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The UK Wintering Waterbird Indicator:
New developments towards a more comprehensive assessment of trends in the wintering waterbird assemblage

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EXECUTIVE SUMMARY

- Multi-species indicators, composites of individual species trends, are a relatively new innovation in ornithology that are used primarily to summarise complex bird trend data in an intuitive fashion.

- Until now, the Wintering Waterbird Indicator for the UK has been based solely on conventional indices generated from data collected by the Wetland Bird Survey (WeBS) Core Count scheme and special goose surveys organised by the Wildfowl and Wetlands Trust. These indices are known to be affected by biased representations of the habitats on which waterbirds occur with inland wetlands and open coast habitats being under represented. This may affect different species to different degrees dependent upon their habitat preferences and geographic distribution and while this can be acknowledged as appropriate when reporting individual species trends, there has to date been no developments that has addressed this problem specifically when generating composite UK indicators.

- This report describes new developments that aim to tackle this problem. It draws heavily on work undertaken by WeBS with the aim of gaining a greater understand of biases in survey data, and on work undertaken on behalf of Scottish Natural Heritage towards developing a Scottish Wintering Waterbird Indicator that offers a more comprehensive assessment of the waterbird assemblage across a broad range of wetland habitats.

- Two new indicators are described. The new Standard Wintering Waterbird Indicator is intended as a direct replacement for the Conventional Wintering Waterbird Indicator previously supplied (e.g. Eaton *et al*. 2006, Defra 2005a). The new Conservation Value Indicator is intended to be complimentary to the standard indicator.

- The new Standard Wintering Waterbird Indicator incorporates data from the periodic non-estuarine waterbird survey (NEWS) in order to gain better representation of open coast habitats. Furthermore refinements are introduced during the generation of the contributory indices to control for the relative contribution of three major wetland types (estuaries, open coast and inland standing water). In keeping with recent developments within WeBS a broader suite of months than before have been used in the generation of the majority of the contributory species indices. The methodology used to generate composite indicators from these indices remains unchanged other than smoothed rather than raw indices are used.

- The new Conservation Value Indicator differs from the Standard Indicator in that the contributory indices are inversely weighted relative to each other by the appropriate national or international conservation threshold. Thus the composite indicator represents the value of the region of interest (UK or England) to the international or national conservation effort. Consequently it compliments the introspective assessment provided by the Standard Indicator with an outward looking perspective.

- The report recommends that both the new indicators are reported from 2008. It further suggests that, because of historical data issues and the effect these have on generating a truly representative single wintering waterbird indicator, separate indicators specific to Northern Ireland and Great Britain would better represent the trends in the wintering waterbird assemblage across the UK than does the current, somewhat compromised, UK indicator. It is recommended that the suite of species contributing to the wildfowl indicators exclude grebes, cormorant and coot, which would however continue to be included in the overall waterbird indicators. The possibility of an additional goose indicator is mooted.

1. BACKGROUND

Multi-species indicators are a relatively new innovation in ornithology (Bibby 1999; Gregory *et al.* 1999). Their use has primarily been to summarise complex bird trend data in an intuitive fashion, so that stakeholders and policy makers have a user friendly tool with which to direct focus and action. Although not without their drawbacks (Siriwardena *et al*. 2001), their simplicity, transparency and frequency of renewal have made their usage popular amongst the non-scientific community (Gregory *et al.* 2004). An example of this process is the UK 'Headline Indicator', used by Defra (Defra 2005a) to influence environmental policy and against which to measure the success of policies introduced to address the widespread decline in farmland bird trends (Gregory *et al.* 2003).

Further development of the composite Wintering Waterbird Indicator is concerned with two objectives. Firstly, it is desirable to produce an indicator that allows greatest comparability with those previously used for wintering waterbirds in the UK (Eaton *et al*. 2006) and England (Defra 2005b). Secondly, it may be also useful to consider local or national changes within a wider (e.g. European) framework. In this report we further explore an approach first applied to Scotland (Austin *et al*. 2006) whereby composite indices are inversely weighted by the proportion of the overall national or international population occurring in the region of interest so as to generate an outward looking rather than an introspective indicator that can compliment the standard approach to provide a means of assessing a region's or country's relative contribution to national or international conservation efforts.

Previous Wintering Waterbird Indicators for the UK and for England have used data solely from the Wetland Bird Survey (WeBS) 'Core Counts' and special goose censuses; however, there are large biases in coverage with respect to both habitat and geographic regions and the 'conventional indices' contributing to the Wintering Waterbird Indicator have made no allowance for these biases. Also, past 'UK' indicators have failed to deliver true representations of the UK. Firstly, they have been based solely on data from Britain for the majority of non-waders due to the problems of combining data from Britain and Ireland, which use different months for annual indexing. Secondly, WeBS was launched in Northern Ireland in 1986 and only holds data from before this time for a few Irish sites and only these have been retained in the UK wader indices, other sites being excluded in adherence to recommendations of Underhill & Prŷs-Jones (1994).

In this report we describe further developments in the construction of the Wintering Waterbird Indicator that aim to address these biases by refinements to contributory indices and so in turn improve the representation of trends in the wintering waterbird community of the UK to be gleaned from the composite indicators. We also describe the new and complimentary 'Conservation Value Indicator' that weights contributory indices by species-specific 'conservation value'.

2. DEVELOPING A REFINED WINTERING WATERBIRD INDICATOR

The Wetland Bird Survey (WeBS) used to monitor numbers of wintering waterbirds in the UK and to generate indices on the long-term trends in numbers of some 51 species (or distinct populations). Results are published annually in *Waterbirds in the UK* (*e.g.* Banks *et al.* 2006). Furthermore, country indices are reported in the annually updated Wetland Bird Survey Alerts report (*e.g.* Maclean & Austin 2006). Therefore, WeBS provides a major source of data for any indicator of trends in wintering waterbirds, and many of these data are readily available in the format of indices for individual species. Such individual species trends can be combined in various ways to produce composite multi-species indicators.

In constructing the new Wintering Waterbird Indicators, many of the techniques considered were based on the approach of Gregory *et al.* (1999). This ensured that the desirable criteria of an effective indicator were met (Bibby 1999; Gregory *et al.* 2003), and engendered comparability between the new indicators and past indicators of waterbirds for the UK (*e.g.* Eaton *et al.* 2006). This approach involves calculating the geometric mean of a series of index values for the species trends reflected by the indicator, and does not weight different species by any measure of conservation importance, scarcity, or other relevant factor (Gregory *et al.* 1999; Siriwardena *et al*. 2001; Gregory *et al.* 2003). Refinements to the approach, whereby the contributory indices are first smoothed, follow the recommendations of Freeman *et al.* (2001).

