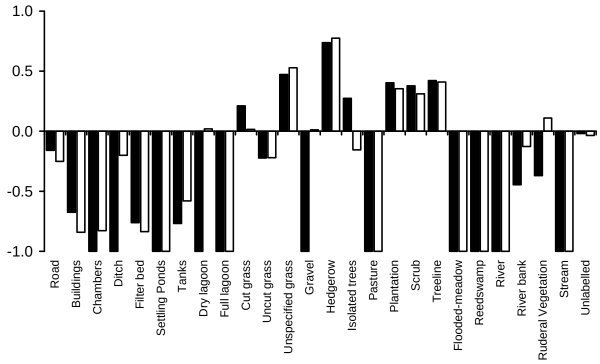
Song Thrush



Dunnock

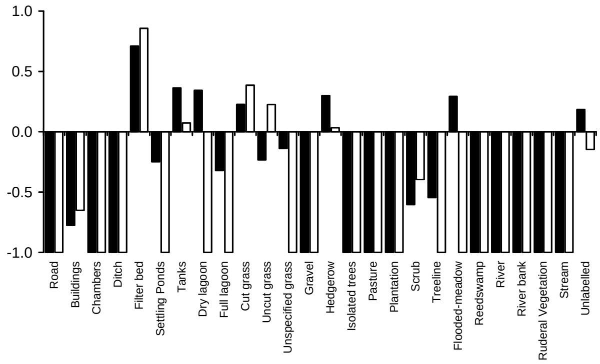


Robin

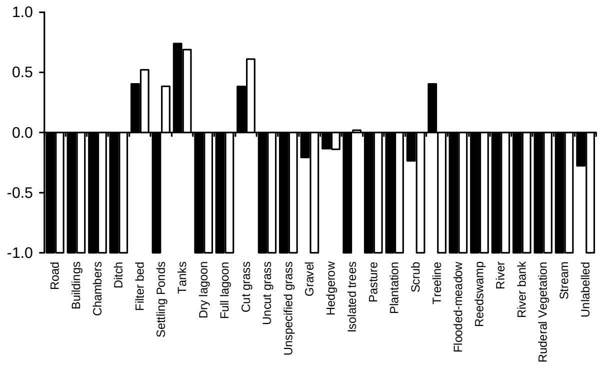


c. Generalists species

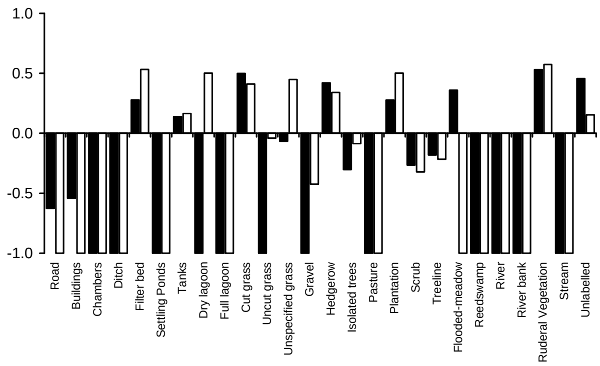
Starling



Rook



Carrion Crow



Magpie

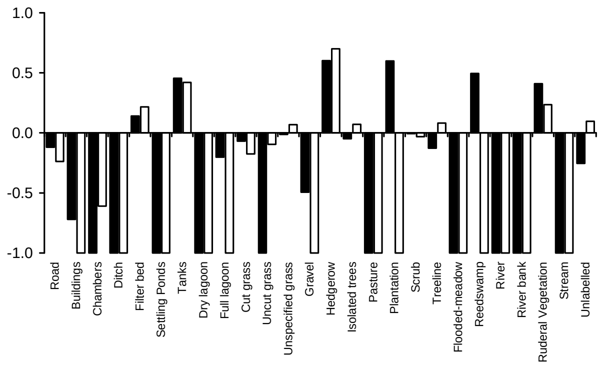
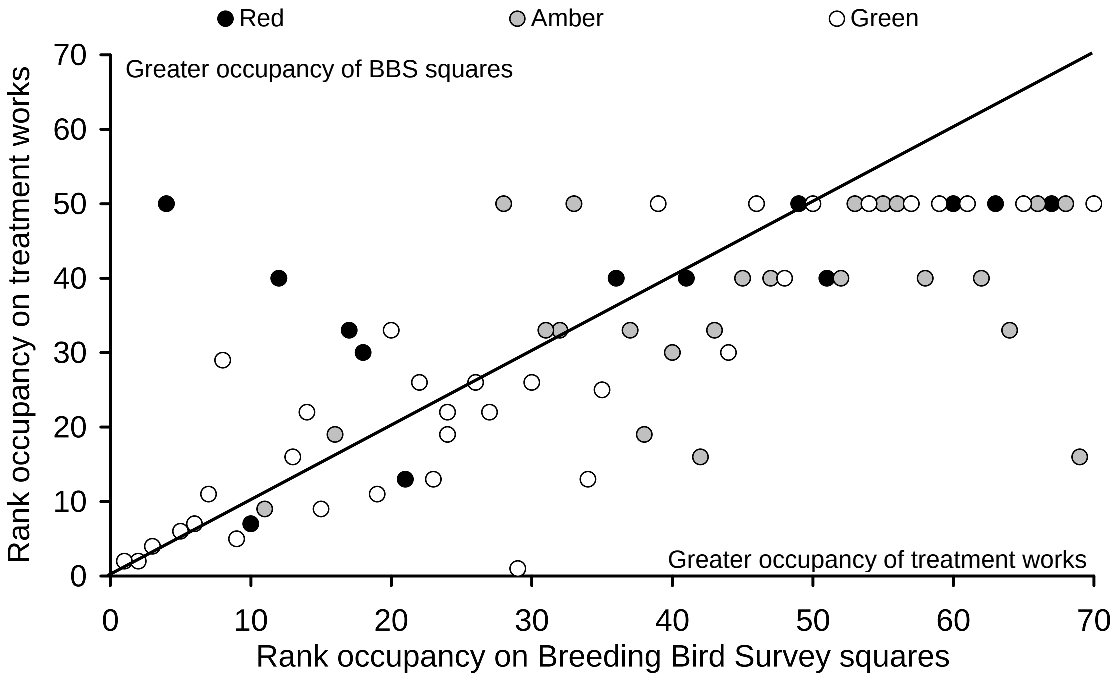


Figure 6 Scatter plot of species rank occupancy on BBS squares versus wastewater treatment works in eastern England. The line shows the 1:1 relationship if species are equally prevalent on sites as in the surrounding areas. Some species were under-represented on treatment works (above line), whilst others were over-represented (below line). Note that several species, all present on only one treatment works, are tied with rank occupancy of 50. Note also that 112 species are omitted that were recorded on BBS squares but not on treatment works. The codes Red, Amber, Green refer to the category under which each species is listed in BoCC (see text and also Gregory *et al.* 2002)



Appendix 1 List of habitat categories, and their codes, to which bird registrations were assigned at wastewater treatment works, along with the number of sites where present (*n*) and a habitat description where necessary.

Category	Code	n	Description
Built features			
Road	RD	26	
Buildings	BU	35	
Chambers	CH	32	usually raised manhole covers
