BTO Research Report No. 498

Development of wild bird indicators for freshwater wetlands and waterways: provisional indicators

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JOINT BTO RESEARCH REPORT / ENVIRONMENT AGENCY REPORT

May 2008

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Registered Charity No: 216652

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Published in May 2008 by the British Trust for Ornithology
The Nunnery, Thetford, Norfolk, IP24 2PU,UK

ISBN No. 978-1-906204-35-8

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1. Introduction

Much of the earlier history of bioindicator development in the UK was to reflect single pressures, such as organic pollution or acidification of wetland habitats. However, more recent legislation (particularly the EU Water Framework Directive (WFD)), broader-scale commitments (such as the Environment Agency's Vision theme of *An Enhanced Environment for Wildlife*), agreements for delivery of public benefit in the UK such as the Defra (Department of Environment, Food and Rural Affairs) PSA (Public Sector Agreement) of "…*biodiversity safeguarded and enhanced*", and evolving awareness of the interactions of environmental impacts means that we require more sophisticated and comprehensive indicators that demonstrate the integrated impacts of multiple pressures.

There are many types of biological indicators underpinned by various 'surrogate species' – including for example keystone species, flagship species, ecosystem engineers, etc. – each of which may serve different purposes by indicating various attributes of the environment and/or the pressures upon it. The characteristics of different taxa suit them to indicating different attributes of the aquatic environment, for example diatoms being sessile and responsive to local pressures whilst higher trophic level organisms such as birds and mammals are generally mobile across the landscape and more likely to reflect the cumulative effects of various environmental pressures. Moreover, in the UK birds have a high public profile, are highly visible, substantial population census datasets exist and there has been considerable development of analytical methods. Birds are therefore highly appropriate for the assessment of attributes of environmental quality at landscape scale.

The purpose of developing this new set of wild bird indicators is to reflect the general health of freshwater waterways and wetland habitats at landscape scale in the UK, based on existing data. This mirrors the development of the farmland bird indicator in the UK, which provided a focus for the aggregated pressures upon the environment from which the need for further investigation and novel land use policy became starkly apparent. By formulating indicators for different freshwater waterways and wetland habitats, it is likely that we will pick up 'signals' that we might otherwise miss, and which may better direct future policy, practice and influence to improve the health of the aquatic environment, its associated biodiversity and ecosystem services.

Throughout the development process, the project team sought synergy, and ultimately convergence, with the development needs of related bird-based indicators across the UK. Particularly important partner indicators were the England Biodiversity Group's *Water and Wetland* indicator and the suite of sustainable development indicators reported upon routinely by Defra.

This report outlines the methods developed for the Environment Agency's bird population indicators, providing an overview but also addressing the ecological, technical and statistical principles that underpin the approach. The approach is based on methods developed by the RSPB and BTO which are already accepted, widely-used and well-tested in other contexts. Details of methods used are noted in Annex 1, and Freeman *et al*. (2001) demonstrate the applicability of various of these methods to measuring population changes in farmland birds in the UK. Where different methods are suggested, reasons and relevant citations are provided. Underlying much of the statistical approach are questions about the aim of the indicators, which are as much policy-related as technical. Nevertheless, the methods explored here can be adapted to different purposes once consensus about aims has been achieved.

2. Methods

2.1 Selection of waterways and wetland habitats and their associated bird species

Following preliminary tests of alternative approaches (for example identifying the bird species likely to be most strongly impacted by particular environmental or anthropogenic pressures), the expert group comprising the Project Board for this work adopted the approach of assigning a range of wetland bird species to one or more of a target set of freshwater waterway and wetland habitats. This process identified a range of freshwater waterway and wetland habitats for which, ideally, indicators might be developed. These comprised seven habitat types (fast-moving waterways, slow-moving waterways, standing waters, reedbeds, wet meadows, wet woodland and wet moorland). However, the likelihood of insufficient data to develop and support the latter two indicators was recognised.
Whereas the practice for development of most British bird indicators developed previously in the UK has been to rely upon expert judgement of habitat preferences as classified in the last UK Breeding Bird Atlas (Gibbons *et al*, 1993), we took the view that it was important to develop and demonstrate an evidence base to inform decisions of allocation of bird species to freshwater habitats. The allocation of bird species to each of the target habitat types is based on the results of a literature review, analyses using two sets of bird census data – the BTO/JNCC/RSPB Breeding Bird Survey (BBS) and the BTO/EA Waterways Breeding Bird Survey (WBBS) - and the sufficiency of data to support inclusion in an indicator set. The evidence base associating bird species to freshwater wetland habitat types is published by Everard and Noble (2008).

Data sources assessed to support indicator development came from six different UK bird surveys undertaken at least since the early 1970s, at least four of them targeted at wetland habitats. These datasets are:

- WBBS (the BTO/EA Waterways Breeding Bird Survey), started in 1998;
- WBS (the BTO Waterways Bird Survey), started in 1974;
- BBS (the BTO/JNCC/RSPB Breeding Bird Survey), started in 1994;
- CBC (the BTO/JNCC Common Birds Census), started in 1962;
- CES (the BTO/JNCC Constant Effort Scheme), started in 1983;
- The BTO Heronries Census, started in 1928; as well as
- Selected additional sources such as Rare Breeding Bird Panel reports and county bird records.

The ways that the data from these surveys are selected, used and combined to produce aggregated trends, approved protocols to account for differences in sampling coverage and intensity, are documented in more detail in an associated technical report (Noble *et al*. 2008) and Annex 1.

Amongst the conclusions of this body of work were:

- There was insufficient evidence to strongly associate any specific bird species with either slow-flowing waterways or standing waters in isolation. The evidence suggests that the habitat provided by such waters and their fringing habitats is broadly similar. This supports the merging of these categories into a combined 'slow-moving and standing waters' indicator. This is entirely consistent with the approach taken to develop the 'slow/standing water indicator' used by the England Biodiversity Group (http://www.defra.gov.uk/wildlife-countryside/biodiversity/biostat/indicators/index.htm), albeit that selection of species for the EBS was based on expert judgement; we provide for it an evidence base. It may nevertheless be possible to produce separate trend lines for these two habitats – 'slow-flowing waterways' and 'standing waters' – in the future.

- Apart from the Willow Tit, there were no other species associated strongly enough with wet woodland, and for which data were available, to support a discrete indicator for this habitat. The trend for Willow Tit already contributes to UK and England woodland bird indicators, but data are sparse for this scarce and declining species.
- Although Golden Plover are at a national population level sufficient to include in a wet moorland indicator, no other species were either strongly enough associated with the habitat or else present at adequate population levels for a reliable index to be generated.

As a consequence of these findings, the indicator set was therefore reduced to four freshwater habitat types: fast-flowing waters; slow-moving and standing waters combined; reedbeds; and wet meadows (the latter including wet grassland and marshes). The species composition of each is listed in Table 1. Note that besides the 22 species in the separate sub-habitat indicators, four additional species (Sand Martin, Kingfisher, Oystercatcher and Grey Heron) were not found to be strongly associated with any one of the habitat types considered but are included in a general aggregated indicator that covers all freshwater species. Although this implies that they should be considered habitat generalists, this is probably true only for Grey Heron: species such as Sand Martin have very specific requirements for nesting habitat (sand banks adjacent to water bodies) but do not fit neatly into the habitat categories used in these analyses.

Table 1 Bird species composition of freshwater habitat indicators. Unless otherwise indicated, the data source used covers all or most habitats.

Fast-flowing waters	**Slow/standing waters**	**Reedbeds**	**Wet meadows**	**'Unclassified' wetland species**
Common Sandpiper[1]	Little Grebe	Reed Warbler	Mute Swan	Grey Heron[3]
Goosander[1]	Great Crested Grebe[5]	Sedge Warbler	Teal[5]	Kingfisher
Grey Wagtail[1]	Mallard	Cetti's Warbler[2]	Curlew	Oystercatcher
Dipper[1]	Tufted Duck	Reed Bunting[1]	Lapwing[1]	Sand Martin
	Moorhen		Snipe	
	Coot		Redshank	
			Yellow Wagtail[1]	
			Little Egret[4]	

[1] Only data from the two waterways surveys (WBS and WBBS) are used.
[2] Data source is Constant Effort Scheme (CES), largely reedbeds and scrub habitat.
[3] Data source is Heronries Census
[4] Data source is full counts (RBBP, Heronries)
[5] Data sources are WBBS and BBS (since 1998 and 1994)

For three species (Lapwing, Yellow Wagtail and Reed Bunting) which are already included in the Farmland Bird index based on their CBC-BBS trends, we use an independent trend based on WBS-WBBS data to reflect changes in the populations of these species in wetland (albeit mainly riparian) rather than farmland habitats.

