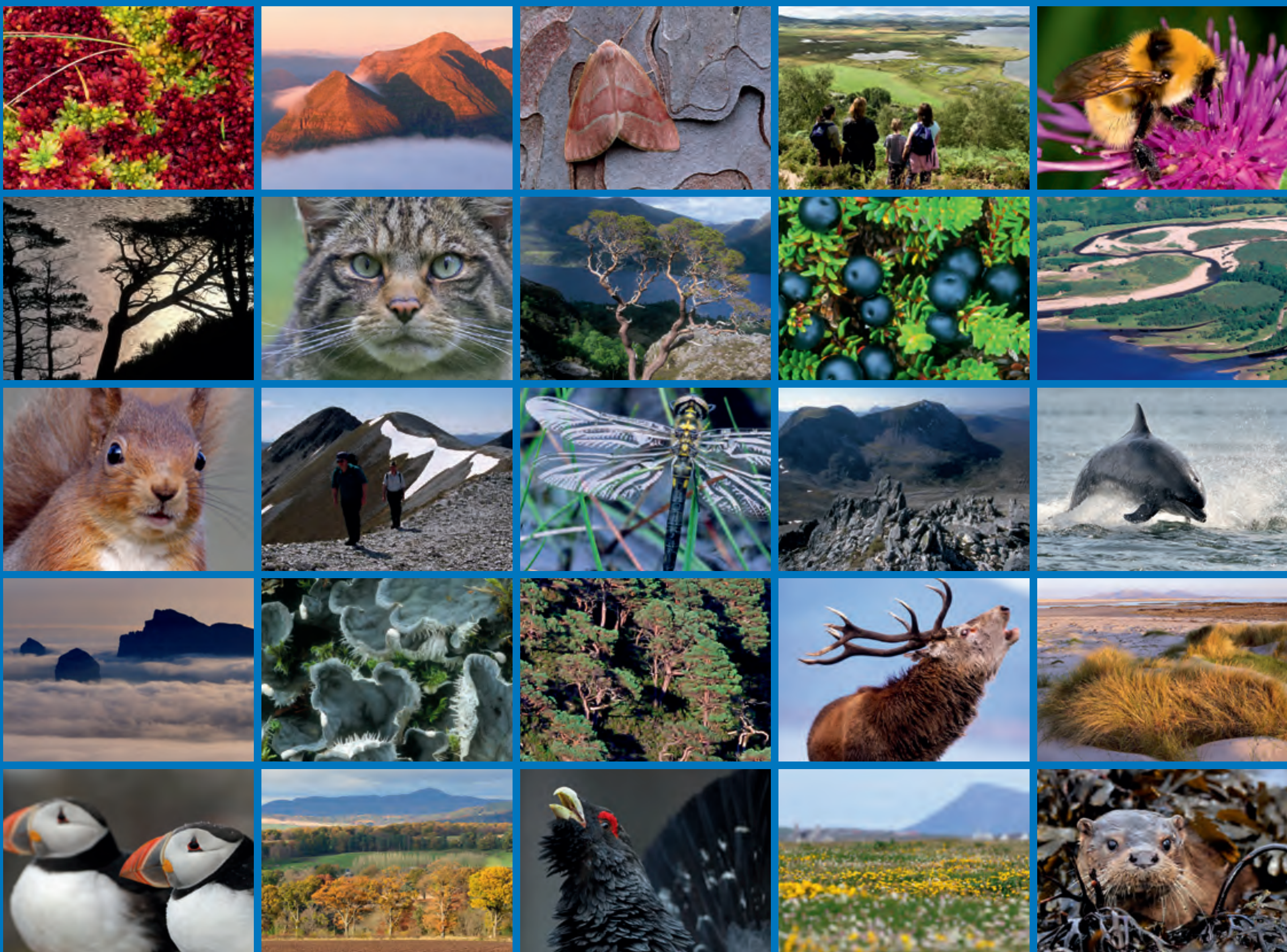
Scottish Natural Heritage
Commissioned Report No. 884

An update of the review on the impacts of piscivorous birds on salmonid populations and game fisheries in Scotland



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COMMISSIONED REPORT

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For further information on this report please contact:

Simon Cohen
Scottish Natural Heritage
Fodderty Way
Dingwall Business Park
DINGWALL
IV15 9XB
Telephone: 01349 865333
E-mail: simon.cohen@snh.gov.uk

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COMMISSIONED REPORT

Summary

An update of the review on the impacts of piscivorous birds on salmonid populations and game fisheries in Scotland

Commissioned Report No. 884
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Keywords

Population estimates; licensing.

Background

The potential impacts of piscivorous birds on wild and stocked fisheries have been the focus of many studies not only in Scotland but also internationally. The current economic value of freshwater fisheries, in terms of salmon and sea trout angling, has been estimated to be worth £87 million per annum to the Scottish Economy. Licensed control of fish-eating birds is available in order to limit the potential losses incurred to these fisheries. To support licensing decisions population estimates, and associated confidence limits, have been produced for Scotland and for SEPA's planning regions for red-breasted merganser, goosander, cormorant and grey heron.

Main findings

- Current relative abundance (with confidence limits) and distribution of four key piscivorous bird species have been derived for Scotland and the SEPA river planning regions for both breeding and wintering populations. There are, however, a number of caveats associated with these derived values. Extreme caution needs to be applied when using these population estimates, and the associated confidence limits, particularly for the SEPA regions if they are to be used to assess the population level impacts of any licensed control activities. If these estimates are to be used as the basis of setting a regional bag limit, we would recommend a precautionary approach and that more weighting is given to the lower confidence limit reported.
- The review of post-2008 studies into the interactions between piscivorous birds and salmonids do not alter the conclusions of earlier reviews. The primary conclusions of studies undertaken to date are:
  I. there is substantial evidence that, at a <u>site level</u>, piscivorous birds can take large numbers of fish from natural and stocked fisheries. In Scotland, the highest levels of concern have been raised for: a) wintering cormorants foraging at still water fisheries where wild (and farmed) trout species are targeted, and also in rivers where salmon parr (large) and smolt are taken; b) sawbill species in early winter period and March/ April foraging on salmon (small) smolts and, to a lesser extent, parr. Grey herons do not appear to be a major concern in Scotland.