More substantially, refinements to the generation of the contributory indices have been made so as to include data collected from the open coast (1984/85 Winter Shorebird Count (WSC; Moser & Summers 1987) and 1997/98 Non-estuarine Waterbird Survey (NEWS; Rehfisch *et al*. 2003a), and to improve estimates of birds on inland waterbodies. Proportional coverage of the total inland water resource by WeBS has so far been impossible to infer. However, as digital Ordnance Survey data have now become available, it has become possible to determine the proportion of available inland freshwater habitats that is not covered by WeBS. Although these digital data have made the task feasible, completing the inventory of waterbodies necessary to calculate coverage has proved to be an onerous task and, although the initial classification of waterbodies has been completed for 83% of Great Britain, it is unlikely to be finalised before June 2008. Regardless of this, the relationship between waterbird densities and the size of inland waterbodies, a method derived and tested during extensive work undertaken on behalf of Scottish Natural Heritage (Austin *et al*. 2006), has allowed estimates of the numbers of a given species on all non-riverine inland waters to be made. Coverage of riverine habitats by WeBS proved inadequate for any defensible extrapolation.

Thus, two complementary types of indicator are presented. Firstly, the 'Standard Indicators' are based on the existing protocol of summing the geometric means of the species indices, and this has been done using both conventional indices, i.e. those published in Banks *et al*. (2006), and newly developed refined indices based on methods described in Austin *et al*. (2006). These are described below (see section 4). These provide an introspective assessment of the 'health' of the wintering waterbird community within the region of interest (i.e. UK and England), in a fashion comparable to that used for previous UK and England waterbird indicators. Secondly, the 'Conservation Value Indicators' are presented. These are similar to the Standard Indicator, except that the individual species indices are weighted. The inclusion of a weighting factor can alter the behaviour of a composite indicator so that pre-determined value judgments may be incorporated. For example, species of conservation concern may be given a higher weighting in the indicator, thus allowing them to dominate trends at the expense of less threatened species; Underhill & Crawford (2005) used the conservation status as determined by IUCN (The World Conservation Union) to weight species trends of seabirds in South Africa. An alternative is to weight the individual species index by some measure of overall population size, thus allowing larger populations to contribute more to the composite indicator than smaller populations (Gregory *et al*. 2005). In contrast, the Conservation Value Indicators weights species by the numeric importance of the region in relation to the wider national (British) or international (East Atlantic flyway) populations rather than absolute numbers. Consequently, the Conservation Value Indicator is less susceptible to being dominated by trends in widespread and numerous species but rather are

sensitive to trends in species for which the UK (or part thereof) is particularly important. These are based on refined indices alone.

3. WEBS COVERAGE OF WETLANDS: OVERVIEW

The reliability of any indicator stems, at least in part, from the reliability of its composite indices.

Whilst WeBS is arguably the most comprehensive survey of its kind in the world, limitations must be considered when interpreting the currently used indices (*e.g.* Maclean & Austin 2006). The most important limitation is that the current indices do not represent trends in waterbirds throughout the country, rather they represent the trends on those wetland sites for which WeBS holds long runs of data. Furthermore, the extent of this problem has different consequences for the indices of different species. These biases are well known and can readily be incorporated in the interpretation of individual species trends. However, when composite indicators are generated from conventional WeBS indices these biases are not controlled for. An understanding of these biases in WeBS sampling underpin the developments described in this report.

With the exception of Arctic and Scottish breeding goose populations, conventional indices for all waterbirds are based entirely on data collected by the WeBS Core Counts, a scheme of synchronised monthly counts undertaken by a network of volunteers. The priority period for Core Counts is between September and March inclusive and data from these months only are used for indexing.

3.1 Geese

Indices for pink-footed goose *Anser brachyrhynchus*, Icelandic- and Scottish-breeding greylag goose *Anser anser*, Greenland and Svalbard barnacle goose *Branta leucopsis* and Greenland white-fronted goose *Anser albifrons* are based on data collected by coordinated winter roost surveys (*e.g.* Icelandic Goose Census and Greenland white-fronted goose Survey) and other special surveys. These species are dispersed widely during the daylight hours making them unsuitable for monitoring by the daytime Core Counts. No biases in these surveys have been identified that give cause for concern.

3.2 Estuarine Habitat

WeBS Core Counts are undertaken on all the major estuaries and consequently trends in estuarine waterbirds are well represented in the indices. For some species of wintering wader (*e.g.* dunlin *Calidris alpina*, knot *Calidris canutus*), the vast majority of birds will be concentrated on this habitat. For other species (*e.g.* oystercatcher *Haematopus ostralegus*), while a significant number of birds occur in other habitats, estuaries are by far the most important habitat. For these mainly estuarine species biases of geographic and habitat coverage gives little cause for concern.

3.3 Open Coast

WeBS Core Count coverage of the open coast is proportionally low compared to that of the estuarine habitat and so is preferentially monitored by the periodic Non-estuarine Waterbird Survey (NEWS) which aims to achieve a single-visit blanket coverage of the open coast. Such surveys were first undertaken in January 1985 (under the guise of the Winter Shorebird Count: WSC, Moser & Summers 1987), repeated in January 1998 (Rehfisch *et al* 2003a) and again in January 2007 (BTO unpublished). The open coast is the principal habitat for a number of wader species including purple sandpiper *Calidris maritima*, turnstone *Arenaria interpres*, sanderling *Calidris alba* and ringed plover *Charadrius hiaticula* which are therefore not well monitored by WeBS Core Counts, and additionally hold a minority (but significant) proportion of numbers of several other species. For these open coast specialists, the effects of biases in geographic and habitat coverage on conventional indices give cause for concern

3.4 Inland Waters

Until recently, WeBS coverage of inland waters has been poorly understood. WeBS has always been aware of the potential biases resulting from the distribution of available counters and from the manner

in which Core Count sites are recruited into WeBS (whereby sites are chosen by the counters who naturally favour sites holding reasonable numbers of waterbirds). The first of these problems is particularly acute in some areas of the UK and result in very poor coverage of wetlands in the areas where human population density is low. Also, although in some areas coverage of bodies of standing water may be considered relatively good, nowhere is coverage of riverine waters satisfactory.

The other major factor that has prevented a better understanding of WeBS coverage of inland wetlands is that, although WeBS holds an inventory of all the wetland sites counted by the scheme, there has not been a readily available inventory that describes the overall wetland resource that would allow the proportional WeBS coverage to be quantified. However, in recent years digital Ordnance Survey data have become available in a format that can form the basis for compiling such an inventory.

For those species with substantial inland populations, the effects of biases in geographic and habitat coverage on conventional indices give cause for concern.