Following precedents set for other wild bird indicators, we exclude introduced species from the proposed indicators on the grounds that, unlike native species, increases in alien species (such as

Ruddy Duck) would often be regarded as a negative outcome and declines a positive one, even in cases where there is little evidence of a negative impact (e.g. Mandarin Duck).

2.2 Production of bird indicators for freshwater waterways and wetland habitats

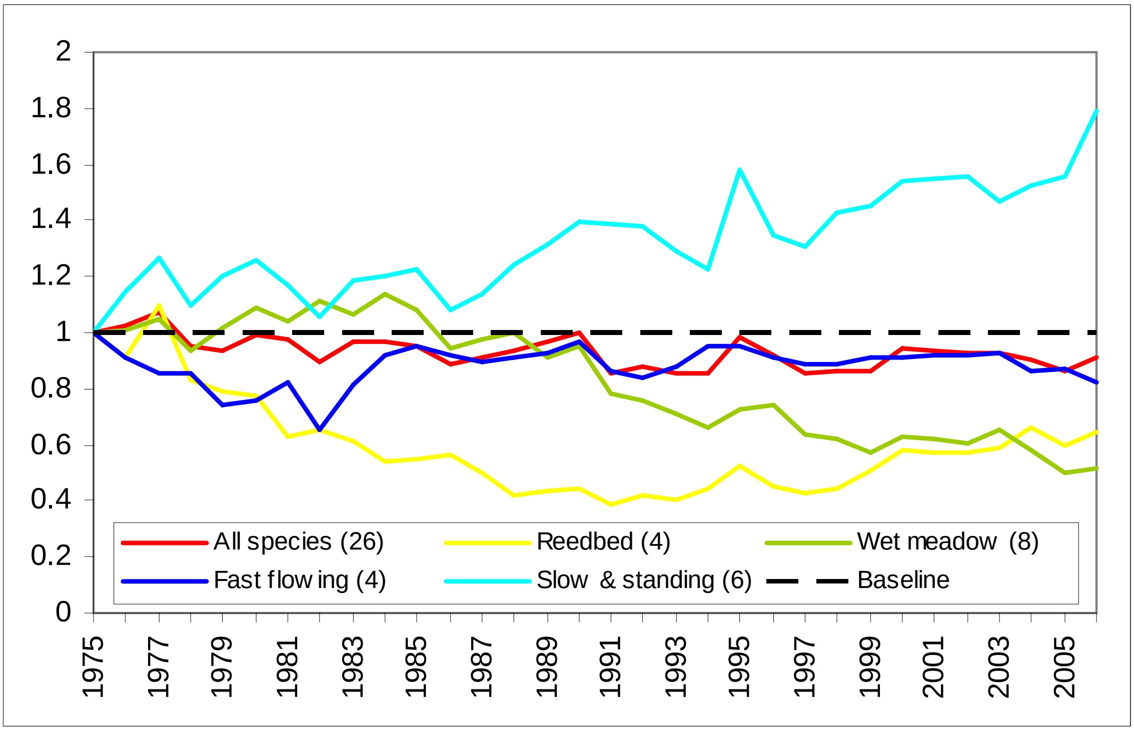
From population trends for each species, composite indicators were developed for the four target habitats: fast-flowing waters; slow-moving and standing waters combined; reedbeds; and wet meadows (comprising wet grassland and marshes). In addition, an all-species composite 'freshwater birds' index was derived for all 22 species in the four habitat-specific indicators augmented by the four additional 'generalist' species. The baseline for index development was 1975, as most of the earlier data are based on the BTO's Waterways Bird Survey (WBS) which started in 1974. However, trends for nine species are incorporated into the indicator in a later year (due to the later period of coverage of the data source, or the time at which the size of the breeding population in the UK reached the agreed threshold level for inclusion) following standard protocols (see Annex 1).

3. Results

3.1 Production of bird indicators for freshwater waterways and wetland habitats at UK scale

Based on the above principles and the detailed methods elaborated at Annex 1, a suite of bird indicators for freshwater habitats were produced. Figure 1 (below) shows the recommended new indicator for the UK, comprised of the unsmoothed trends of 26 bird species that occupy these habitats. In Figure 1, the trend for birds of 'slow-moving and standing waters combined' is the only one to increase, almost doubling since 1975. Birds of wet meadows show a marked and steady decline since the early 1980s, whereas birds of fast-moving waters have fluctuated in numbers at levels about 20% below the 1975 baseline. Birds of reedbeds declined from 1975 through to the 1990s and then increased almost back to the 1975 index.

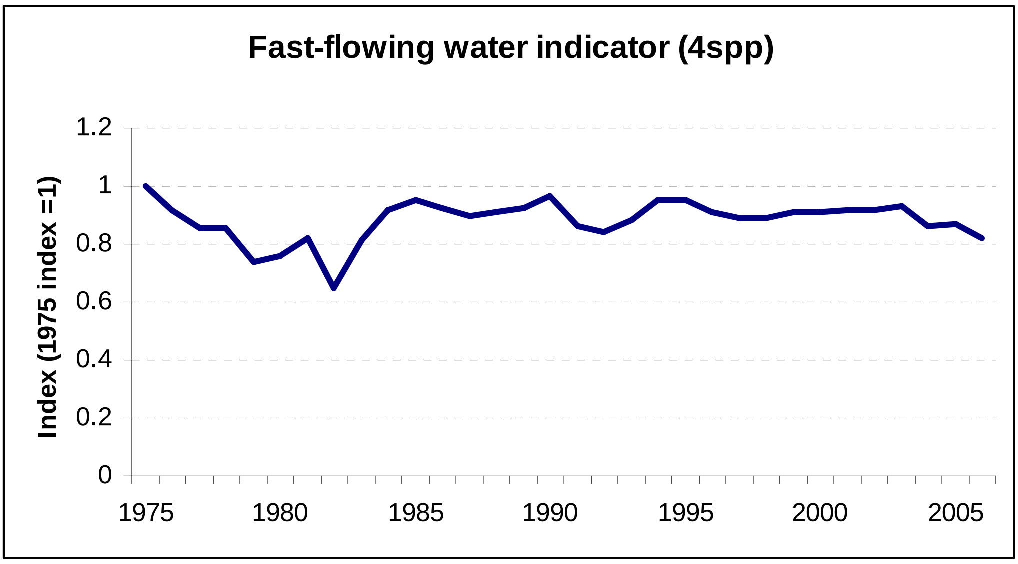
Figure 1 Proposed indicator set for freshwater wetland birds in the UK (unsmoothed)



The indicators for each of these habitat types are described below:

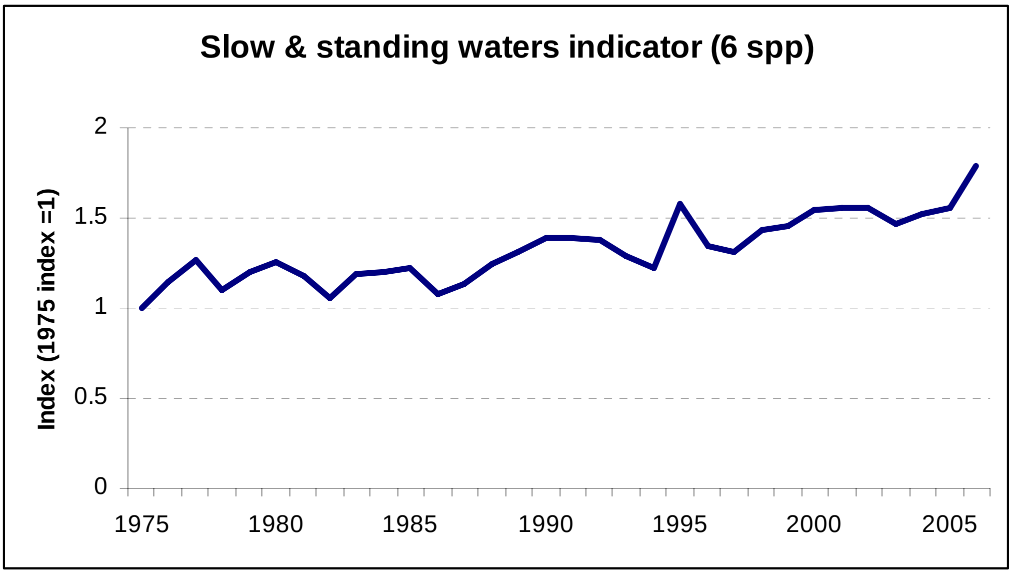
- **Figure 2a** Indicator for fast-flowing waters (UK)

  Three of the four species (Common Sandpiper, Dipper and Grey Wagtail) in the indicator for fast-flowing waters are the same as in previously published EBS indicators for wetlands and waterways, where categorisation was based on expert judgement. Goosander is added to the list due to improved coverage of this species by the more recently-established WBBS survey. For all four species, the population trend used is derived exclusively from the two waterways surveys (WBBS and its predecessor the WBS) because there were sufficient data. This means that the indicator better reflects changes in the populations of these species in the target habitat (fast-flowing linear waterways) and is not influenced by changes in populations on other habitats such as ponds or lakes.