II. there is a lack of evidence that such predation impacts effect fish species at the population level, or causes direct economic losses, however this cannot be interpreted as a lack of the existence of an effect, rather that it is very difficult to measure.

- The lack of evidence available for key parameters of fish population and accurate assessments of fish consumption rates by piscivorous birds has hindered any attempts to demonstrate any reduction in numbers or productivity of fish species.
- The impacts of control measures should be monitored through regular survey of the populations regardless of whether the overall aim is to derive more accurate periodic population estimates or to generate annual population indices. This will be particularly critical if the overall aim is to manage populations of piscivorous birds using an approach which is based broadly on the principles of adaptive management.
- Recommendations are made for future work to support management of the interactions between piscivorous birds and fish in Section 9.

For further information on this project contact:
Simon Cohen, Scottish Natural Heritage, Fodderty Way, Dingwall Business Park, Dingwall, IV15 9XB.
Tel: 01349 865333 or simon.cohen@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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1. INTRODUCTION

1.1 Background

The impacts of piscivorous birds on salmonid populations and game fisheries in Scotland has previously being considered as part of a much more extensive review, on a wider suite of predatory birds, commissioned by the Moorland Forum (Park *et al.*, 2005). This work was published later in a peer-reviewed journal as Harris *et al.* (2008). Both of these reviews presented the evidence for population-level and economic impacts on Scottish game fisheries of predation by four freshwater piscivorous species: great cormorant *Phalacrocorax carbo* (hereafter referred to as cormorant), goosander *Mergus merganser*, red-breasted merganser *Mergus serrator* and grey heron *Ardea cinerea.* (The European shag *Phalacrocorax aristotelis* was also included but is not discussed here because it has an entirely marine distribution). It is worth noting that the Scottish populations (both breeding and wintering) of cormorant consist mostly of the race *Phalacrocorax carbo carbo* – the Atlantic great cormorant, as opposed to *P.c. sinensis* - the continental great cormorant (Carss, 2007). In terms of key fish species in Scottish freshwater fisheries, these two reviews considered the following to be of primary interest: Atlantic salmon *Salmo salar* (hereafter referred to as salmon), sea trout *Salmo trutta trutta* and brown trout *Salmo trutta fari* – although rainbow trout, a non-native species was also discussed to a lesser extent.

Harris *et al.* (2008) concluded that there was substantial evidence that, at a site level, piscivorous birds can take large numbers of fish from natural and stocked fisheries. In Scotland, the highest levels of concern were raised over wintering cormorants foraging at still water fisheries, where wild (and farmed) trout species are targeted and also from rivers when salmon parr (large) and smolt are taken (citing Carss & Marquiss (1992) and McIntosh (1978) amongst others).

For Scottish sawbills, concern was highest at rivers where salmon (small) smolts and, to a lesser extent, parr were important prey species, and for these age-classes greater numbers were consumed in the early winter and March/April (citing Marquiss *et al.* 1998; Marquiss & Carss (1998). It was also highlighted that there were concerns about piscivorous birds, particularly cormorants, wounding or disturbing fish so that they become harder for anglers to catch. However, they concluded that there was a lack of evidence that piscivorous predation impacted fish species at the population level or caused a direct economic loss to Scotland (Harris *et al.,* 2008).

It is a widely accepted tenet of ecology that, in order for predation to have an impact at the population level it must represent additive mortality for the prey species. In other words mortality caused by predation is simply not compensated for by an increased survival rate or productivity of the remaining individuals, or reduced mortality rates arising from other factors (Begon *et al.,* 1990). The lack of evidence available for key parameters of fish populations (e.g. fish abundance and mortality rates caused by other factors), and accurate assessments of fish consumption rates by piscivorous birds has hindered any attempts to demonstrate any reduction in numbers or productivity of fish species (Harris *et al.,* 2008). The conclusions of the 2008 paper supported the findings of earlier reviews that the evidence for impacts of piscivorous birds at the population level was very scarce (e.g. Marquisss & Carss, 1994; Russell *et al.,* 2012; Marquiss *et al.,* 1998). However, the lack of research which has effectively demonstrated the impact of piscivorous birds on fish populations (citing the case of cormorant in particular), cannot be interpreted as a lack of the existence of an effect - rather that it is very difficult to measure (Harris *et al.,* 2008; Marzano *et al.,* 2013).

More recently the Department for Environment, Food and Rural Affairs published a ‘Review of fish eating birds policy’ (Defra, 2013). As well as gathering the evidence for the current impact of piscivorous birds on inland fish stocks and fisheries in England, this project sought to: ascertain the effectiveness of management techniques for the control of piscivorous birds; review the current licensing regime; assess the current levels of lethal control of piscivores and whether changes are required; determine the effectiveness of the current model used by Natural England (NE) for setting the level of cormorant licensing; and to ensure that the conservation status of these piscivorous species is not jeopardised. Evidence for damage to fisheries was based on a wide range of sources: case studies submitted by the Angling Trust; responses to these case studies made by NE and Royal Society for the Protection of Birds (RSPB); bird sightings submitted to Angling Trust as part of 'Cormorant Watch'; site visits carried out by the review team; licensing data provided by NE; and two Centre for Environment, Fisheries and Aquaculture Science (CEFAS) reviews of cases studies/peer reviewed literature. Key messages from this part of the review included the following:

1. Although all three piscivorous species considered by the review (cormorant, red-breasted merganser and goosander) could cause problems for inland fisheries, the impacts of predation at individual sites were highly variable;

2. Damage caused by cormorants was generally considered to be the most problematic and was considered to affect a broader range of fishery types. Moreover, cormorants were concluded to have sub-lethal effects through wounding of fish, behavioural changes and loss of fish condition. It was also noted that this species presents a significant challenge in terms of attempting to quantify their use of sites due to their opportunistic foraging behaviour, resulting in complex patterns of movements in response to changes in prey availability or management activities;

3. Goosander mainly affected upland rivers in the north and west of England, many of which support migratory salmonids;

4. There was little evidence that red-breasted mergansers were a problem in England and much of the likely impact was thought to be restricted to Scotland.