3.5 Terrestrial And Other Wetland Habitats

Aside from major wetlands such as lakes, ponds, reservoirs and rivers, some species of waterbirds can be found associated with a variety of habitats such as ditches and wet meadows that do not lend themselves to monitoring using the site-based methodology employed by the WeBS Core Count scheme. WeBS has assessed the scale of this problem by conducting a randomised stratified quadrat survey, the Dispersed Waterbirds Survey (DWS, Jackson *et al*. 2006). As a result of this survey WeBS has a clearer understanding of the species specific biases associated with this issue but unfortunately the sample obtained was smaller than desired (relatively successful in England but with poor take-up in Wales, negligible take-up in Scotland and no take-up in Northern Ireland) and so does not allow the issue to be resolved without further development within the WeBS sampling protocol which are due to be phased in over the next ten years.

No attempt is currently made to index the wintering populations of species found overwhelmingly on these habitats (e.g. moorhen *Gallinula chloropus*, snipe *Gallinago gallinago*) and so they are not available to the composite indicator.

4. IMPROVING THE REPRESENTATIVENESS OF WEBS INDICES

Given the coverage of wetlands outlined in section 3, it follows that there is no need to modify the manner in which data from goose roosts and estuarine habitat are utilised for deriving indices. In contrast, there is considerable scope to improve the manner in which data from inland wetlands are utilised and this could result in a significant improvement in the representativeness of the indices for many wildfowl in particular. Additionally there is scope to utilise additional data from the open coast and this could result in a substantial improvement in the representativeness of the indices for open coast specialists (especially purple sandpiper, turnstone, ringed plover and sanderling).

Methods for refining the underlying species indices have been explored in detail elsewhere (Austin *et al*. 2006) and so a summary will be given here.

4.1 Terminology

4.1.1 Conventional indices

Throughout this report, the term "conventional indices" refers to those indices currently published annually in the WeBS Alerts report (Maclean & Austin 2006), except that here they have been rescaled to set the base year to the beginning rather than the end of the time series. These indices are based on WeBS Core data from all sites sufficiently well monitored to be included under the standard protocol adopted by WeBS (Banks *et al.* 2006; Maclean & Austin 2006) and those previously used to generate Waterbird Indicators (e.g. Eaton *et al*. 2006, DEFRA 2006a). The assumption being made when generating these indices is that the sample of sites from which data are drawn is representative of the overall waterbird habitat resource. As such, these indices make no allowance for the relative contribution of sites from the three principal habitats (estuarine, open coast & inland water) in relation to the importance of each habitat to the species in question. Also, they make no allowance for bias of coverage in terms of geographic area, and furthermore broad differences in site morphology within the habitats are not considered. It is clear from other work (e.g. Jackson *et al*. 2006, Austin *et al.* 2006) that these assumptions are not met for the majority of waterbirds.

In essence, conventional WeBS indices are derived by estimating annually the total numbers of the species in question across a suite of sites, the trends on which are taken to be representative of the entire country, with values of missing observations being imputed as necessary. The index value for a given year is obtained by dividing the number of birds estimated for that year by the value for an arbitrarily chosen base year. It follows that the concept of an index and that of a population census converge when all potential sites are represented in the index.

Refined Indices

The term "refined indices" is used for indices derived from WeBS Core data, and where appropriate WSC and NEWS data, while attempting to control for biases in observer coverage. Furthermore, as part of this refinement of the indices, imputation of missing counts has been undertaken within a regional context to buffer the indices against shifts in the distribution of wintering waterbirds, due to climate change, reported by Austin & Rehfisch (2005) and Rehfisch *et al*. (2006). Thus the refined indices are based on estimates of overall numbers across all habitats and potential sites and is obtained by summing what is essentially census data from estuarine habitats with estimated numbers from open coast and inland standing waterbodies. Numbers on estuarine habitats are based solely on WeBS Core Count data, while estimates of numbers on the open coast are derived from a combination of WeBS Core Count, WSC and NEWS data. Estimates of numbers on inland waters are derived solely from WeBS Core Count data. Indices of goose species censused by special surveys remain unaltered.

Throughout this report, the naming conventions, conventional and refined, are extended to the resulting composite indicators to indicate the nature of the contributory indices.

4.2 Estimating Numbers On Estuarine Waters

Essentially the WeBS Core Count scheme covers all estuarine habitat in the UK. Consequently WeBS Core Count data from estuaries can be treated as a census of waterbird numbers on this habitat.

4.3 Estimating Numbers On The Open Coast

The open coast has been monitored preferentially by means of single-visit blanket coverage carried out periodically throughout the UK. These surveys (initially WSC, now NEWS) have added to our knowledge of the numbers and distribution of a range of wader species, and have provided the main source for estimates of the winter numbers for several such species. Potentially, these surveys could also feed data into the estimates of seaduck numbers, an important element of the wintering waterbird assemblage in some areas. With the exception of eider *Somateria mollissima*, WSC only recorded waders and, consequently, any indices for other seaduck species would have a large margin for error until data from the recently completed NEWS 2006/07 survey can be incorporated.

The principal issue to be addressed with regard to the open coast component is that estimates of wader numbers, based on wide-scale coverage, are only available for two points in time, winters 1984/85 and 1997/98. In order for this habitat to be comprehensively represented in the indicator an annual index value is required for each species. Consequently, numbers for other years must be imputed. For headline indicators of wild bird populations, Gregory *et al*. (1999) interpolated between intermittent surveys assuming a constant annual rate of change. While this approach may be acceptable (though simplistic given the variation in trends across other habitats over the same period) for interpolating between the intervening winters 1985/86 to 1996/97 inclusive, the approach is flawed for extrapolating beyond these limits because declines of some species extrapolate numbers to extinction.

The approach used here aimed to impute numbers for years in which there were no blanket surveys of the open coast by making use of open coast data collected as part of the WeBS Core Count survey, assuming that relative changes in numbers on the whole open coast can be characterised by relative changes on open coast sites that are monitored annually by WeBS Core Counts. Under this assumption, it is then possible to use the standard indexing programs to impute numbers across all open coast sites covered by WSC and NEWS. In essence, what this achieves is a rescaling of the between-year changes in the index trajectory observed across WeBS Core open coast sites such that the trend passes through the population estimates for 1984/85 and 1997/98. Although the degree of imputing is beyond the recommended level suggested by Underhill & Prŷs-Jones (1994), it may well provide a more realistic estimate of the trend between, and especially beyond the extremes of, the two surveys than would the Gregory *et al*. (1999) approach. It will be possible to test this assumption further once the NEWS 2006/07 data are available for analysis.