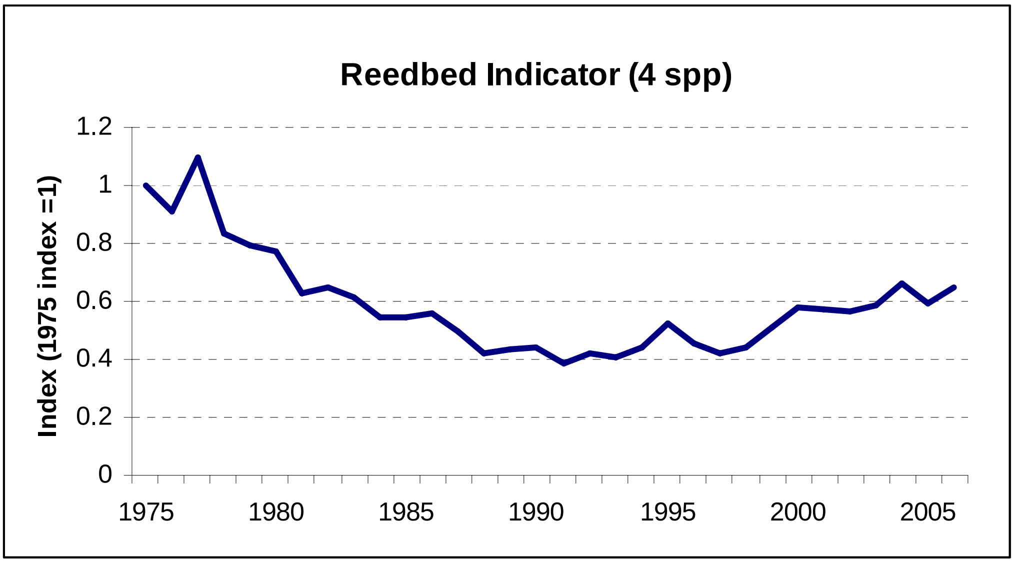
- **Figure 2b** Indicator for slow-flowing and standing waters (UK)

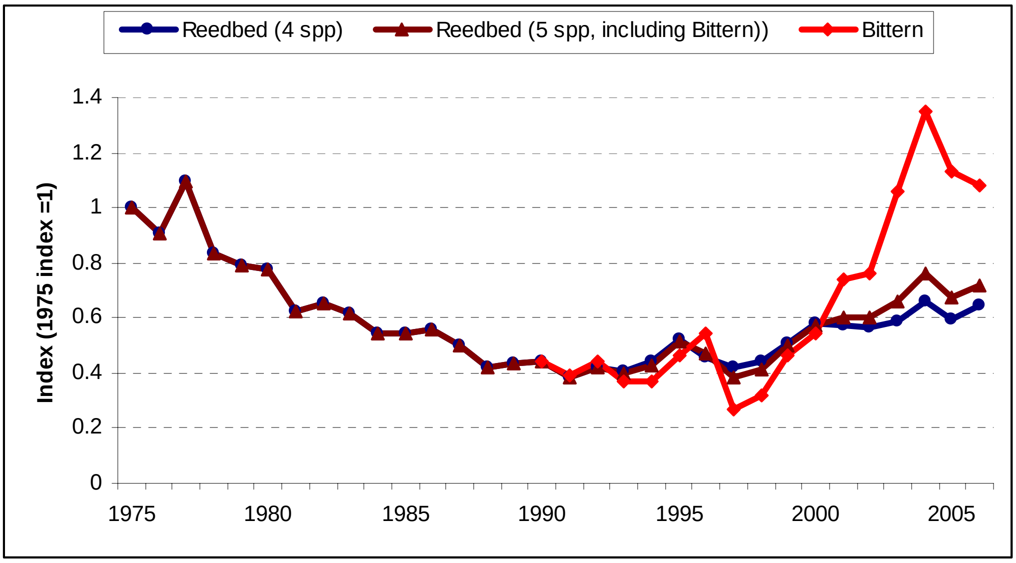
Trends for six species (Coot, Moorhen, Tufted Duck, Mallard, Little Grebe and Great Crested Grebe) comprise the indicator for slow-moving and standing waters. For all six species, the data sources used cover linear waterways, standing water and other occupied habitats (e.g. urban water bodies in the case of Mallard). Other slow/standing water specialists were excluded due to their restricted range and/or lack of regularly available data. These include Pochard, Red-breasted Merganser and Little Ringed Plover, the latter particularly associated with reservoirs and gravel pits. It is potentially possible to generate trends specific for each of the 'slow-flowing water' and 'standing water' habitat types for relatively common species found at higher densities in other wetland habitats (such as Mute Swan and Grey Wagtail) but not for scarcer species. The impact of adding a trend for inland-breeding Cormorants, which are found in large numbers in these habitats, was explored but this species is currently excluded from the indicator because the population trend for the increasing freshwater component of the population has not been updated since 2005 and unlikely to be calculated regularly without further resources. The impact of including this species is explored elsewhere, as is the effect of removing the trend for Mallard whose numbers are arguably strongly influenced by releases and partly-domesticated birds.



- **Figure 2c** Indicator for reedbeds (UK)

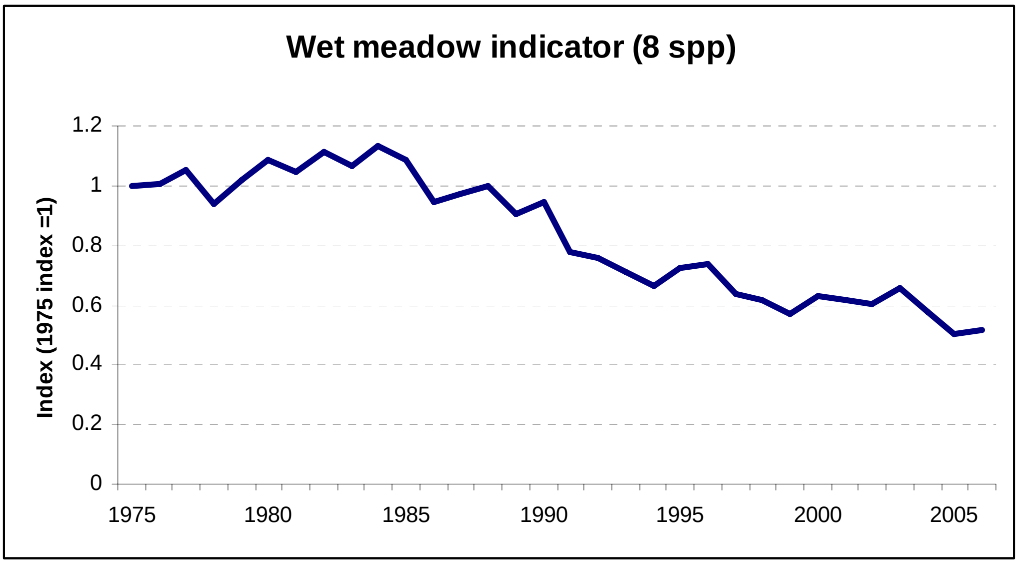
This indicator is comprised of the trends of four common reedbed species (Reed Bunting, Reed Warbler, Sedge Warbler and Cetti's Warbler). Other reedbed specialists were excluded due to their restricted range and numbers and/or lack of regularly available data. Bitterns, which are counted every year, might be a particularly good indicator of effective reedbed management, and the effect of adding Bittern to this indicator is shown on the lower plot. The lines diverge slightly from 1990 (when the Bittern trend is added) but its exclusion makes little difference to the overall pattern. Bittern remains excluded due to its small population size (a total British population of less than 50 booming males) and a range restricted to southern England, largely in reserves subject to intensive conservation action. Marsh Harrier and Bearded Tit are also reedbed specialists but monitored too infrequently to be included in annual updates of the indicator. It is also potentially possible to generate reedbed-specific trends for a suite of relatively common species such as Moorhen, Reed Bunting, Cuckoo, Coot and Mallard that also showed a positive association with reedbeds. However, this is not feasible for scarcer species such as Little Grebe or Great Crested Grebe despite their occurrence in this habitat.