5. With respect to economic losses, the review concluded that very few studies had actually quantified losses but for some of those which had, the costs arising from loss of stock and the cost of implementing management actions were substantial (amounts were not presented).

1.2 Licensing arrangements for control of piscivorous bird populations

Game fishing (rod and line) for salmon is known to occur across the whole of Scotland (see Figure 1 in Malcolm *et al.* (2010) which shows the location of the main salmon rivers) and there is anecdotal evidence that game fishing for brown trout and sea trout is likely to be similarly well distributed across the country (SPICe, 2012). Given the strong evidence that piscivorous birds can consume relatively large numbers of salmonids at a site level, it is unsurprising that there is still a great deal of concern amongst managers of fisheries (wild and stocked) and anglers collectively about fish-eating birds. The current economic value of freshwater fisheries, in terms of salmon and sea trout angling, has been estimated to be worth £87 million per annum to the Scottish Economy (Marine Scotland, 2014). Statutory Nature Conservation Bodies are obliged to offer licensed control methods for piscivores in order to limit any potential damage to these industries. This is achieved primarily through granting licences to permit the killing or taking of wild birds for the purpose of preventing serious damage to fisheries (under section 16 of the Wildlife and Countryside Act).

Separate licensing arrangements for the control of piscivorous birds in Scotland are in place for three categories: salmon and sea trout fisheries (SNH, 2011a), stocked fisheries (SNH, 2011b) and fish farms (SNH, 2011c) – although only the former two are considered here.

Licences are granted only in instances where evidence of serious damage can be provided and when non-lethal methods of control have been proven to be unsuccessful or impractical. Serious damage is assessed according to set criteria laid out in the guidance notes on: (a) the damage or risk to fish stocks (which vary according to which of the three categories is being considered); and (b) the provision of results of bird counts, at the time of year that damage occurs (see section 3.2 for further details). With respect to demonstrating the effectiveness on non-lethal methods, the applicant should provide details on the methods used and length of time methods were in place. However, it should be noted that the quality of evidence can be highly variable in terms of describing how methods were applied and any impacts recorded (SASA pers. comm).

In England, a predation management trial started in April 2014 which involves a range of partners including NE, Defra, the Environment Agency (EA), the Angling Trust and the RSPB[1]. The main aim of this initiative is to help fisheries and fish farms reduce predation by all piscivorous birds. This will involve a new approach to cormorant predation management called Area-Based Management and Licensing whereby fisheries work together at a wider scale (rather than just at site level) to coordinate the most appropriate non-lethal and, where necessary, lethal management techniques. In addition NE has also developed a number of guidance leaflets which offer fisheries managers a series of management options (including human disturbance, scaring techniques, the use of fish refuges, netting/wires over stock) in order to reduce the impacts of predation by all of the piscivore species (Natural England, 2011 a, b, c). Some of these measures (e.g. netting and wires) are likely to be impractical for use on most river systems.

1.3 Aims

The specific aims of this current project are as follows (as laid out in the Statement of Requirements):

- Undertake a review of the literature published since 2008 on the interactions of piscivorous birds and salmonids;

- Produce updated information on the numbers, trends and distribution of breeding and wintering great cormorant, grey heron, red-breasted merganser and goosander in Scotland using information from the 2007–11 Bird Atlas (Balmer *et al.,* 2013);

- The review should also provide population estimates for these species at a regional level. Given the issues involved, SNH suggests using the boundaries of the Area Advisory Groups formed to implement the Scottish Environment Protection Agency's (SEPA) River Basin Planning[2].

[1] http://www.naturalengland.org.uk/ourwork/regulation/wildlife/species/fisheatingbirds.aspx
[2] The boundaries of these regions are currently under review by SEPA and may change.

2. STATUS OF BREEDING AND WINTERING PISCIVOROUS BIRDS IN SCOTLAND (AND FOR THE SEPA RIVER BASIN PLANNING REGIONS)

2.1 Data sources used in analyses

2.1.1 Atlas

There have been three atlases of breeding birds in Britain and Ireland (1968–72, 1988–91 and 2008–11, hereafter BA1970, BA1990 and BA2010; and published as Sharrock, 1976; Gibbons *et al.,* 1993; and Balmer *et al.,* 2013) and two wintering atlases (1981/82–83/84 and 2007/08–2010/11, hereafter WA1980 and WA2010; and published as Lack, 1986, and Balmer *et al.,* 2013). Each provided information on distribution at a 10-km square ("hectad") resolution. The two most recent breeding atlases (BA1990 and BA2010) and the recent winter atlas (WA2010) also included timed counts for at least eight of the 25 tetrads (2 km × 2 km squares) within each hectad, known as Timed Tetrad Visits (TTVs). Most of the analyses were conducted at the hectad resolution but some analyses involving BA1990, BA2010 and WA2010 also used tetrad resolution data to calculate measures of abundance and breeding-season abundance change. Note that no tetrad-resolution data were collected in WA1980 so we were unable to measure abundance changes in winter using Atlas data.

From these data it is possible to determine the proportion of the national distribution found in different areas, for example in Scotland relative to Great Britain, or in a particular SEPA region relative to Scotland (subject to the quantity of data that can be collected in increasingly small areas). Furthermore, by comparing range size estimates for different areas between atlases we can derive estimates of distribution change which will help to highlight areas of concern (both for expanding and declining populations). All records went through a dual validation process, first at point of entry against various region-, season- and species-specific thresholds, and second by manual checking by local experts (e.g. see section 1.4.8 and 3.7.2 in Balmer *et al.,* 2013).