4.4 Estimating Numbers On Inland Waters

Although the majority of sites within the WeBS Core Count scheme fall into this habitat category, proportional coverage of inland waters within the UK had only previously been quantified for Scotland (Austin *et al*. 2006). The underlying work necessary to extend this to the entire United Kingdom is currently being undertaken by WeBS (due for completion in 2008). Although the work is still incomplete, knowledge of WeBS coverage of inland waters now covers 83% of Britain, including all of Scotland and Wales and much of England. It has been the availability of Ordnance Survey MasterMap® data that includes digital vector data of inland waters that has made this task feasible. However, they are far from ideal and considerable data manipulation, checking and correction is therefore necessary in order to derive the required inventory. Full methodological details are available in Austin & Banks (2006). Currently, the necessary data has not been sourced for Northern Ireland.

Attempts to impose a post-hoc stratification on WeBS data for inland sites has to date failed to prove successful because inland standing waterbodies do not lend themselves to a stratification based on area, perimeters or similar morphological attributes currently available. However, Austin and Banks

(2006) demonstrated that for certain species, numbers for a given winter could be predicted from water area, having first determined a lower cut-off for water area before establishing the winter and species specific relationships. The lower cut-off was taken to be the smallest waterbody on which a given species has been recorded in all winter months while excluding data from the highly unrepresentative sample of the smallest waterbodies as to extrapolate from these sites would lead to population estimates many orders of magnitude greater than any realistic estimates. This approach is not without its problems, as the relationship between density and area could arise in two ways. Firstly, lower densities may occur on larger waterbodies because they are generally less favourable, having a higher proportion of unsuitable habitat (*e.g.* deep and wind-exposed water). Secondly, total numbers may be unrelated to the size of the waterbody, and thus density is a function of the inverse of area. Further investigation of these potential drivers of the relationship and the relative importance of each is warranted and will be undertaken as part of the ongoing WeBS wetland inventory work.

5. DEVELOPING A REFINED WINTERING WATERBIRD INDICATOR

Following Freeman *et al.* (2001), the indicators presented in this report have been based on smoothed indices. Standard WeBS practice is to derive smoothed trends through annual indices using generalized additive models (GAM; Hastie & Tibshirani 1990) (see Maclean & Austin 2006 for details). Because the extremes of the GAM model used to smooth the data are overly influenced by the first and last index values, having generated the smoothed trend the first year of the time series was discarded to avoid the smoothed trend being referenced to an unreliable base year value (Freeman *et al.* 2001). Thus, throughout this report, all indices from which indicators have been derived are referenced to an arbitrary base value of 100 set for the value of the smoothed trend corresponding to the second winter of the time series being analysed.

5.1 Conventional Wintering Waterbird Indicators

In the past, wintering waterbird indicators have been based solely on WeBS Core Count data (and special survey goose data), using indices derived from all available sites with no allowance being made for disproportionate coverage across habitats (*i.e.* the conventional indices). Such indicators have been published for the UK and for England (*e.g.* Eaton *et al.* 2006; DEFRA 2005b). Methodologically, the Conventional Indicator, being based on the unrefined indices, is essentially unchanged from these, other than that smoothed indices have been used in accordance with Freeman *et al*. (2001). However, changes have been made to the generation of the contributory indices in that WeBS has revised the suite of months that will be used as standard for generating waterbird indices (essentially September to March inclusive for all non-waders and November to March inclusive for waders). The Conventional Indicators are presented here to be used as a baseline against which to judge new developments.

5.2 Refined Wintering Waterbird Indicators

Two new, mutually non-exclusive types of indicators are presented in this report. Both are based on the refined indices.

5.2.3 Standard Indicator

The "Standard Indicator" is based on existing methods (Gregory *et al*. 1999, Freeman *et al*. 2001). They differ from the Conventional Indicator only in that they are constructed from refined indices.

Conservation Value Indicator

The "Conservation Value Indicator" is a more recent development that weights contributing indices in a species specific manner according to their conservation value in terms of the proportional contribution to overall National or International flyway populations of the target region. Thus International Conservation Value Indicators are presented for both the UK and England and the national Conservation Indicator is also presented for the latter.

Standard versus Conservation Value Indicator

The two types of indicator are not mutually exclusive alternatives as they represent the wintering waterbird trends in different contexts. The Standard Indicator provides an introspective assessment of the trends in the biodiversity of the wintering waterbird assemblage. The Conservation Value Indicator provides an assessment of the importance of the UK or England in terms of its contribution to overall international or national waterbird biodiversity.

5.3 Calculation Of The New Indicators

There are various options for indexing individual species and various ways in which these could be combined to give indicators (Table 1).

The refined indices may include data from any or all of the estuarine, open coast and inland habitats. For some species, data from particular habitat components have not been incorporated because few if any individuals occur regularly on those habitats. Where this is the case, relatively large fluctuations in small numbers can lead to nonsensical indices for that habitat. So, for example, to incorporate inland data for Dark-bellied brent goose, for which, by chance, only one bird was recorded inland during the base year can, especially after smoothing, produce index values for recent years in the tens of thousands. Consequently, for each species an assessment was made as to which habitat components (essentially habitat specific indices) would be incorporated in the overall refined index (Table 2). For similar reasons, European white-fronted Goose *Anser albifrons albifrons*, formerly included in the Wintering Waterbird Indicator, has been excluded because the total numbers recorded by WeBS of this species is too low to warrant its inclusion.

Ideally, refined indices only would be used for deriving this indicator. However, because of remaining concerns regarding the contribution of the inland habitats towards the refined indices for many of the widely dispersed species that we would wish to include, the reporting of an indicator based solely on refined indices alone is not yet possible and so an intermediate approach was used by which inland standing water specific indices were generated from WeBS Core Count data. These 'Adjusted Indices' were derived from inland sites and the data underlying the trend scaled to fit the most recent population estimates for inland habitats gleaned principally from Kershaw & Cranswick (2003) and Rehfisch *et al.* (2003b).

In keeping with previous derivation of multi-species indicators, the indicators were calculated as the geometric mean of the sum of individual species index values (*e.g.* Gregory *et al.* 1999), so that the indicator represents the average population trend of the species included. Standard Indicators were generated using the equation below:

$$\textit{Standard Indicator} = e^{\left(\frac{\sum_{s=1}^{n} \ln I_{s,y}}{n} \right)}$$

where $I_{s,y}$ = index value for species s in year y, and n = number of species in the indicator.

One of the issues with WeBS Core Count data is that different species groups have been surveyed over different time periods. Wildfowl data have been collected since 1966 for most species, whilst waders have only been counted on a sufficient number of coastal sites since 1974, and since 1993 inland; cormorants and grebes have been recorded since the late 1980s. Sequential additions of species with different base years follow the method recommended by Newson & Noble (2004). Effectively all index values for a species joining the indicator at a point later than the base year are scaled to the overall indicator value for that year, so that new species do not influence the indicator until after the year in which they are introduced. All indicators displayed run from a base year no earlier than 1975/76, the point at which wildfowl and wader counts became simultaneously available with good overall coverage.