- **Figure 2d** Indicator for wet meadows (UK)

Trends for eight species comprise this indicator. Most of these species (e.g. Mute Swan) are also positively associated with other wetland habitats such as slow-moving and standing waters that are adjacent to the wet grassland and marsh habitat that comprise this category. Other wet meadow specialists are excluded due to their very restricted breeding range (Black-tailed Godwit) and/or lack of regularly available data (Gadwall, Shoveler and Wigeon). As a recent addition to the British avifauna, Little Egret was included from 2004 onwards when its population in England had reached 300 pairs. Little Egret data are included in the indicator using agreed protocols as previously described. It is potentially possible to generate wet grassland/marsh-specific trends for widespread species such as Mallard, Moorhen, Coot and Sedge Warbler that also show a positive association for these habitats, but not for species that were less common.



3.2 Production of indicators for birds of freshwater habitats at different geographical scales

The indicators presented above have been produced at UK scale, making use of national bird census datasets, and are analogous to the UK Sustainable Development Strategy wild bird indicators developed for other habitats (e.g. farmland, woodland and marine bird species). Using exactly the same rules for allocating species to freshwater wetland habitats but using datasets appropriate for England only, we have also produced English versions in order to link with developments in indicators currently produced for the England Biodiversity Strategy (EBS). The new recommended EBS indicator for England is shown below, comprised of the smoothed (using methods explained in Annex 1) population trends of 26 freshwater wetland bird species. Birds of slow-moving and standing waters have increased steadily since the mid-1980s to 60% more than the 1975 baseline. Birds of reedbeds declined strongly between the mid 1970s and early 1990s and then increased to more than the baseline. Following an initial dip in numbers, birds of fast-flowing waters have recovered and remained steady since the late 1980s, whereas birds of wet meadows have declined steadily since the early 1990s.

Figure 3 Proposed new indicator for freshwater wetland birds in England (smoothed)

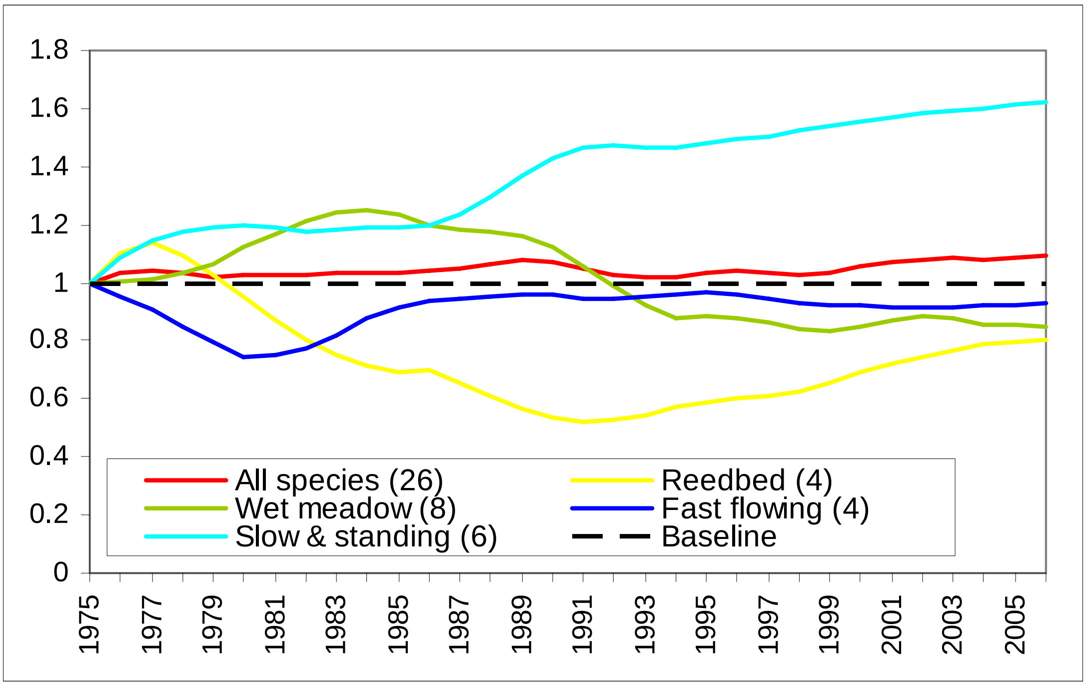
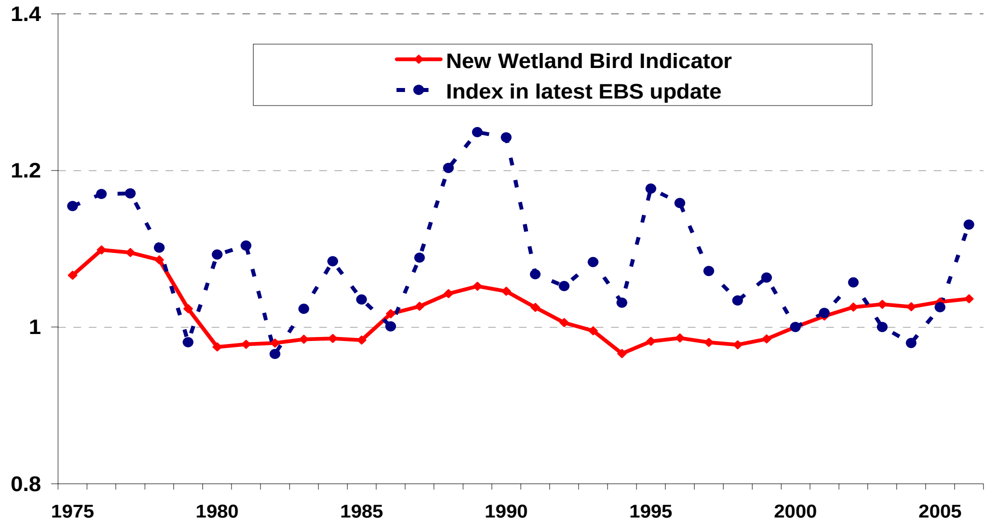


Figure 4 shows the difference between the recommended new indicator for all species of freshwater wetland habitats (the red line in Figure 3 above and in Figure 4 below) and the latest update of the EBS indicator for wetlands and waterways, both set to a baseline of 1 in the year 2000. The new line differs from the previous version by comprising the trends of 26 wetland species (instead of 21), including data from more sources (particularly the WBBS) and also, in the revised plot, by being smoothed rather than based on annual indices. Nevertheless, it is clear that improvements to the indicator, due to changes in both the species composition and the data sources used, have not had a profound effect on the overall trend. The pattern for the sub-indicators for fast-flowing waters, slow and standing waters, and wet meadows are also broadly similar to the previous EBS versions. However, the sub-indicator for birds of reedbeds is a new development.

Figure 4 Comparison of the proposed new bird indicator for freshwater habitats with the previous EBS indicator for waterways and wetlands



3.3 Links to developments in reporting on PSA

In the next section, we present the results of a recalculation of the recommended all-species line for freshwater wetland bird species in England relative to a baseline year of 2000, rather than the 1975 baseline used previously for PSA reporting, and also derived from the bootstrapped England smoothed trends for each of the 26 species. This element of the work was carried out at the request of Defra in order to inform assessment of the proposed new Public Service Agreement indicator for birds of farmland, woodland and freshwater wetlands, and an aggregate of those three indicators. The confidence limits for the 2006 index provide a means of assessing the significance of the observed change over the six-year period since 2000. This measure can be updated each year to assess the most recent index relative to 2000 (see Figure 5). The second plot (Figure 6) shows the rate of year–on-year change of the same indicator. This figure highlights annual changes in the index reflecting fluctuations in environmental conditions, including possible climate change effects.

Figure 5 The proposed new waterways and wetlands bird indicator (including trends for all 26 species) for England calculated in relation to a baseline year (2000), with bootstrapped confidence intervals showing the statistical measure of change in the index relative to that in 2000.