2.1.2 Wetland Bird Survey

The Wetland Bird Survey (WeBS[3]) monitors non-breeding waterbirds in the UK on an annual basis. Data are available for red-breasted merganser and goosander from the winter of 1966/67 onwards whereas data for cormorant and grey heron are available from 1987/88 and 1993/94 respectively. The principal aims of WeBS are to identify population sizes, determine trends in numbers and distribution, and identify important sites for waterbirds. WeBS involves monthly co-ordinated, synchronous counts (the core counts) of the number of waterbirds at a sample of inland and coastal wetland sites (including estuaries). Most of these surveys tend to be repeated by the same highly experienced volunteers from one year to the next. Any unusual records (e.g. unexpectedly high /low numbers of birds or rarities) submitted online are also flagged up for the attention of the inputter in order to ensure that they are not typographical errors.

Since the mid-1960s, a total of 2,687 sites in Scotland have been surveyed as part as WeBS although there has been turnover as some sites drop out and other sites enter the scheme, although sites supporting large numbers of waterbirds can be expected to have sustained coverage. Survey coverage is generally higher during the winter months. In terms of producing abundance indices (see Austin *et al.,* 2014), all species considered are routinely indexed using data from September to March inclusive. Data used for indexing are restricted to those that come from sites with relatively good coverage. Thus, following the recommendations of Underhill & Prŷs-Jones (1994), only data from sites that have been visited on at least 50% of designated monthly count dates (from September to March) over the entire time series are used. Furthermore, for any given species, only sites on which the

[3] http://www.bto.org/volunteer-surveys/webs

species has actually been recorded will be included and so the number of sites underpinning the index will vary from species to species. The number of sites (inland/coastal) which meet this criteria, for each species are as follows: red-breasted merganser (169/32); goosander (134/62); cormorant (359/62) and; grey heron (469/70).

2.1.3 Heronries Census

The overall aim of the Heronries Census is to collect counts of 'apparently occupied nests' (AON) of herons, egrets and other colonial waterbirds from as many heronries as possible in the United Kingdom each year[4]. Data are available from 1928 at UK level and from 1934 for Scotland.

2.1.4 Breeding Bird Survey

The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is line transect survey of randomly selected 1 km squares distributed throughout the UK. These are visited twice annually, during April to June. Data are available for all species from 1994 onwards. At the UK scale, population trends are only considered sufficiently precise for species recorded on an average of at least 40 BBS squares per year, but for the country scale this figure is lowered to 30. This criterion was only met for grey heron with respect to the piscivorous species considered here. Long-term average BBS sample size (for data up to 2013) for each species are as follows: red-breasted merganser = 8, goosander = 11, cormorant = 12, and grey heron = 51.

2.1.5 National breeding seabird censuses

To date there have been three complete national breeding seabird censuses which are as follows (years covered are given in parenthesis): Seabird 2000 (1998-2002); Seabird Colony Register (1985-1988); and Operation Seafarer (1969-1970). With respect to this review only data for cormorant is relevant and figures taken from the most recent census are used as the basis for the population estimates (see section 2.5.1). It is worth noting that cormorants are known to be asynchronous breeders and therefore single colony counts, as commonly carried out during the seabird census, are likely to under-estimate the total number of breeding pairs. In addition the location of colonies can vary from one year to the next and this can introduce uncertainty when counts from different years and different regions are combined to derive a single population estimate – although effort was put into ensuring the number of survey years were kept to a minimum for Seabird 2000 (Sellers, 2004).

2.2 Other potential sources of population trend information

2.2.1 Seabird Monitoring Programme (SMP)

The Seabird Monitoring Programme (SMP) monitors all seabird species which regularly breed in Britain and Ireland. This is achieved by the collection of sample data on the breeding numbers and breeding success of seabirds on an annual basis. Population trends for both regional and national levels are calculated as part of the SMP web based reporting scheme and this information is used in the assessment of their current conservation status[5]. Although there is sufficient data to generate a UK annual population trend for breeding cormorant based on both inland and coastal colonies, the data used to derive the Scottish abundance index are not regarded as being representative and hence this is not calculated for their annual reporting. Data (non-confidential sites only) from the first complete survey in 2012 of inland breeding cormorant in England and other historical data since 1981 (see

[4] http://www.bto.org/volunteer-surveys/heronries
[5] http://jncc.defra.gov.uk/page-3201

Newson *et al.,* 2013) have recently been submitted to the SMP database but have not yet been incorporated into generated population trends.

2.2.2 Waterways Bird Survey /Waterways Breeding Bird Survey

Waterways Breeding Bird Survey (WBBS)[6] is an annual survey of breeding birds along rivers and canals and was developed alongside the Waterways Bird Survey (WBS), which ran from 1974 to 2007 when it was replaced by WBBS. It uses transect methods akin to those of the Breeding Bird Survey (BBS) but with minor adaptations to survey a linear habitat. Although 52 stretches have been covered in Scotland, there are insufficient surveys carried out in order to be able to generate a Scottish specific population trend for the piscivore species considered here. Trends are not reported until the average number of sites in which a species is recorded, over the period of the trend, reaches 40 at UK level or 30 at a country level. None of the four piscivorous species considered here meet these criteria for Scotland (see Table 24 in Section 14 for sample sizes).