Ditch	DI	5	man-made ditches in which water is moving
Filter bed	FB	34	round rotary filter beds
Settling Ponds	SP	10	brick built with stationary water
Tanks	TT	34	any brick built tanks/filters not otherwise coded
Lagoon dry	LD	3	brick/stone built, usually lined with polythene
Lagoon full	LF	10	brick/stone built, usually lined with polythene
Semi natural habitats - dry			
Grass cut	GC	35	
Grass uncut	GU	10	
Grass unspecified	GX	7	
Gravel	GR	23	
Hedgerow	HH	30	
Isolated trees	IT	21	
Pasture	PA	3	
Plantation	PL	3	
Scrub	SB	18	
Treeline broadleaf	TB	14	
Semi natural habitats - wet			
Meadow flooded	MF	5	surface water present (on old sewage farm systems)
Reedswamp	RS	5	surface water present (on old sewage farm systems)
Grass/scrub mosaic	SC	1	damp area unmown with developing scrub
River	RV	6	
River bank	RB	9	
Ruderal Vegetation	RU	5	rough areas often with building work in process
Stream	SM	4	
Unlabelled\Other	XX	20	

Appendix 2 Summary of occurrence of the 114 bird species reported from Anglian Water treatment works. Code is the two-letter species code used in some figures. S, W and T are occurrence details for Summer visits, Winter visits and across all visits (Total) respectively. Occurrence is the total number of visits, across all sites, during each period, when a species was recorded (% of visits when present in parentheses).