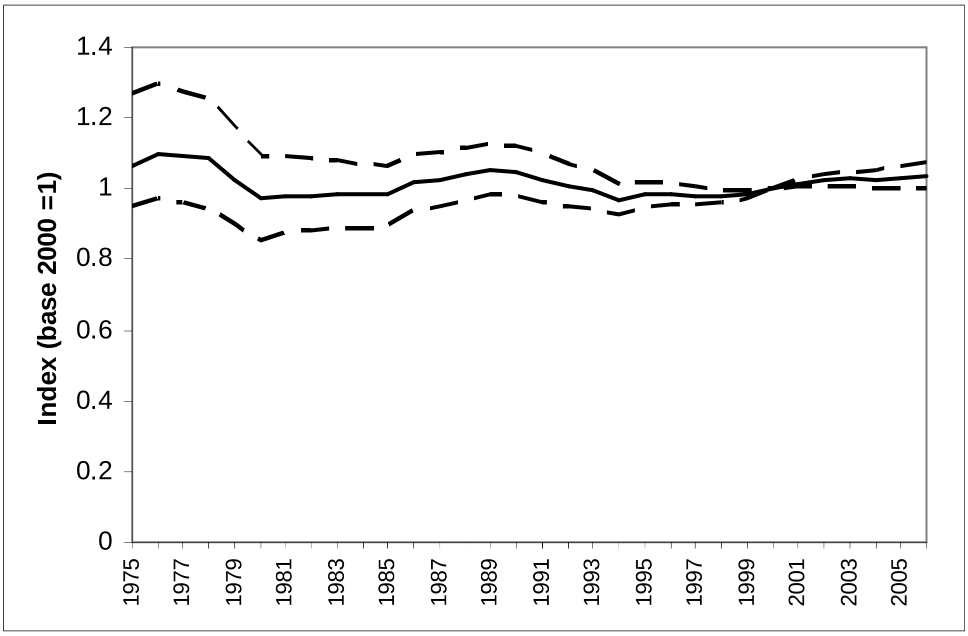
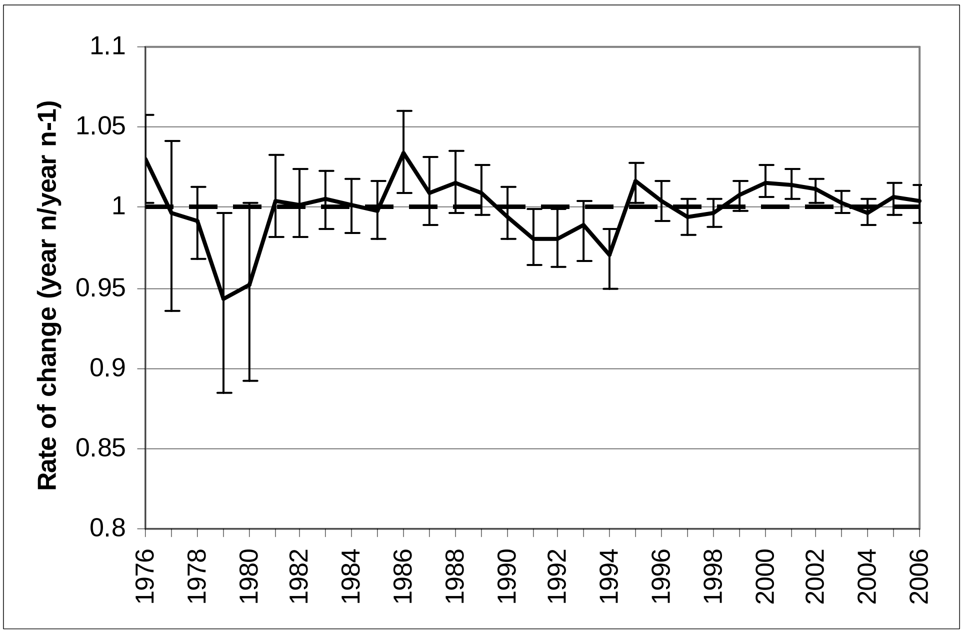


Figure 6 The annual rate of change in the proposed new waterways and wetlands bird indicator (including trends for all 26 species) for England with bootstrapped confidence intervals showing the statistical measure of change in the index relative to that in the previous year.



It would be desirable to produce regional or catchment versions of wetland bird indicators if there were adequate quality and quantity of data to support this analysis. Regional boundaries could be political (i.e. government regions) or biogeographical (including Water Framework Directive River Basin Districts and/or catchments). BTO survey data are geo-referenced at the start and end of the transect route, so linking to different definitions of 'region' is feasible. However, trends reported from too few survey squares will be imprecise and unreliable, and the loss of scarcer but nonetheless important species (such as Dipper and Kingfisher) from the various sub-indicators will make them less representative and less comparable across regions. Table 2 provides the current national sample sizes of BBS and WBBS, and an assessment whether species trends could be disaggregated at the country or regional/catchment level, depending on the range of species used in the indicators and the availability of data for these regions. Note that it may subsequently be possible to break WBBS data down towards transect level for analysis to reduce some elements of error, as discussed in Vaughan *et al*. (2007), but the general applicability of this procedure would require further investigation.

Table 2 Sample sizes of current surveys and the feasibility of generating sub-national trends

	BBS (2006)	**WBBS (2006)**	**Country**	**Regional (GOR)**	**River catchments**
Little Grebe	96	21	E	No	No
Great Crested Grebe	79	29	E	No	No
Grey Heron*	871	198	E,S,W	Yes	Yes
Mute Swan	318	121	E,S	Yes	Yes
Mallard	1632	263	E,S,W	Yes	Yes
Tufted Duck	185	48	E,S	Yes	Yes
Teal	38	15	E	No	No
Goosander	53	59	E	No	No
Moorhen	831	164	E,S,W	Yes	Yes
Coot	352	79	E	Yes	Yes
Common Sandpiper	74	77	E,S	No	No
Curlew	520	76	E,S,W	Yes	Yes
Lapwing	(844)	96	E,S,W	No	No
Redshank	97	23	E,S	No	No
Snipe	166	26	E,S	No	No
Oystercatcher	(379)	87	E,S	Yes	Yes
Dipper	68	110	E,S	No	No
Kingfisher	88	79	E	No	No
Sand Martin	165	99	E	No	No
Grey Wagtail	257	151	E,S,W	Yes	Yes
Yellow Wagtail	(178)	29	E	No	No
Reed Warbler	170	96	E	Yes	Yes
Sedge Warbler	166	61	E,S,W	Yes	Yes
Cetti's Warbler**	(28)	(5)	E	No	No
Reed Bunting	(649)	133	E,S,W	Yes	Yes

* data are collated from the Heronries Census
**data are collated from the Constant Effort Sites monitoring scheme

In undertaking this assessment of the feasibility of indicator desegregation into finer geographical scales, note that:

- Generating a national (UK) indicators was the primary aim;
- Generating wetland indicators for England synergistic with further development of EBS indicators is equally important;
- Indicators for Northern Ireland are not feasible due to data scarcity;
- It is possible to generate indicators for Scotland (with 15 of 25 possible species) and for Wales (with 8 of 25 possible species) but these would exclude some important wetland species such as Kingfisher;
- It would be possible to generate indicators covering England and Wales (the area of jurisdiction for the Environment Agency) and for Britain (England, Scotland and Wales).

3.4 Peer review and testing

Ongoing project steerage and testing of assumptions, model development and publications was provided by a Project Board noted in the *Acknowledgements* towards the end of this report. In addition, two project workshops were run in London in which a wide range of experts contributed their ideas, views and suggestions. The first of these workshops took place in January 2007 and the second in January 2008. Agenda, attendance list and key points for workshops are listed in Annex 2. The authors are grateful to this extended group for effectively peer reviewing assumptions and the draft indicators and publications.

4. Discussion

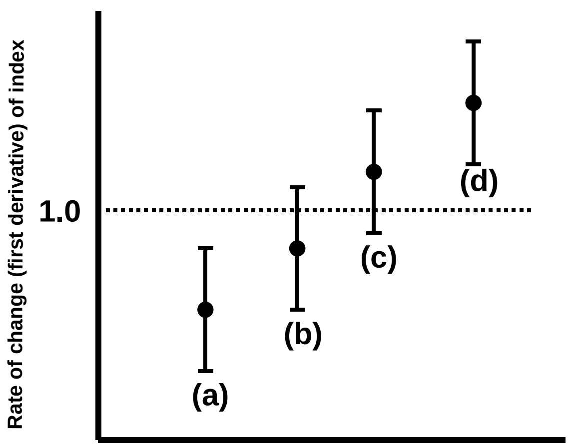
4.1 Setting targets for success

Targets (or milestones) for wetland bird indicators will be influenced by the direction of the historical trend (analogous to reversing the decline in farmland birds), the variability (noise) in the reported changes, and the political message that the indicator is intended to convey. Most wild bird indicators currently in use in the UK (for example the Sustainability Development Strategy Wild Bird Indicators) are so-called *state* indicators with no defined targets. For the Farmland Bird PSA, the target since 2001 has been a significant upturn in the direction of the index, as measured by the annual rate of change of the smoothed trend. The target is achieved when the lower 95% confidence interval of this year-to-year rate of change is greater than 1, i.e. when numbers are increasing significantly. Note that the population could still be markedly lower than the index in the baseline year (1970) and there is no formalised concept of a desired endpoint, as set for a number of Biodiversity Action Plan (BAP) species.