2.2.3 District Salmon Fisheries Board (DSFB) licensing data

All licence applications made to SNH must provide bird count data at the time of year that damage occurs. The methods for counting birds are laid out in a series of guidance notes: salmon and sea trout fisheries (SNH, 2011a), stocked fisheries (SNH, 2011b) and fish farms (SNH, 2011c) – although only the former two are considered here. The five possible methods for carrying out bird counts for the first category of salmon and sea trout fisheries on rivers and are: (i) simultaneous counts; (ii) consecutive counts; (iii) vantage points; (iv) combined counts based on a combination of at least two of the three former methods; and (v) roost counts. It is recommended that these bird counts should be carried out at least once for the larger catchments or on a monthly basis for the smaller river catchments. For the other categories of stocked fisheries and fish farms, no recommended methodology is provided in the relevant SNH guidance (but see below for how methods are determined) although it is suggested that birds should be counted at least once a day if the site is manned or several times a week if it is unmanned. It is also stipulated in the guidance notes for fish farms and stocked fisheries that counts should take place immediately prior to the onset of shooting. Licences are normally only granted for the period from 1 September to 30 April. It is a formal requirement that licensees submit an annual return to SNH of the actual numbers that have been shot under licence.

Science and Advice for Scottish Agriculture (SASA, a Division of the Scottish Government Agriculture, Food and Rural Communities Directorate) originally devised the SNH guidance on the methods used to count piscivorous birds on rivers based on accepted methods and constraints of the DSFBs. Whilst SASA recommend that, where possible, effort is put into ensuring that counts are carried out across the whole of the catchment, even if the more remote or difficult regions are only covered on a rotational basis, most DSFBs will focus counts along restricted areas of the lower main stream (SASA pers. comm). SASA also recommends that, on an annual basis, at least two counts should be conducted during the licence period (although precise timings are not stipulated, it is recommended they should be kept the same from one year to the next where possible) and that the same methodology should be used to ensure comparability of results. SASA will also carry out site visits to stocked fisheries and fish farms and use this to recommend the most appropriate methods for counting riverine birds at their site.

Since the mid-1990s, SASA has compiled all the counts supplied by applicants to the licensing authority, Scottish Government (SG) or SNH, as part of the licence application. For DSFBs, where only parts of the catchment are counted, it is assumed that these counts

[6] http://www.bto.org/volunteer-surveys/wbbs

represent a minimum figure. However, no extrapolation of the count data is accepted or assumed, and a recommended annual bag limit (the numbers that can be taken) is based on the most recent year's count data. Very occasionally, for example where poor weather conditions may result in lower counts than would have otherwise have been expected (based on previous counts), recommendations may resort to earlier counts. SASA quality check the written data, and will remove potential double-counting errors where the Board do not do this, and where the data suggest this has taken place. SASA currently hold data from 15 DSFBs (out of a total of 109) which apply for licences in Scotland and on average, each has at least 10 years' worth of data.

Recognising that the licensing period only covers part of the smolt run (April - May), SASA has also devised a protocol to allow shooting in May of adult male sawbills only. The protocol is very restrictive in terms of the area and licensing conditions in order to reduce disturbance to breeding birds throughout the catchment. Data from smolt traps have shown that by May the smolts are typically in the lower stretches of the river and moving out to sea. Anecdotal observations of feeding sawbills (including males and almost certainly immature birds) in the lower river and estuaries suggests that these birds exploit this source of food). To date only one DSFB has put in a licence application to cover this time of year (although there have been more enquiries from DSFBs about the feasibility of doing so).

Although SASA processes the data, the data are owned by the relevant DSFBs and hence cannot be passed to a third party or used for other purposes other than those for which they were intended without the Board's permission. Therefore the comments which follow are based on those provided by SASA and are not based on an independent review of the database. Whilst SASA has sought to minimise differences between individual DSFBs (in terms of survey methods, data recording and reporting of results) through the introduction of a survey form (which has been adopted by SNH's guidance notes), differences still persist. Each DSFB is responsible for individual catchments, where the number and size of the river(s) present, and the area of the catchment, differ widely. Alongside this issue, different DSFBs have varying levels of resource, which has inevitably led to each Board adopting a method that most suits their individual circumstances. This manifested as each DSFB having its own format in terms of how the data are collected and entered in order to match its historical data base. Differences in the timing of when counts were carried out further compounds the problem of making sensible comparisons between the counts made by different DSFBs.

Another issue is the quality of the data, which are variable in terms of the level of detail provided and the amount of effort put into ensuring that double counting does not occur. The data are not consistent although SASA tries to apply appropriate corrections to these where sufficient information is provided (e.g. counting different lengths of river in different count surveys). SASA actively removes any extrapolations (where numbers have been estimated in the absence of counts being carried out) and counts at river mouths where the impact of piscivorous birds on salmonids is likely to be lower as the fish species diversity is relatively high (although during the smolt run this may change).

Therefore at this stage it is not possible to ascertain whether these data as it stands have the potential to provide supporting evidence for the population trends even at a district level. There may, however, be scope do so in the future (see Recommendations section 7).

2.3 Calculation of distribution, relative abundance and change

Atlas data for Great Britain were extracted from the Britain & Ireland atlases. Hectads in Scotland were identified and, where they overlapped with the border between Scotland and England, they were only coded as Scottish when at least 50% of the land area occurred in Scotland. All Scottish hectads were then assigned to one of the 10 SEPA regions, again on the basis of proportional land area (Figure 1). Of the 1490 hectads classified, 1257 (84%) fell in a single region, 222 (15%) spanned two regions and 11 (< 1%) spanned three regions. Of the 11 hectads spanning three regions, only one (NM99) had less than 50% in the nominal region (47% in Argyll, 42% in North Highland and 11% in West Highland). For the Solway and Tweed SEPA regions which extend into England, each region was truncated at the Scottish border.