To calculate the Conservation Value Indicator, it was necessary to include a weighting value, which was undertaken thus:

$$\textit{Conservation Value Indicator} = e^{\left(\frac{\sum_{s=1}^{n} \left(\ln I_{s,y} \right) \times W_s)}{\sum_{s=1}^{n} W_s} \right)}$$

where W_s = the average proportion of the national or international (flyway) population, as appropriate, of species *s* occurring in the region during the study period. The national and international population estimate taken as appropriate from Wetlands International (2006), Kershaw & Cranswick (2003), and Rehfisch *et al.* (2003b). In calculating the Conservation Value Indicator only species for which data are available from the beginning of the time series have been included. This is a programming rather than a conceptual issue and further program testing is required before more recently added species can be included with confidence. Consequently, grebes, cormorant and coot are not yet incorporated into the Conservation Value Indicator.

There has also been a reassessment of the species suite contributing to the new Wintering Waterbird Indicator. Austin *et al*. (2006) identified several additional species or goose populations that could contribute to the indicator. Furthermore, introduced and feral populations have been excluded as it is generally considered undesirable to include non-native species in conservation motivated reporting of waterbirds (e.g. Maclean *et al*. 2006).

Table 1. Alternative approaches for deriving the Wintering Waterbird Indicator. In all alternatives goose indices are based on goose census data.

Indicator Type	Indices used as input	Derivation of Indicator
Conventional / Standard Indicators	Conventional (only WeBS Core data, as currently published)	Geometric mean of individual species indices.
	Refined / Adjusted indices (WSC, NEWS and WeBS Core Count data)	Geometric mean of individual species indices.
Conservation Value Indicators	Refined / Adjusted indices (WSC, NEWS and WeBS Core Count data)	Geometric mean of individual species indices, weighted across species by the proportion of the national / international population occurring in the region of interest

Table 2. Waterbird species incorporated in the Wintering Waterbird Indicator with details of type of indices used (R=refined, A=adjusted, C=all habitats census, X=excluded) and the regions to which they contributed. Superscripts indicate the first winter a species or species/habitat was available for inclusion where this differs from the base year (winter 1975/76).

Species	Open Coast	Estuarine	Inland	Region
Mute swan	R	R	A	UK, En
Whooper swan	R	R	A	UK, En
Bewick's swan	R	R	R	UK, En
Pink-footed goose	C			UK, En
Greenland white-fronted goose [82]	C			UK,
Greylag goose (Icelandic population)	C			UK,
Greylag goose (northwest Scottish population) [91]	C			UK
Barnacle goose (Greenland population) [88]	C			UK
Barnacle goose (Svalbard population)	C			UK
Dark-bellied brent goose	R	R	X	UK, En
Light-bellied brent goose (east Canadian pop.)	R	R	X	UK
Light-bellied brent goose (Svalbard pop.)	R	R	X	UK, En
Shelduck	R	R	R	UK, En
Wigeon	R	R	A	UK, En
Gadwall	R	R	R	UK, En
Teal	R	R	A	UK, En
Mallard	R	R	A	UK, En
Pintail	X	R	A	UK, En
Shoveler	X	R	A	UK, En
Pochard	X	R	A	UK, En
Tufted duck	X	R	A	UK, En
Scaup	R	R	X	UK, En
Eider	R	R	X	UK, En
Goldeneye	R	R	R	UK, En
Red-breasted merganser	R	R	X	UK, En
Goosander	X	R	X	UK, En
Little grebe [88]	X	X	R	UK, En
Great crested grebe [85]	X	X	R	UK, En
Cormorant [87]	R	R	A	UK, En
Coot [85]	X	X	A	UK, En
Oystercatcher	R	R	R [93]	UK, En
Avocet	R	R	X	UK, En
Ringed plover	R	R	X	UK, En
Golden plover	R	R	R [93]	UK, En
Lapwing	R	R	R [93]	UK, En
Grey plover	X	R	X	UK, En
Knot	X	R	X	UK, En
Sanderling	R	R	X	UK, En
Purple sandpiper	R	R	X	UK, En
Dunlin	R	R	X	UK, En
Bar-tailed godwit	R	R	X	UK, En
Black-tailed godwit	R	R	X	UK, En
Curlew	R	R	R [93]	UK, En
Redshank	R	R	X	UK, En
Turnstone	R	R	X	UK, En

6 RESULTS

6.1 Conventional Indicator Based On Conventional Indices

Conventional Indicators for wildfowl, waders, and all waterbirds were produced using conventional WeBS Core species indices, plus special goose survey data indices (Figures 1a UK, 1b England). Conventional WeBS indices cover all habitats and with no allowance for between or within habitat biases in survey coverage. Essentially these indicators are indicators of waterbird numbers on estuarine habitat and larger inland waterbodies.

These indicators are equivalent to those previously supplied by the BTO (e.g. Eaton *et al*. 2006, DEFRA 2005a) other than they are based on smoothed indices following Freeman (2001) that, in keeping with WeBS developments, use an expanded suite of indexing months for the majority of species.

6.2 New Standard Indicator Based On Refined Indices

New Standard Indicators for wildfowl, waders, and all waterbirds were produced using refined species indices (Figures 1c UK, 1d England). Refined indices are based on data from WeBS Core Counts, WSC and NEWS, plus special goose survey data indices and make allowance for biases in between and within habitat coverage.

Consequently, the New Standard Indicators differ from those previously supplied by the BTO in that they are more comprehensive in their representation of habitats.

6.3 Conservation Value Indicator Based On Refined Indices

Conservation Value Indicators wildfowl, waders, and all waterbirds were produced using refined species indices. Both International Conservation Value Indicators (Figures 2a UK, 2b England) and National Conservation Value Indicators (Figure 2c England) and have been derived. The weighting is based on the population estimate (*i.e.* numbers contributing to the refined habitat index, averaged over all years) divided by the national or international threshold (~1/100*GB or flyway population) as appropriate.

The Conservation Value Indicators are presented for the first time for the United Kingdom and England.

Figure 1. Comparison of Conventional Wintering Waterbird Indicator to new Standard Wintering Waterbird Indicator for the UK and England.