The wetland indicators developed in this report are also state indicators, without explicit targets. For trends in decline, the implication is that it is clearly desirable to reverse the trend. Whether the baseline in 1975 represents a desirable ecological endpoint is another question, not addressed by this work, although the 1970s were highlighted as a period of sharp decline in the UK farmland bird indicator. Declines in many wetland birds may have also preceded the recording period. The indicators as presented above show changes in abundance of freshwater bird species relative to 1975, but the change in the trend can be calculated over any time period, such as since 1990 or since 2000. Further, for example, we present a recalculation of the trend for all species (N=26) in relation to a baseline year in 2000 for the purpose of illustrating the method of using bootstrapping to estimate the significance of the change in the index since 2000.

Estimates of rates of change of the smoothed indicator and their 95% confidence intervals provide an alternative straightforward means of assessing trends. This method, advocated by Freeman *et al.* (2001) for the farmland bird indicator, is also appropriate to the freshwater wetland bird indicators developed in this report. The government's PSA target of "*…reversing the long-term decline in the number of farmland birds by 2020…*" is judged to have been met when the trend in the 'smoothed' farmland index and the associated lower confidence limit (using bootstrapped 95% confidence limits) both exceed one (see Figure 7).

Figure 7 Illustration of potential target development based on significance of trends (after Freeman *et al.*, 2001)



If this were to be applied to the bird-based freshwater waterways and wetland indicators, assessment of the outcome could be similar to those in Table 3 below.

Table 3 Potential protocol for assessing updates of the proposed indicators

'Colour'	**Technical method**	**Plain-English descriptor**
Green	Both the rate of change and the lower 95% confidence limit are positive	Rising rate of population change or halting of a decline
Amber	The degree of uncertainty (either the upper or lower 95% confidence limit) overlaps one	Population or its rate of change are stable
Red	Both the rate of change and the upper confidence limit are negative	Declining rate of population change or halting of a rise

Another alternative is the 'turning point analysis' method, developed for single species trends by Siriwardena *et al.* (1998), which could potentially be used to identify years at which the second derivative of the indicator is significantly different from zero. The second derivative is a measure of the extent to which the rate of a population increase (or decline) is itself changing, accelerating or slowing down. If it is zero, the population may stable or changing (increasing or decreasing) but doing so at a constant rate. A statistically significant 'positive' turning point could therefore be the first milestone towards the desired change in status towards the ultimate endpoint of increased numbers. However, note that the nature of turning points is that they cannot be identified at the end of a time series.

A simple 'traffic light' indicator might be feasible and readily-understood, but must be statistically robust, communicable in simple terms, and must achieve the aim of the indicator. Indicators that vary annually according to fluctuations in populations could be misleading, producing random switches between 'red', 'amber' and 'green' in response to the 'noise' in the data. Conversely, too insensitive an indicator might be uniformly 'amber', neither indicating change nor informing policy.

Identifying and testing possible targets for the proposed indicators, once agreed, would help its users to determine the effort required to meet them and their associated costs. Further work is required to apply them at geographic levels for which fewer survey data are available (e.g. Wales, Scotland, water catchment areas, etc.). It is not the purpose of this report to recommend methods for target-setting, although the options noted above may inform subsequent decision-making.

4.2 Interpretation of indicators

Caution is required in interpretation of implementation of these freshwater wetland indicators, to ensure that resultant action maximises environmental gain and does not inadvertently deliver sub-optimal outcomes. Species may respond in different ways, both positive and negative, to policy mechanisms and drivers. Gregory *et al*. (2004) note that the UK government's 'Farmland Birds' target could conceivably be met by strong increase in 'increasing' species and continued decline in 'declining' species; an undesirable outcome. This outcome is suggested by the observed pattern of generalist bird species faring rather better than specialists. The target plan for Defra's Farmland Birds PSA provides a useful model, as the aim is not only to reverse the trend but to have stable or rising populations of as many of the 20 key farmland birds as possible.

Conversely, the failure of a particular species to respond positively from mitigating conservation action does not always imply that of the policies and practices of the Environment Agency or other partner organisations are ineffective. Although the effects of environmental quality tend to over-ride the effects of density dependence, this process could potentially inhibit population increases in highly territorial species such as Dipper where the suitable habitat is already effectively saturated. Changes in the amount of habitat could potentially be confounded with changes in the 'quality' of the habitat and we should ensure that increases in one species (or a set of habitat-specific birds) are not at the expense of another, for example reedbed encroachment upon wet grassland habitat or the converse. Over-riding factors such as climate change can also be expected to have a pervasive and often unpredictable influence on wetland habitats and their biota, and should be considered in interpretation of trends.

Everard (in preparation) is drafting a paper reviewing the literature to associate indicators of the quality of different types of wetland with the ecosystem functions performed by these habitats, highly germane to the range of ecosystem services they provide.

5. Summary

The proposed approach to the development of freshwater wetland indicators was to generate a suite of 'state' indicators reflective of the quality of different freshwater waterways and wetland habitat types. These indicators were not intended to reflect specific pressures, but rather to reflect the cumulative impacts of multiple pressures on the 'wetland environment' at a landscape scale. Further research, including more detailed exploration of existing datasets, will be required to determine and/or diagnose the ways in which distinct 'pressures' on the environment influence bird populations and the indicators derived from them.

Indicators occupy a mid-point between science and politics, informed and substantiated by the former though often serving the latter in one guise or another. We have therefore sought consistency, accuracy and defensible assumptions throughout, but also relevance to 'real world' problems.

The resultant indicator set uses twenty-two bird species allocated across four target freshwater wetland types – fast-running water; slow-flowing and standing water (combined); reedbeds; and wet grassland – adding in a further four bird species to an inclusive 'all freshwater habitats' indicator. None of these bird species are so rare that their population trends cannot be interpreted as reflecting changes in the wider countryside. One colonising species (Little Egret) is included, but only from the point at which numbers were well established; accordingly, its trend only influences the indicator in the three most recent years of the time series. Cormorants, an invasive species which appears to be spreading into inland habitats, are currently not included due to the absence of an established monitoring programme for inland populations. Nevertheless, this would be feasible with a small amount of additional resources.

This report concludes at the point of development of the recommended new bird indicators for freshwater habitats in the UK and in England. Use of the same approach as for other bird indicators developed in the UK with the supporting evidence base for the allocation of freshwater wetland bird species to the target habitats ensures their value as state indicators of the populations of their constituent bird species. It is necessary to undertake further testing in practice, and against the desired outcomes envisaged for the indicator set, to assure potential users of their value in relation to particular drivers of change and to test their representativeness of freshwater biodiversity in general.

Our intention is that the England version of these indicators will supersede the EBS *Water and Wetlands* indicators from 2008, and that a 'Waterways and Wetlands' indicator line will be added to the UK Sustainable Development Strategy indicators.

Acknowledgements

This work was supported under an Memorandum of Understanding between the British Trust for Ornithology and the Environment Agency, further supported by Environment Agency Science project SC07005. Ideas and guidance was provided by a Project Board comprising Dr Paul Raven, Dr Robert Willows and Lucy Baker (Environment Agency), Mark Stevenson (Defra), and Professor Steve Ormerod and Dr Ian Vaughan (University of Cardiff). Dr Lucy Wright (BTO) assisted with the analyses, and John Marchant, the WBBS coordinator at the BTO, provided advice. Two project workshops, the first in January 2007 and the second in January 2008 (agenda and attendees noted in Annex 2) enabled a wider network of experts to debate and provide some assurance about the methods developed. The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is organised by the BTO and jointly supported by the BTO, RSPB and JNCC, the latter on behalf of the Country Agencies. The Waterways Breeding Bird Survey (WBBS) is supported largely by the Environment Agency and also the BTO. The work required to produce this report was supported by the Environment Agency. We are also extremely grateful to all of the volunteers and regional organisers that participate in all of the surveys contributing data to the development of wetland bird indicators.