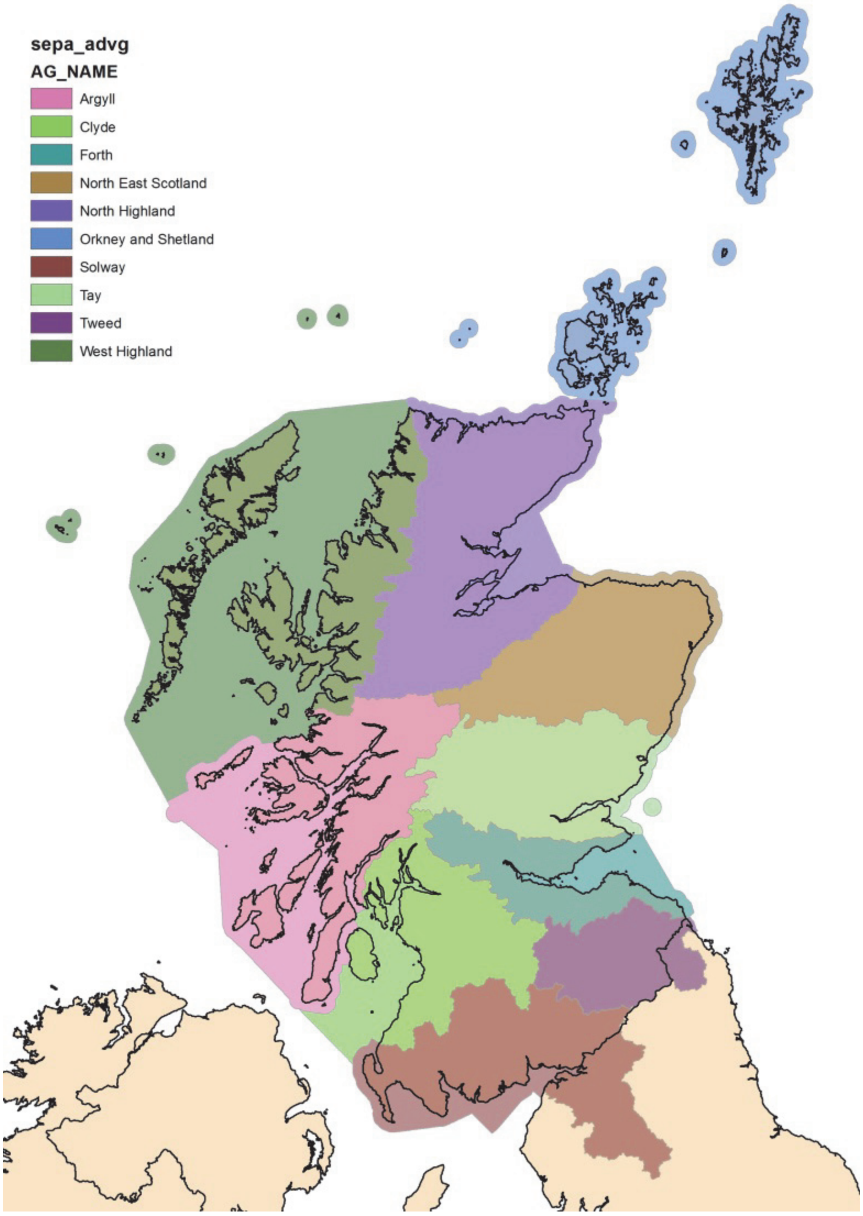


Figure 1. Map of SEPA river basin planning regions (as of July 2014).

2.3.1 Current distribution (breeding and wintering)

Winter distribution data are simply an indication of which hectads were occupied whereas breeding-season distribution data include additional attributes indicating whether or not breeding was thought to have occurred on the basis of standard breeding evidence codes (Balmer *et al.,* 2013). There are three standard levels of breeding evidence: possible breeding, probable breeding and confirmed breeding. These do not imply the success or otherwise of breeding attempts but the probability that a breeding attempt took place given the observations made. These levels of breeding are relevant because estimates of population size usually relate to the number of territorial breeding birds, and range size derived from possible/probable/confirmed breeding records are used routinely for this purpose.

The collection of breeding evidence for every species in every hectad was an aim of each Atlas, but recording of presence in the absence of breeding was not. Such records were submitted during *BA2010* and accumulated in a more *ad hoc* manner, and are potentially biased towards areas with high recording effort. These presence-only records are of interest as they indicate occurrence patterns of non-breeding birds – such birds may inhabit particular areas away from known breeding grounds so are relevant to the assessment of predation pressure. For this reason we present the number of hectads with "presence" but recommend these figures are used only for additional context; they are not used in formal estimates of range size or change because of the uncertainties of completeness of coverage and lack of comparable historical records.

For Scotland and each of the SEPA regions we calculated the number of hectads occupied by each species in each season. Separate totals are provided for the different levels of breeding evidence, and for presence records. As explained above, the latter are not used in any further calculations of population size or change. To enable comparisons among regions of differing size we also calculated the percentage of hectads in the region that were occupied. To indicate relative contribution to status we determined the percentage of the Scottish range occurring in each region, and the percentage of the Great Britain range occurring in Scotland.

2.3.2 Current relative abundance (breeding and wintering)

The range size and percentage contribution figures detailed above provide a simple means to assess the importance of different regions. However, the densities of these species vary throughout their ranges (Balmer *et al.,* 2013), so a better measure of regional importance would be based on the number of birds in each region. Absolute measures of abundance – that is numbers of birds per square – are not available. The two most recent breeding atlases include systematically collected data in a sample of tetrads from which estimates of relative abundance and change can be derived. It must be emphasised that the timed counts (1 or 2 hours per tetrad) were designed to provide a standardised measure of relative abundance – visit times were insufficient to allow the observer to visit every part of the tetrad and count every bird. For this reason the counts cannot be used as either absolute counts or densities (numbers of birds per square) but can be used to indicate the proportional contribution of each region to the overall total. This necessitates an analytical technique that combines atlas analyses with estimates of national population size.

The first step of the analysis was to derive an abundance figure for each hectad based on information collected at the tetrad level. We could not simply sum the counts across the tetrads within a hectad because in some cases more than eight tetrads were surveyed. Instead we used a bootstrapping approach to take randomly drawn subsets of the data, thereby making full use of the large sample of data whilst removing potential geographical biases. The procedure involved first standardising the counts per tetrad (by calculating the average number of birds detected per hour averaged across visits and hours of survey). Then we randomly selected eight tetrads from those surveyed within a hectad, summing the standardised counts. This gives one estimate of abundance for each hectad based on one random selection of tetrads. These hectad relative abundance estimates were summed within each SEPA region, within Scotland and for Britain.