■ wildfowl ● waders ○ waterbirds

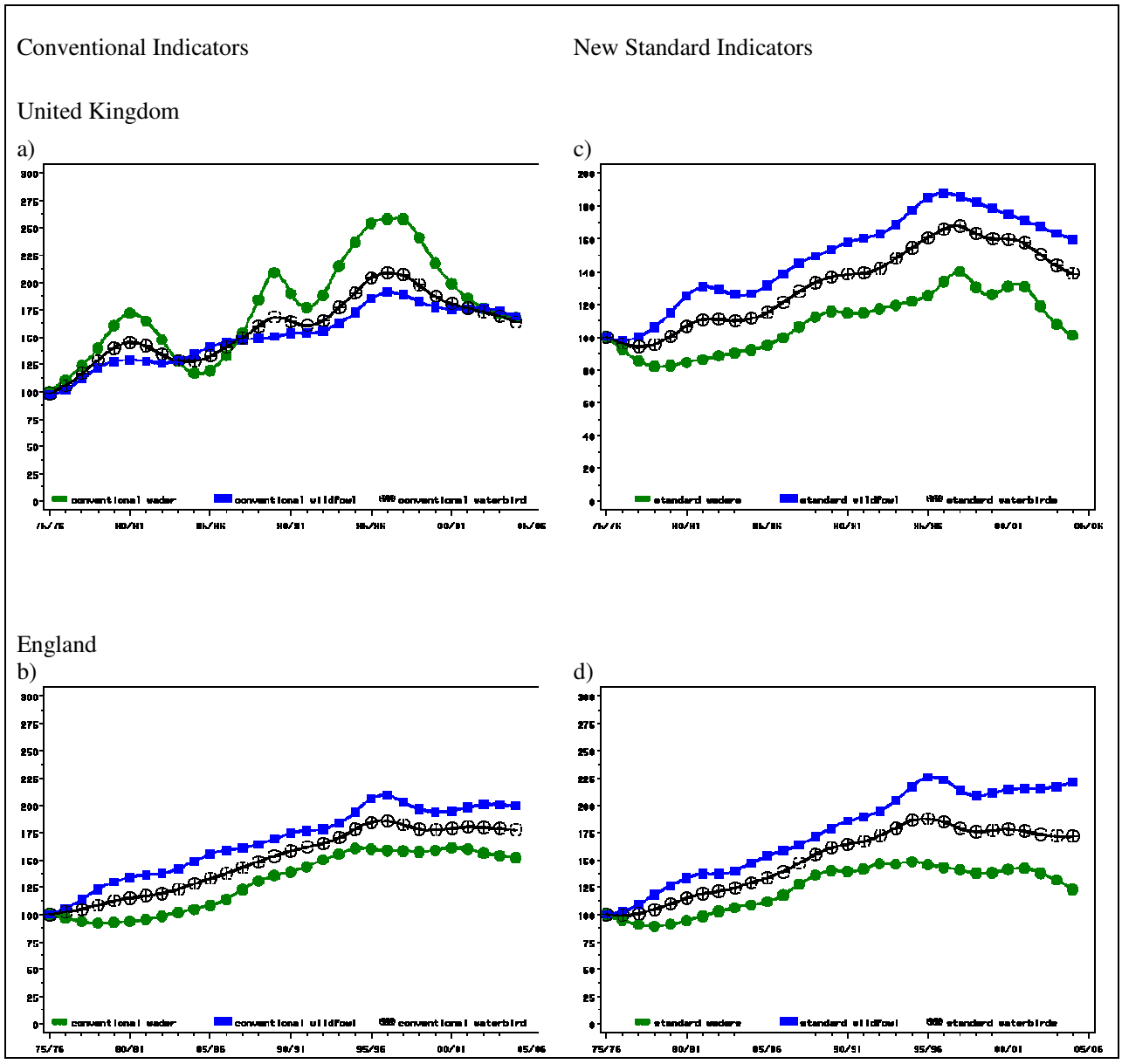


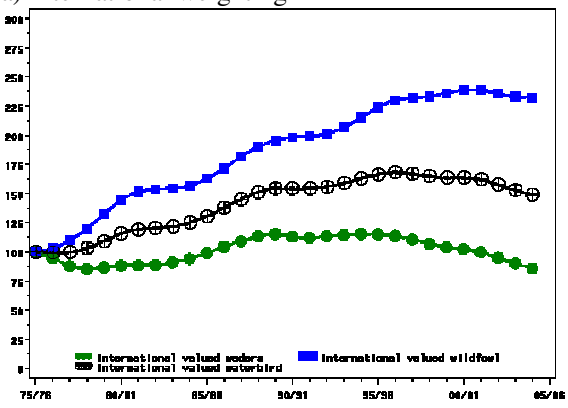
Figure 2. Conservation Value Wintering Waterbird Indicators for the UK and England. The new Standard Wintering Waterbird Indicator is repeated here for comparison.