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Annex 1: Methods for the production of bird indicators for freshwater waterways and wetlands

Constructing the indicators from constituent species trends

To produce these provisional indicators, we use the same method of amalgamating trends for individual species into a composite indicator as in other bird indicators for the UK (Gregory *et al*., 2004) and Europe (Gregory *et al*. 2005). The annual index of each indicator is the simple geometric mean of individual species 'trends' (smoothed or unsmoothed according to the type of indicator being produced).

Allocation of bird species into habitat-based indicator groups

The minimum annual sample size for inclusion of a species in the proposed wetland bird indicators has been provisionally set at 20 sites. This is lower than the threshold of 30 sites used for standard reporting of BBS trends at the country or regional level (see Raven *et al*., 2007) but species with sample sizes as low as 20 have been previously included in the development of regional wild bird indicators for England. This is justified by the fact that the effect of increased variation within a species (due to a small sample) is partly mitigated by the potentially large number of species trends comprising the indicator. In a composite indicator, threshold values determined by the number of survey squares covered by each individual species can be relaxed on the grounds that a composite (multi-species) indicator enables more uncertainty in individual species trends to be tolerated (Noble *et al*., 2006).

Freeman *et al*. (2001) found that individual species showing particularly strong increases or decreases could influence the farmland bird index. In general, the use of a larger suite of species within composite indicators minimises this risk, but in the proposed wetland bird indicators where relatively few species comprise some habitats, it is a potential reason for excluding species known to be in an invasive phase (e.g. Cormorant) or with small and fluctuating numbers (e.g. Bittern).

Weighting of bird species within indicators

The population trends for Defra's farmland and woodland birds composite indicators reflect the average behaviour of their constituent species, all of which are weighted equally (Gregory *et al*., 2004). Weighting by population size or conservation status would have led the indicator into being dominated by the most abundant species or by those judged to be the most threatened. Indicators of wintering waterbirds developed for the Scottish Biodiversity Strategy, for example, include a version based on 'conservation value' as measured by the proportion of the flyway population, but these have not yet been published. Other criteria for weighting include level of precision and degree of habitat specialisation (trends for fast-water specialists could for example be weighted more heavily than species such as Grey Wagtail, which is grouped into that habitat indicator but which occurs more widely). Overall, given that many of these criteria could change over the time series, neutral weighting appears to best serve the purpose of a general barometer of broad-scale change in the countryside (prior to planned analyses to relate these provisional indicators to drivers of change in wetland ecosystems). However, other options could be explored in the future.

Species excluded on the basis of scarcity

In most wild bird indicators developed elsewhere, rare species are excluded because: (i) they are found in relatively few locations and hence do not represent broader biodiversity; and/or (ii) their population status is likely to be more strongly influenced by direct conservation action rather than the drivers affecting all species. In the Sustainable Development Strategy wild bird indicators for the UK, all species with a national population of less than 500 pairs are excluded for this reason, and species with less than 300 pairs are excluded from the EBS (England Biodiversity Strategy) bird indicators. The selection of these thresholds for excluding species on these grounds is clearly somewhat arbitrary but has proved suitable to date. However, when considering bird indicators for the scarcer wetland habitats, such as reedbeds, it might be appropriate to consider rare but characteristic species of these habitats such as Bittern and Marsh Harrier. Accordingly, we demonstrate the effect of adding Bittern (a species for which annual numbers of 'booming males' are available) to the reedbed sub-indicator.

Treatment of species with weak freshwater wetland habitat associations

The literature review and correlation analyses used to determine the habitat associations of bird species (Everard and Noble, 2008) confirmed the view of the Project Board that some species in earlier versions of wetland indicators show very little association with wetland habitat. An example is the Pied Wagtail – previously included in the EBS 'wet grassland' indicator – but which is found in a wide variety of habitats including urban areas and farmland. It is feasible to produce wetland habitat-specific trends for these more generalist species (Pied Wagtail, Cuckoo) but since a large number of other 'non-wetland' species also occur at high densities in riparian habitats (e.g. Blackbird, Willow Warbler, Whitethroat, Woodpigeon) we have excluded all of these species on the grounds that the majority of the population occurs outside this habitat.

We also excluded two species where we judged the population to be largely coastal, albeit in habitats including estuaries, salt marshes, dunes and coastal grazing marshes. Counts of Avocets come almost entirely from RSPB coastal reserves. According to the last published British bird atlas, Shelducks remain an essentially coastal bird in this country and there are, moreover, too few counts for the small inland population to be indexed. Although 66% of Redshank are estimated to breed coastally, we have retained this more widespread species in the wet meadow indicator on the grounds that the data sources (CBC, WBS, WBBS and BBS) reflect the inland populations (especially historically). Similarly for Oystercatcher, we have used the WBS/WBBS trend to best reflect the inland population breeding in floodplains.

Selection of datasets

With a number of bird surveys available, selection of appropriate datasets to support analysis becomes a significant issue. Ecologically, data relevant to linear waterways (e.g. from WBS and WBBS) and freshwater wetlands (e.g. CES) are of greatest importance. BBS and CBC comprise more sites across the UK, albeit without a wetland focus, but importantly they cover areas of wet grassland, reedbeds, wet woodlands, still waters and other habitat types that are not the linear waterway focus of WBS/WBBS.

WBBS and BBS are the two main current surveys, incorporating rigorous protocols for recording, a random stratified design to achieve a representative sample, and simplified methods to achieve greater coverage by volunteers. These surveys have essentially replaced their predecessors (WBS and CBC) although both sets of surveys (the terrestrial BBS and CBC, and the waterways WBS and WBBS) were run in parallel for a number of years in order to develop rules and methods for combining data to generate long-term trends. In order to make use of the maximum amount of data and to calculate trends based on the largest sample size, we use data from terrestrial habitats (BBS) and waterways habitats (WBBS) to generate joint trends. These 'single-species' trends use weightings to account for differences in sampling intensity among surveys, but further investigation of the proportion of populations in each habitat type could be carried out to determine whether information from different habitats should be differentially weighted. For some species, the recommended trend is solely WBBS (and WBS) because incorporating BBS data is an unnecessary complication.

The statistical power to detect change in trends of this type (whether single species or composite indicators) is affected by: (1) count variability in space and time; (2) the magnitude of the change; (3) the length of the time series; (4) the number of survey plots; and (5) sampling error associated with the survey design. For routine reporting of BBS trends, Joys *et al*. (2005) developed a protocol to take account of the relationship between sample size and precision and aspects of species biology. Two aspects were considered most relevant when determining which species to include for reporting BBS population trends: sample size; and survey suitability for species. This led to the recommendation to report UK trends for species counted on at least 40 sites annually and 30 for regional trends. Recommendations to exclude or provide cautionary caveats for marine, nocturnal and colonial species not well monitored by the BBS were also made.

Rules for inclusion or exclusion of species from indicators

Sometimes, it is necessary to add or remove species from an indicator midway through the time series in order to make use of newly available survey data, to deal with species increases that results in them becoming common birds of wetland habitats, and to deal with species that decline so markedly that they are confined to a few sites or are no longer feasibly monitored. Rules for removing and adding in species ('declining' populations or 'increasing') to indicators have been developed elsewhere (Noble *et al*. 2004). An example of one such species is the Little Egret which was too scarce previously to be monitored but, with a national population size that reached 500 in 2005 and with counts at 45 WBBS sites, this species is now included. At the other end of the spectrum, numbers of declining species such as Yellow Wagtail may become too low on wetland habitats for a trend to be calculated.

Setting the baseline of the indicator

The proposed indicator trend lines are set against a baseline year (1975) when data from the key schemes (CBC and WBS) were available. This is necessary for all of these types of index, because the counts represent a relative (not an absolute) index of abundance and hence are suitable for temporal comparisons but not necessarily spatial comparisons. The CBC and WBS surveys have been superseded by the BBS and WBBS, respectively, but in separate developments, methods to combine data for CBC and BBS (Freeman *et al*. 2007) and WBS and WBBS (Noble, unpublished), have been established. Included in this report are population trends based on all four data sources, following development of techniques to handle difference in the sampling design, and period of coverage, of the four surveys (CBC, WBS, BBS and WBBS). Figure 5 shows an example of setting the baseline to a different year (2000). We note wherever the baseline is set (in order to compare trends in different habitats), this does not imply that all freshwater habitats are of equal quality in that year. Further work is required to explore changes in numbers of wetland birds in relation to possible drivers of change such as drainage of wet meadows and reductions in pollutant loads of rivers during the 1970s and 1980s.