For each species, SEPA region totals were expressed as a percentage of the Scotland total, and the Scotland total was expressed as a percentage of the British total. This entire procedure was repeated 1000 times. Each time a potentially different and randomly selected set of tetrads are used, thereby giving 1000 estimates of percentage contribution to abundance for each SEPA region relative to Scotland, and for Scotland relative to Britain. From each set of 1000 values we take the median as the estimate of percentage contribution and the 25th and 975th ranked values as the 95% confidence limits around the estimate.

2.3.3 Changes in distribution (breeding and wintering)

Distribution maps derived from pairs of atlases were compared to classify each hectad according to apparent changes in occupancy during the period in question: those hectads which went from having birds present in one atlas period to none recorded in the next (-); those which went from having no birds recorded to having birds recorded (+); and those which had birds recorded in both periods (=). We present the numbers of hectads showing each type of change plus the percentage change in range size during the period for Scotland and each SEPA region. For the breeding season we present three measures of change: first 20 years (BA1970–BA1990), second 20 years (BA1990–BA2010) and the whole 40-year period (BA1970–BA2010). Just one winter change measure can be calculated for the c.30-year period (WA1980–WA2010). Changes are only calculated for hectads that were surveyed in both atlases in question. Very few hectads (mostly small marine islets) were surveyed in one atlas and not in the other (see Balmer *et al.* (2013) for details). When distribution range sizes within a region are very small, minor fluctuations can lead to anomalously large percentage change in figures. To help interpret such figures we tested range size changes for statistical significance using a binomial model which determines whether the proportion of hectads occupied in one period is different from the proportion occupied in another period, subject to the total number of hectads being considered. A potential weakness of this method is the assumption that occupancy of individual hectads arises independently but we think this method is adequate for highlighting major changes in the number of occupied squares.

Some caveats are necessary for the interpretation of these results. First, care should be applied when interpreting values for cormorant and grey heron because the loss or gain of a single 10-km square could entail the loss/gain of a variable number of pairs for these colonial species. For other species, because of their more dispersed (non-colonial) distribution, changes in range size are likely to equate more closely to changes in underlying abundance. Secondly, it is possible that assignment of breeding evidence codes varied among atlases for the colonial breeders. This is because, unlike most species where breeding evidence is relatively easy to assign (if the species is in suitable nesting habitat then breeding evidence can be submitted), for colonial species some observers might ignore the lower levels of breeding evidence if they “know” that a colony is not present. It is therefore possible that anomalous gains and losses could appear on the change maps which merely reflect variation through time in how sightings of birds away from known colonies were recorded. When calculating range changes for seabirds, it is standard procedure to omit possible breeding records in an attempt to alleviate this problem. We have followed this procedure for cormorant but not for grey heron (as it is not uncommon to record single nests) so that the statistics produced here match those in the definitive published Atlases. Thirdly there is potential for the winter range changes to be biased by changes in recording effort. The main area of concern is the western Highlands and islands where recording effort from WA1980 to WA2010 increased and therefore some apparent ’gains’ could be spurious.

2.3.4 Changes in relative abundance (breeding only)

The observed distribution changes are the result of local extinction and colonisation, or redistribution events, but even where range limits are apparently stable there can be changes in abundance within the occupied area. Here we aim to provide estimates of how the abundance of species is changing within SEPA regions and across Scotland. Similar to in Section 2.3.2, we use the tetrad-resolution data from the BA1990 and BA2010 atlases to estimate relative abundance for each hectad so that we can then calculate changes. This is only possible for the breeding season because no tetrad-resolution data were collected for WA1980.

Note that although individual birds were counted during each timed tetrad visits in BA2010, many species were only listed as present during the visits in BA1990. At that time the measure of relative abundance used was the “frequency index”, taken as the proportion of surveyed tetrads that were occupied in a hectad. We converted the BA2010 data to the same format, thereby giving, for each species, a frequency index figure for each hectad for each period. For each period these values were summed (weighted by area of the hectad) within each SEPA region, within Scotland and within Great Britain. Then, for each area we calculated the % change in total frequency index and used this as an index of abundance change for the area in question for the period c1990 to c2010. As in Section 2.3.2, this analysis was performed using a resampling approach to make full use of the data whilst removing potential geographical biases, with the added benefit that each change estimate is presented with confidence limits. The procedure involved randomly selecting eight surveyed tetrads in each hectad and determining the proportion of tetrads that were occupied. Note that these calculations were based on the first hour of fieldwork (either visit) in each tetrad to standardise effort. For each atlas period, these proportions were summed across hectads to give an overall measure of relative abundance for the period. We then calculated the percentage change between these figures as an estimate of abundance change. This procedure was repeated 1000 times, with a potentially different set of tetrads being used each time. For each species the 1000 estimates of abundance change were ranked and the median value taken as the overall estimate of change; the 25th and 975th ranked values were taken as the 95% confidence limits – where these do not overlap zero the abundance change is statistically significant, but care should be taken in regions where a species was scarce throughout. In terms of interpreting the results as highlighted in section 2.3.3, the frequency method for calculating relative abundance change does not work well for highly aggregated breeding species such as cormorant and grey heron. For this reason change in relative abundance may also be underestimated. Therefore, where change is apparent, it will be noteworthy.