■ wildfowl ● waders ○ waterbirds

Conservation Value Indicator

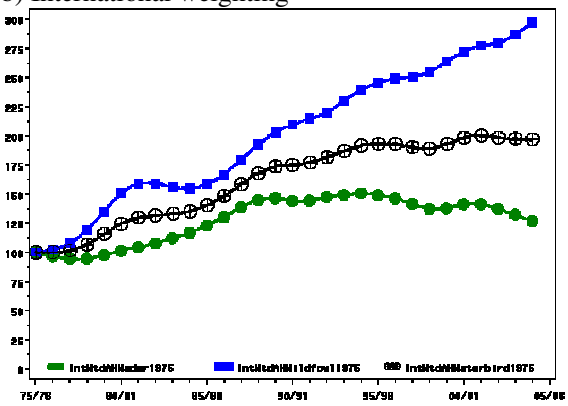
United Kingdom

a) International weighting

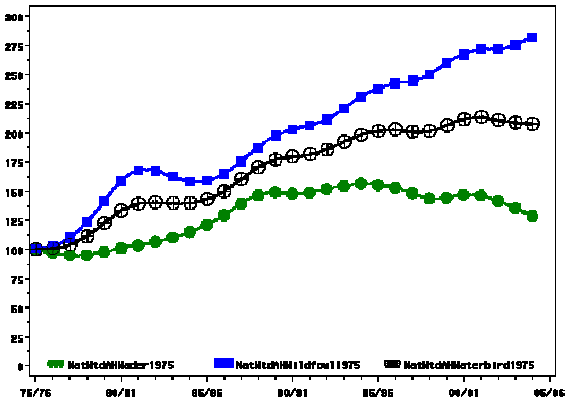


England

b) International weighting

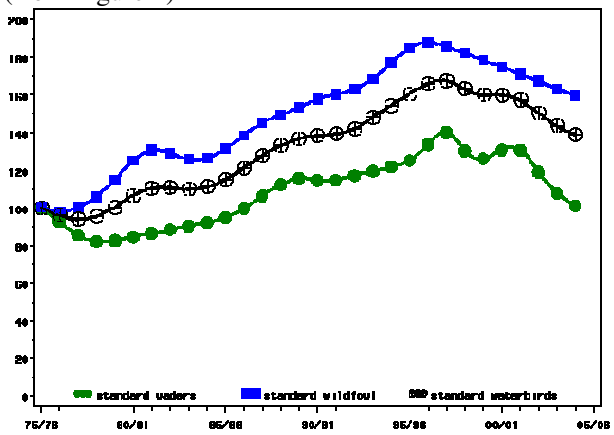


c) National weighting

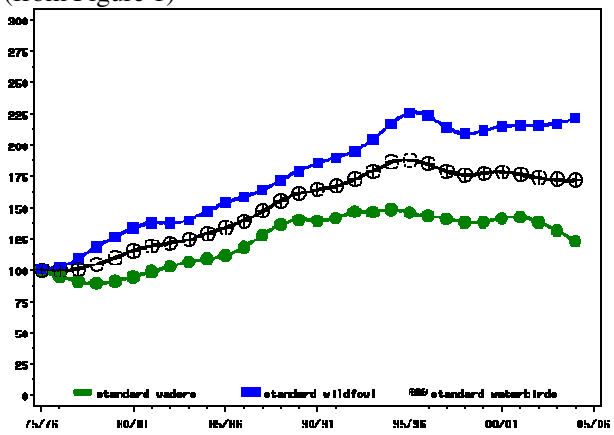


New Standard Wintering Waterbird Indicator

(from Figure 1)



(from Figure 1)



7 DISCUSSION

The various indicators presented in this report all point towards a favourable trend in the overall 'health' of the wintering waterbird assemblage in England and the UK in general and wildfowl in particular. However, this is somewhat tempered by the situation for waders, especially when refined indicators are considered.

7.1 Conventional Indicator

The Conventional Indicators are comparable to indicators previously supplied by WeBS (e.g. Eaton *et al*. 2006, DEFRA 2005a) although the smoothing and changes to the standard months used by WeBS for generating the contributory indices and a revised species suite has resulted in some differences. However, the main point of discussion here concerns differences between these and the new Standard Indicators.

7.2 New Standard Indicator Based On Refined Indices

Standard Indicators based on the refined indices promise to be more robust than those based on solely on the conventional indices. This is because the derivation of the refined indices attempts to control for within- and between-habitat biases in coverage and make use of data from WeBS Core, WSC and NEWS. Although for some species refined indices were not available for the inland habitat, this is still a substantial improvement over indicators based solely on conventional indices as for many of the species the indices used will be more representative of trends across all wetlands, something that for conventional indices is only true for a few habitat specialists such as Knot (almost exclusively estuarine) that occur on well monitored habitats or species such as Light-bellied Brent Goose that occur almost exclusively on well monitored sites.

In the case of the UK indicators the refinements made have resulted in a substantial smoothing of the long-term trend, especially in the case of the waders indicator. One possibility for this is that being biased towards estuarine habitat, the Conventional Indicator was susceptible to cold weather shifts in habitat or geographic distribution such as occurred in the early to mid 1980s (e.g. Clark *et al*. 1982, Davidson & Clark 1985). The new Standard Indicator would be less affected by such movements due to better representation of more sheltered inland habitats or the relatively warm west coast (especially western Scotland).

In the case of the English indicators the refinements have had a more subtle impact. This is probably because WeBS obtains an above average representation of inland waterbodies in some areas of England as compared to the UK as a whole. Thus there is little difference between the Conventional and new Standard Indicators for wildfowl. However, there is an indication of a slight but consistent downturn in the wader indicator, possibly due to better representation of the open coast habitat on which a number of species have shown declines and northward shifts in distribution (Rehfisch *et al*. 2003).

7.3 New Conservation Value Indicator Based On Refined Indices

The new Conservation Value Indicators represent either the contribution of the region in question towards the biodiversity of the British wintering waterbird assemblage, or the contribution of the region towards the biodiversity of the international flyway population of wintering waterbirds. Indicators have been generated for wildfowl, waders and all waterbirds.

In the case of the UK, the recent declines apparent in the new Standard Indicator across all groups are less marked in the new Conservation Value Indicator. This suggests that, on balance, species for which the UK is especially important in an international context are fairing comparatively well. However there is no room for complacency as in all cases there is a slight but sustained downward trend.

In the case on England this is true in both an international and British context. While there is still a slight downward trend for waders this is somewhat countered by a sustained increase in the wildfowl trend suggesting that wildfowl for which England is especially important in both a national and international context are fairing comparatively well.

7.4 Evaluation Of The New Indicators

Indicators can only be as good as their contributory indices. There is some concern over indicators derived from conventional WeBS indices that differ greatly between species in their comprehensiveness. Thus, for example, while the conventional indices for knot or light-bellied brent goose *Branta bernicla bernicla* can be considered comprehensive in their representation of these species throughout the UK, for other species, such as mallard *Anas platyrhynchos*, golden plover *Pluvalis apricaria*, and turnstone which occur extensively or primarily on habitats not well monitored by WeBS the conventional indices are recognised as biased. These biases are well known and can readily be incorporated in the interpretation of individual species trends. However, when conventional indices are combined to give the Conventional Indicator, which is intended to give a comprehensive representation of the wintering waterbird community, all indices are treated as equal. Consequently, any improvements to the contributory indices in their comprehensiveness of representation across the various wetland habitats should be welcomed. This is precisely what the incorporation of the refined indices aims to achieve.

In order to fully realise this aim, ongoing work being undertaken by WeBS needs to be completed. This will reduce the number of caveats needed to accompany the Indicators, many of which apply equally to both the conventional and new approaches. Most pressing is further work towards dealing with problems identified by our new understanding of the biases in coverage of inland waters. A species-by-species methodology is recommended. For this report we applied a common approach towards refining indices for the inland habitat across all species with a substantial inland component to their population. However, it has become clear that this has not been equally successful for all species. Specifically, species that occur in large numbers on wetland habitats such as grazing marsh, but which are not substantially associated with standing water within those habitats, (*e.g.* swans, wigeon) have proved especially problematic (Austin *et al*. 2006). Consequently, alternative methods for deriving inland indices for the affected species will be required. The ultimate aim will be to use the most representative indices available and this would be assessed on a species by species basis.

For some species, such as knot and light-bellied Brent Goose, the conventional indices may well be retained as occasional records from inland and open coast (knot) or sporadically used sites (light-bellied brent goose) only serve to add 'noise' to the indices. For other species, the extrapolations used here will almost certainly be retained for the foreseeable future.