Smoothing

Long-term, gradual change in the population of birds can be obscured by year-on-year variability. Typical causes of this are climatic variability (many resident bird populations decline after hard winters whereas various migrant species are adversely affected by remote factors such as Sahelian drought) and sampling error (particularly for low populations of birds or where the species is recorded in only a small number of survey sites). Smoothing overcomes some of this short-term 'noise', providing the best measure of the underlying trend from which most short-term fluctuations due to weather and sampling error have been removed. Smoothed indicators have the advantage of minimising short-term effects and sampling error, and provide a better measure of significant change (increase, decrease or stable) in the index over a specified period of time – usually one of the main goals of producing indicators. Nevertheless, unsmoothed indicators provide the best picture of year to year changes in numbers, which are at least partly related to year to year changes in the environment. We present examples of both smoothed (England) and unsmoothed (UK) in this report.

A number of smoothing methods (e.g. moving averages) are available, but for these indicators we have utilised the same smoothing methods as for the BTO's annual reporting of bird population trends in the UK – namely a post-hoc smoothing spline equivalent to the application of Generalized Additive Modelling (GAM). This method is used in many BTO/RSPB bird population indices, including the Defra 'headline' Farmland Bird Indicator, to smooth inter-annual variation in bird numbers and deduce longer-running trends. A small disadvantage of smoothing is that the estimate for the last year of data should be interpreted with care as results may be unreliable due to endpoint effects.

Freeman *et al*. (2001) conducted an analysis that demonstrated no significant difference (at least for the CBC-based Farmland Bird Index) as to whether: (a) smoothed indices are thus combined into a collective indicator; or (b) species' indices are integrated in their unsmoothed form with the smoothing algorithm subsequently applied to calculate the indicator.

Estimating the precision of the proposed indicators

Confidence intervals can be calculated by bootstrapping, a statistical method that estimates the uncertainty in a trend through repeated re-sampling and trend estimation. Confidence intervals for the estimated trend are calculated from percentiles (such as 2.5% and 97.5%) of the sample of estimated trend lines.

An example of bootstrapped confidence intervals is shown in Figure 5, with the recommended all-species line for freshwater wetland bird species in England set to a baseline year of 2000 (comprised from the bootstrapped England smoothed trends for each of the 26 species set relative to a baseline in 2000). The confidence limits for the 2006 index provide a means of assessing the significance of the observed change over the six year period since 2000. This measure can be updated each year to assess the most recent index relative to 2000.

End of Annex 1

Annex 2: Project workshops, attendees, and notes of discussion

Two workshops took place during the lifetime of this project, each contributing ideas, steerage and peer-review of the evolving indicators and publications.

Workshop 1: 22nd January 2007

The Workshop 1 agenda comprised:

- Introduction and welcome
- Why the Environment Agency needs these indicators
- Outline of the draft indicators
- Demonstration of sample outputs
- Workshop discussion of methods
- The bigger picture (UK and international context)
- Discussion of context in small groups
- Strength/weaknesses, synergies and opportunities for feedback in plenary
- Bird populations in relation to other river variables
- Discussion on interpretation of change (small groups then plenary)
- Proposals for 'next steps'
- Discussion of future priorities (small groups then plenary session)
- Thanks and sum-up

Workshop attendees were:

Environment Agency	Other
Mark Everard Paul Raven (and EBS) Robert Willows	Mark Eaton (RSPB) Rob Cunningham (RSPB / EBS) Steve Ormerod (University of Cardiff) Ian Vaughan (University of Cardiff) Adam Donnan (IES) Chantal Brown (IES) Miranda Davis (NWL / Essex & Suffolk Water) Simon Foster (SNH) Rhys Bullman (SNH) Rob Cathcart (Natural England) Colin Shawyer (York University) Amy Coyte (Bat Conservation Trust) James Williams (JNCC)
BTO	
David Noble Andrew Joys John Marchant	
Defra	
Mark Stevenson Rocky Harris	

Workshop 2: 16th January 2008

The Workshop 2 agenda comprised:

- Welcome and scene-setting
- 'Big picture' of bird-based indicators across the UK (Defra, SEPA, Wales)
- Presentation of the wetland bird indicators
- Plenary question and answer session on the wetland bird indicator set
- Working groups: 'Testing of the birds indicators – have we got them right?'
- Summary of key points raised by discussion and testing of assumptions
- Discussion of onward development of 'multi-taxa' indicators:
  - 'Opportunities with combined indicators'
  - Feasibility study into 'multi-taxa' indicators

- Plenary around key issues and questions

- Sum up and thanks (Paul Raven)

Workshop attendees were:

<table>
<tr><td>Environment Agency</td><td>Other</td></tr>
<tr><td>Mark Everard
Paul Raven (and EBS)
Lucy Baker
Neil Weatherley
Steve Colclough</td><td rowspan="6">Mark Eaton (RSPB)
Willie Duncan (SEPA)
Steve Ormerod (University of Cardiff)
Miranda Davis (NWL / Essex & Suffolk Water)
Rhys Bullman (SNH)
Andy Brown (Natural England)
Richard Hearn (WWT)
Colin Shawyer (Wildlife Conservation Partnership)
Anne Powell (Freshwater Biological Association)
Melanie Fletcher (Freshwater Biological Association)
Mike Dobson (Freshwater Biological Association)
Mary Burgis (FBA Council)
Amy Coyte (Bat Conservation Trust)
Karen Haysom (Bat Conservation Trust)
James Williams (JNCC)
Chris Gleed-Owen (NARRS/
The Herpetological Conservation Trust)
David Sewell (Durrell Institute, University of Kent)
Jenny Holden (Cumbria Wildlife Trust)
Colin Bull (Stirling University)</td></tr>
<tr><td>BTO</td></tr>
<tr><td>David Noble
Andrew Joys</td></tr>
<tr><td>Defra</td></tr>
<tr><td>Mark Stevenson
Stephen Hall</td></tr>
</table>

Some of the key points captured (not structured) during workshop feedback addressing the indicator set are recorded below:

- The purpose is national-scale quality indicators to inform policy
- They should have public resonance, and tell us what we should worry about
- Note of caution of linking drivers and responses
- Synchronisation of data: currently requires continuous annual data
- May help with condition assessment outside of designated sites
- Detectability: birds are OK for this but other taxa less so
- Species chosen… particularly for those using wetlands in only part of their life cycle (including migrants), should we weight indicators?
- Adding in and dropping out indicators: clear criteria required for UK indicator (i.e. Little Egret)
- What are we communicating? Indicators are above all a communication tool (particularly birds), though some implication of diagnostic tool. Do species chosen communicate this purpose clearly? For example, Mallard respond quite nicely to dirty water so may not tell us about quality (particularly if bred for stocking/shooting)
- What other data would reinforce this message?
- Fish: ongoing work on guilds rather than individual species shows how this approach can help identify ecosystem functioning and changes to it: highly germane to ecosystem services
- Devolution is a reality, so there will be a requirement for country-based indicators. They should be giving the same messages, even if different birds are used with respect to sample sizes
- Interpreting trends… are they real?
- Terminology: definition of 'indicators' seems to differ in different use. Type 1 indictors are about biodiversity whereas Type 2 are indictors of environmental change (the miner's canary), but today we are talking about flagships (useful to generate funds or set policy)

- Sometimes people expect too much about indicators, so we have to be clear about communications – virtues of simplicity versus complexity. ‘Keep it simple’ is not a bad maxim
- Use of migrant species: discomfort about using migrants as a large component of species in each indicator, as these may get us away from UK pressures
- What is the purpose of using sub-habitats, and should we bring in more generalist species into the amalgamated indicator?
- Should the indicator represent quality or quantity? Probably quality, though quantity influences this. However, over the timescale of the study there has probably been little change in quantity. There is a case for looking at the influence of both quantity and quality on species
- Scaling up and down: can this index have a role at site level? Could provide site information by putting it into larger regional/national context. Methods are replicable at a range of nested scales, though limitations of bird numbers at more local scale is understood
- Validation process: happy with general process, and the extra tests of adding taxa showed similar response
- Targets for trends or absolute numbers? Probably not the latter – though this may be a longer-term goal
- One of the troubles with a baselined trend is the perception of meaning in starting date
- Are targets dangerous?
- Timeframe of expected change

General workshop consensus:

- There was consensus that the general approach was OK
- Some of this can also be applied to other wetland taxa
- We need to confirm what it is we want the information to indicate…
- …then test this by linking to pressure datasets
- Need to be able to answer the ‘So what?’ question
- The indicator is for landscape scale (not single-pressure) assessment

End of Annex 2