Common name	Scientific name	Code	W	S	T
Little Grebe	*Tachybaptus ruficollis*	LG	1 (1%)	1 (1%)	2 (1%)
Cormorant	*Phalacrocorax carbo*	CA	2 (2%)	2 (2%)	4 (2%)
Grey Heron	*Ardea cinerea*	H.	6 (6%)	2 (2%)	8 (3%)
Mute Swan	*Cygnus olor*	MS	3 (3%)	1 (1%)	4 (2%)
Whooper Swan	*Cygnus cygnus*	WS	0 (0%)	1 (1%)	1 (0%)
Greylag Goose	*Anser anser*	GJ	2 (2%)	0 (0%)	2 (1%)
Canada Goose	*Branta canadensis*	CG	1 (1%)	1 (1%)	2 (1%)
Shelduck	*Tadorna tadorna*	SU	2 (2%)	1 (1%)	3 (1%)
Wigeon	*Anas penelope*	WN	3 (3%)	0 (0%)	3 (1%)
American Wigeon	*Anas americana*	AW	1 (1%)	0 (0%)	1 (0%)
Gadwall	*Anas strepera*	GA	3 (3%)	1 (1%)	4 (2%)
Teal	*Anas crecca*	T.	7 (7%)	2 (2%)	9 (4%)
Mallard	*Anas platyrhynchos*	MA	25 (25%)	33 (25%)	58 (25%)
Shoveler	*Anas clypeata*	SV	2 (2%)	0 (0%)	2 (1%)
Tufted Duck	*Aythya fuligula*	TU	5 (5%)	2 (2%)	7 (3%)
Ruddy Duck	*Oxyura jamaicensis*	RY	1 (1%)	0 (0%)	1 (0%)
Sparrowhawk	*Accipiter nisus*	SH	8 (8%)	1 (1%)	9 (4%)
Buzzard	*Buteo buteo*	BZ	1 (1%)	0 (0%)	1 (0%)
Kestrel	*Falco tinnunculus*	K.	9 (9%)	10 (8%)	19 (8%)
Peregrine	*Falco peregrinus*	PE	1 (1%)	0 (0%)	1 (0%)
Red-legged Partridge	*Alectoris rufa*	RL	8 (8%)	10 (8%)	18 (8%)
Grey Partridge	*Perdix perdix*	P.	1 (1%)	4 (3%)	5 (2%)
Pheasant	*Phasianus colchicus*	PH	22 (22%)	22 (17%)	44 (19%)
Water Rail	*Rallus aquaticus*	WA	3 (3%)	0 (0%)	3 (1%)
Moorhen	*Gallinula chloropus*	MH	39 (39%)	40 (30%)	79 (34%)
Coot	*Fulica atra*	CO	6 (6%)	6 (5%)	12 (5%)
Oystercatcher	*Haematopus ostralegus*	OC	0 (0%)	4 (3%)	4 (2%)
Little Ringed Plover	*Charadrius dubius*	LP	1 (1%)	0 (0%)	1 (0%)
Golden Plover	*Pluvialis apricaria*	GP	1 (1%)	0 (0%)	1 (0%)
Lapwing	*Vanellus vanellus*	L.	5 (5%)	6 (5%)	11 (5%)
Dunlin	*Calidris alpina*	DN	2 (2%)	0 (0%)	2 (1%)
Ruff	*Philomachus pugnax*	RU	1 (1%)	0 (0%)	1 (0%)
Jack Snipe	*Lymnocryptes minimus*	JS	3 (3%)	1 (1%)	4 (2%)
Snipe	*Gallinago gallinago*	SN	7 (7%)	5 (4%)	12 (5%)
Woodcock	*Scolopax rusticola*	WK	1 (1%)	0 (0%)	1 (0%)
Curlew	*Numenius arquata*	CU	3 (3%)	0 (0%)	3 (1%)
Redshank	*Tringa totanus*	RK	6 (6%)	1 (1%)	7 (3%)
Green Sandpiper	*Tringa ochropus*	GE	10 (10%)	8 (6%)	18 (8%)
Common Sandpiper	*Actitis hypoleucos*	CS	0 (0%)	3 (2%)	3 (1%)
Black-headed Gull	*Larus ridibundus*	BH	33 (33%)	40 (30%)	73 (31%)
Common Gull	*Larus canus*	CM	3 (3%)	1 (1%)	4 (2%)
Lesser Blk-b. Gull	*Larus fuscus*	LB	1 (1%)	4 (3%)	5 (2%)
Herring Gull	*Larus argentatus*	HG	0 (0%)	3 (2%)	3 (1%)
Common Tern	*Sterna hirundo*	CN	0 (0%)	1 (1%)	1 (0%)
Feral Pigeon	*Columba livia*	FP	0 (0%)	1 (1%)	1 (0%)
Stock Dove	*Columba oenas*	SD	3 (3%)	11 (8%)	14 (6%)
Woodpigeon	*Columba palumbus*	WP	53 (53%)	108 (81%)	161 (69%)