In the short-term, updates of the indicators will draw upon data from the recently completed NEWS 2006/07 survey that will increase the robustness of indices for species with a substantial open coast component to their population.

In the medium term, forthcoming Atlas work planned for 2007 to 2011 will inevitably improve our understanding of the winter distribution of waterbirds throughout the UK, and provide updated and increased resolution data. This will in turn improve our understanding of biases in geographical coverage. It should also make it possible to quantify the proportion of each species counted in the various habitats and so allow the extrapolated estimates of numbers that underlie the refined indices to be better assessed.

In the longer-term, WeBS will be seeking to improve representation of poorly monitored habitats, including waterbird use of the wider countryside away from primary wetland habitats (e.g. drainage ditches, wet grasslands) and riverine habitats. This hinges on completing the WeBS wetland inventory, exploring further the value of imposing a stratified sampling approach to smaller inland water bodies, riverine habitat and the open coast, and the incorporation of new survey elements into

annual WeBS monitoring. In addition to improving the comprehensiveness of wetland coverage for existing contributory species these developments may also allow additional species to be incorporated in the long-term.

The concept of the Standard Wintering Waterbird Indicator is widely understood by stakeholders. In essence it provides an acceptable overview of trends in a regions waterbird community. The concept of the Conservation Value Indicator is relatively new and a stakeholders' assessment of its potential benefits need to be made. It is important to understand that the Conservation Value Indicator is complimentary to and not a replacement for the Standard Indicator.

Whereas the Standard Wintering Waterbird Indicator provides an introspective assessment of waterbird trends in the target region the Conservation Value Indicator provides an outward looking assessment of waterbird trends. Thus, the trajectory of the Standard Waterbird Indicator would be unaffected were declines in numbers of a species for which the target region is especially important to be offset by increases in numbers of a species that is much more wide spread. For example, were there to be a substantial decrease in numbers of Redshank, a species for which the UK hold over 90% of the international flyway population, the Standard Indicator would be unaffected if this were to be balanced by an increase in a species such as Coot a species for which the UK hold less than 10% of the international flyway population. However, the Conservation Value Indicator would be affected downwards. Consequently, the Conservation Value Indicator may better assess the relative contribution of the UK towards the international conservation effort. Similarly the relative contribution of different UK regions towards the UK conservation goals could be compared.

7.5 Geographic Coverage Of The New Indicators

There remain considerable problems producing Wintering Waterbird Indicators that are truly representative of the UK as a whole. The issues are largely historic and therefore it is not obvious how these could be addressed. In reality, previous UK indicators were essentially British indicators other than for the addition of one race of light-bellied brent goose and the inclusion of data from four sites in Northern Ireland to the contributory wader indices.

Although the exclusion of non-wader data from Northern Ireland has been overcome by equating of the suite of months used for indexing between Great Britain and Northern Ireland (a development within WeBS), the major issue, that of data availability, remains. When adopting the recommendations of Underhill & Prŷs-Jones, all but four sites in Northern Ireland remain excluded from the contributory indices on the grounds of data availability. Although additional sites will qualify for inclusion as future winters' data are added to the time series, pre-1987 data for all sites, excepting the four for which data extends back to 1974/75, would be imputed. However, an indicator specific to Northern Ireland and beginning in 1987 would be based on indices conforming to all the recommendations and thus be considerably more defensible. In the absence of habitat data for Northern Ireland equivalent to that derived from the Ordnance Survey for Great Britain, this would also have benefits when extrapolating inland waterbird numbers in that the optimal approach for Northern Ireland and Great Britain may be different. Thus, an indicator specific to Northern Ireland (from 1987/88), together with one specific to Great Britain (from 1975/76) would give a true representation of trends in the UK's wintering waterbird assemblage. This would be comparable to the reporting of species indices by WeBS (e.g. Banks *et al*. 2006).

7.6 Recommendations For Further Work

Once the NEWS 2006/07 data are available for analysis it is recommended that the imputing of open coast populations from a combination of WeBS Core Count and NEWS data is further tested by comparing expected and observed estimates within a 'jackknife' framework.

Further work towards developing refined indices for a more comprehensive suite of species should be undertaken. Alternative methods to those used here for a sub-set of species may be appropriate in

some cases. Much of this work would be best tackled in the long-term within the WeBS forward strategy.

As a result of the work done to refine existing indices it would be relatively straightforward to develop habitat-specific indices and in turn habitat-specific indicators for the three major wetland habitats substantially monitored by WeBS: estuaries, open coast, and larger inland standing water (waterbodies exceeding 0.5 ha).

The methodology that has been established as part of this work could be readily extended to enable indicators pertinent to each of the four constituent countries of the UK to be generated. Furthermore, for some parts of the UK, indicators pertinent to finer level regions would be feasible. Already, as part of the refinement of the indices imputation of missing counts has been undertaken within a regional context. Historically, WeBS has found it convenient to base its regional analysis and reporting of regional trends (e.g. Maclean & Austin 2006) on Environment Agency and Scottish Environment Protection Agency regions. However, in principal other regional breakdowns could be used to report finer scale indicators.

7.7 Recommendations For Reporting And Annual Updating

We recommend that the annual reporting of the Standard Wintering Waterbird Indicators be extended to include the Conservation Value Indicators from 2008. The BTO would deliver the indicators for all waterbirds combined and the constituent groups, wildfowl and waders.

The annual revision of the Wintering Waterbird Indicator needs to be aligned to the annual data analysis schedule of WeBS. As such it is recommended that the indicator be supplied annually in September. Thus the forthcoming revision, to include WeBS data to winter 2005/06 could be supplied in September 2007.

We further recommend that both the Standard Wintering Waterbird Indicator and the Conservation Value Indicator should be based on what the WeBS partnership believes to be the best available indices at the time (refined, adjusted or resulting from as yet undeveloped methodology) and this will be reassessed at the species specific level on an annual basis in light of ongoing improvements derived from work being undertaken by WeBS.

For this report we have largely maintained the traditional suite of component species for the group breakdowns. We would recommend that this undergoes minor revision to bring it into line with recent decisions made for the future reporting of the Scottish Wintering Waterbird Indicator. All existing species would be retained for reporting of the overall waterbird and wader indicators, but that non-wildfowl (grebes, cormorant and coot) be removed from the wildfowl indicator which currently remains somewhat of a misnomer. While geese will remain a contributory part of the wildfowl indicator, it is intended that a separate goose indicator will be delivered for the Scottish Wintering Waterbird Indicator and this option may well be relevant to the UK.

Given the problems of generating truly representative indicators for the UK, we also recommend that from 2008 the UK indicators are replaced by separate indicators for Great Britain from 1975/76 and Northern Ireland from 1987/88. These would be comparable to the species indices reported annually by WeBS.

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