Collared Dove	*Streptopelia decaocto*	CD	7 (7%)	12 (9%)	19 (8%)
Turtle Dove	*Streptopelia turtur*	TD	0 (0%)	4 (3%)	4 (2%)
Ring-necked Parakeet	*Psittacula krameri*	RI	0 (0%)	1 (1%)	1 (0%)
Cuckoo	*Cuculus canorus*	CK	0 (0%)	1 (1%)	1 (0%)
Barn Owl	*Tyto alba*	BO	1 (1%)	0 (0%)	1 (0%)
Little Owl	*Athene noctua*	LO	2 (2%)	1 (1%)	3 (1%)
Tawny Owl	*Strix aluco*	TO	1 (1%)	0 (0%)	1 (0%)
Long-eared Owl	*Asio otus*	LE	1 (1%)	0 (0%)	1 (0%)
Short-eared Owl	*Asio flammeus*	SE	3 (3%)	0 (0%)	3 (1%)
Swift	*Apus apus*	SI	1 (1%)	11 (8%)	12 (5%)
Kingfisher	*Alcedo atthis*	KF	2 (2%)	0 (0%)	2 (1%)
Green Woodpecker	*Picus viridis*	G.	10 (10%)	18 (14%)	28 (12%)
G. S. Woodpecker	*Dendrocopos major*	GS	5 (5%)	5 (4%)	10 (4%)
Skylark	*Alauda arvensis*	S.	3 (3%)	2 (2%)	5 (2%)
Sand Martin	*Riparia riparia*	SM	0 (0%)	8 (6%)	8 (3%)
Swallow	*Hirundo rustica*	SL	1 (1%)	25 (19%)	26 (11%)
House Martin	*Delichon urbica*	HM	1 (1%)	14 (11%)	15 (6%)
Meadow Pipit	*Anthus pratensis*	MP	35 (35%)	12 (9%)	47 (20%)
Rock Pipit	*Anthus petrosus*	RC	1 (1%)	0 (0%)	1 (0%)
Yellow Wagtail	*Motacilla flava*	YW	2 (2%)	8 (6%)	10 (4%)
Grey Wagtail	*Motacilla cinerea*	GL	61 (61%)	47 (35%)	108 (46%)
Pied Wagtail	*Motacilla alba*	PW	89 (89%)	107 (81%)	196 (84%)
Wren	*Troglodytes troglodytes*	WR	64 (64%)	83 (62%)	147 (63%)
Dunnock	*Prunella modularis*	D.	45 (45%)	60 (45%)	105 (45%)
Robin	*Erithacus rubecula*	R.	75 (75%)	96 (72%)	171 (73%)
Redstart	*Phoenicurus phoenicurus*	RT	1 (1%)	0 (0%)	1 (0%)
Whinchat	*Saxicola rubetra*	WC	0 (0%)	1 (1%)	1 (0%)
Stonechat	*Saxicola torquata*	SC	3 (3%)	0 (0%)	3 (1%)
Blackbird	*Turdus merula*	B.	83 (83%)	103 (77%)	186 (80%)
Fieldfare	*Turdus pilaris*	FF	10 (10%)	3 (2%)	13 (6%)
Song Thrush	*Turdus philomelos*	ST	19 (19%)	25 (19%)	44 (19%)
Redwing	*Turdus iliacus*	RE	10 (10%)	1 (1%)	11 (5%)
Mistle Thrush	*Turdus viscivorus*	M.	9 (9%)	5 (4%)	14 (6%)
Sedge Warbler	*A. schoenobaenus*	SW	0 (0%)	7 (5%)	7 (3%)
Reed Warbler	*Acrocephalus scirpaceus*	RW	1 (1%)	0 (0%)	1 (0%)
Whitethroat	*Sylvia communis*	WH	0 (0%)	16 (12%)	16 (7%)
Garden Warbler	*Sylvia borin*	GW	1 (1%)	2 (2%)	3 (1%)
Blackcap	*Sylvia atricapilla*	BC	2 (2%)	13 (10%)	15 (6%)
Chiffchaff	*Phylloscopus collybita*	CC	7 (7%)	32 (24%)	39 (17%)
Willow Warbler	*Phylloscopus trochilus*	WW	1 (1%)	9 (7%)	10 (4%)
Goldcrest	*Regulus regulus*	GC	2 (2%)	5 (4%)	7 (3%)
Long-tailed Tit	*Aegithalos caudatus*	LT	22 (22%)	7 (5%)	29 (12%)
Marsh Tit	*Parus palustris*	MT	0 (0%)	1 (1%)	1 (0%)
Willow Tit	*Parus montanus*	WT	4 (4%)	3 (2%)	7 (3%)
Coal Tit	*Parus ater*	CT	1 (1%)	0 (0%)	1 (0%)
Blue Tit	*Parus caeruleus*	BT	41 (41%)	66 (50%)	107 (46%)
Great Tit	*Parus major*	GT	30 (30%)	34 (26%)	64 (27%)
Treecreeper	*Certhia familiaris*	TC	2 (2%)	3 (2%)	5 (2%)
Jay	*Garrulus glandarius*	J.	2 (2%)	1 (1%)	3 (1%)
Magpie	*Pica pica*	MG	32 (32%)	40 (30%)	72 (31%)
Jackdaw	*Corvus monedula*	JD	10 (10%)	19 (14%)	29 (12%)
Rook	*Corvus frugilegus*	RO	15 (15%)	26 (20%)	41 (18%)
Carrion Crow	*Corvus corone*	C.	30 (30%)	51 (38%)	81 (35%)
Starling	*Sturnus vulgaris*	SG	39 (39%)	57 (43%)	96 (41%)
House Sparrow	*Passer domesticus*	HS	5 (5%)	9 (7%)	14 (6%)

Tree Sparrow	*Passer montanus*	TS	5 (5%)	3 (2%)	8 (3%)
Chaffinch	*Fringilla coelebs*	CH	61 (61%)	88 (66%)	149 (64%)
Brambling	*Fringilla montifringilla*	BL	1 (1%)	0 (0%)	1 (0%)
Greenfinch	*Carduelis chloris*	GR	19 (19%)	51 (38%)	70 (30%)
Goldfinch	*Carduelis carduelis*	GO	14 (14%)	23 (17%)	37 (16%)
Siskin	*Carduelis spinus*	SK	1 (1%)	0 (0%)	1 (0%)
Linnet	*Carduelis cannabina*	LI	9 (9%)	16 (12%)	25 (11%)
Lesser Redpoll	*Carduelis cabaret*	LR	3 (3%)	0 (0%)	3 (1%)
Bullfinch	*Pyrrhula pyrrhula*	BF	5 (5%)	2 (2%)	7 (3%)
Yellowhammer	*Emberiza citrinella*	Y.	9 (9%)	6 (5%)	15 (6%)
Reed Bunting	*Emberiza schoeniclus*	RB	13 (13%)	7 (5%)	20 (9%)
Corn Bunting	*Miliaria calandra*	CB	1 (1%)	2 (2%)	3 (1%)