2.4 Calculation of annual population trends

2.4.1 Wintering (WeBS)

WeBS monthly counts from the ’winter period’ September–March were used to generate annual population trends (e.g. Austin *et al.,* 2014) using the Underhill Indexing approach (see Underhill & Prŷs-Jones (1994) for more details). The Underhill index uses an iterative process to impute missing counts so as to populate, completely, a matrix of counts by site, winter and month. For each species, it sums the monthly observed and estimated counts in each winter. These annual totals are then standardised to a percentage of the value in the baseline year (the most recent winter which in this case was 2012/2013). Generalized Additive Models (GAMs; Hastie & Tibshirani, 1990) were used to fit both index values and a smoothed trend to the count data, whilst retaining elements from the Underhill method that allows the assessment of whether or not counts flagged as incomplete should be treated as missing data. The generated smoothed trends are less influenced by winters of abnormally high or low numbers and sampling 'noise' than are raw index values. This makes smoothed trends preferable when assessing changes through time (e.g. WeBS Alerts; Maclean *et al.,* 2008) because they capture the underlying trajectory of the population.

2.4.2 Breeding (Heronries Census)

Population trends are derived from the Heronries Census data using the ratio-estimators approach (Thomas, 1993). Using this method the ratios of the populations in any two (not necessarily consecutive) years of the survey are estimated from counts at sites visited in each of those years. These ratios can be used to estimate the counts at sites that were not visited, and hence build an estimate of the total population (along with upper and lower confidence limits). Further modifications to the analytical approach have been made to allow for the extinction of colonies and the establishment of new ones (Marchant *et al.,* 2004). Trends are generated at the level of the UK and separately for Scotland, Wales and England (Baillie *et al.,* 2014). Samples for Scotland are poor in some years: where the analyses failed to derive an estimated number of AONs (or upper and lower confidence limits), values were interpolated from those from the most recent preceding and subsequent years or as the geometric mean of the confidence limits.

2.5 Calculation of population estimates

Population estimates were not produced as part of the most recent atlas publication (covering the periods we have defined here as BA2010/WA2010). In order to revise such estimates, data from a wide range of other monitoring schemes and relevant sources would also be have to be collated. Furthermore, there is a precedent set for producing and revising all breeding and wintering bird estimates for the UK and GB (see section 1.6 in Balmer *et al.* (2013) for further details). Hence we use the population estimates for GB as published in Musgrove *et al.* (2013) which have been agreed by the Avian Population Estimates Panel (APEP). We have not carried out extensive searches of local bird reports, made use of local atlas data or otherwise liaised directly with birdwatchers, anglers or others with intimate knowledge of specific areas since this was considered beyond the scope of this review. The GB estimates include Scotland, England, Wales and the Isle of Man but not the Channel Islands, hereafter referred to as Britain (or British, whichever is the most appropriate). Most of the GB estimates are simply repeated in this report, although unrounded values have been used to ensure that subsequent calculations do not carry rounding assumptions forwards unnecessarily. Exceptions to this were breeding red-breasted merganser and breeding/wintering grey heron, and reasons underlying this are given as follows.

There have been two surveys of sawbills in the UK: one in 1987 (published as Gregory *et al.,* 1997) and; the other in 1997, based on a partial resurvey of the areas and times of year covered by the former (unpublished report by Armitage *et al.,* 1997). The main habitat covered, on river systems, did not adequately reflect where red-breasted merganser tend to breed and hence the population estimate was not considered to be complete (Gregory *et al.,* 1997). The estimate used in Musgrove *et al.* (2013) was based on the previously accepted estimate derived from BA1990 (Gibbons *et al.,* 1993). Therefore a new British breeding estimate for red-breasted merganser was generated for the purpose of this review using BA2010 to update the earlier estimate. In addition, annual estimates of grey heron breeding population size are made by BTO and hence it was possible to produce new estimates for the period 2008–11 (to match the period covered by Balmer *et al.,* 2013) for the breeding and wintering period.

We now outline in detail how the British and Scottish (breeding and wintering) population estimates were derived for each of the four piscivorous species being considered here.

2.5.1 Britain and Scotland (breeding)

Red-breasted merganser: The British breeding population estimate was derived by taking the value cited from BA1990 for Britain and applying a correction based on the change in relative abundance between BA1990 and BA2010 (see section 2.3.4). Then the British population estimate was multiplied by the proportion of relative abundance estimated to occur in Scotland based on BA2010 data (see section 2.3.1) in order to calculate the Scotland breeding population estimate. Hence the breeding population estimates for red-breasted merganser relate to the years 2008-11.

It is worth noting that the red-breasted merganser population estimate initially derived from BA1990 data was regarded as a minimum number as it was based on an extrapolation of tetrad counts and included the assumption that all birds were located during the timed tetrad visit. As the new estimate is a temporal extrapolation of the old one, the same caveat applies: all breeding red-breasted merganser estimates must be treated as minima.

Goosander: The British breeding population estimate was taken from Musgrove *et al.* (2013). This was calculated by taking the value cited by Gregory *et al.* 1997 (based on data collected in 1987) rather than the less reliable but later estimate derived from Armitage *et al.* (1997) and applying a population trend measure of 1.3163 based on estimates derived from WBS/WBBS up until 2009. The Scottish estimate was derived from combining the British estimate with the proportion of relative abundance estimated to occur in Scotland based on BA2010 data (see section 2.3.1). Hence the breeding population estimates for goosander relate to the year 2009.

Cormorant: Both the British and Scottish breeding population estimates were taken from Musgrove *et al.* (2013). These figures were derived from the most recent national seabird census (see section 2.1.5) in the absence of a representative trend measure with which to scale the estimate forwards in time. Hence the breeding population estimate for cormorant relates to the years 1998–2002 and further updates will not be possible until the next national seabird census.

Grey heron: The British and Scottish population estimates were calculated using data from the BTO Heronries Census data by averaging the population estimates calculated for 2008–11 in order to make them more comparable with data used in the most recent atlas period (Balmer *et al.* 2013). Hence the breeding population estimates for grey heron also relate to the years 2008–11.

2.5.2 Britain and Scotland (wintering)

Red-breasted merganser: The British wintering population estimate was taken from Musgrove *et al.* (2011), also later cited in Musgrove *et al.,* (2013) and was derived using a variety of data sources including WeBS, county bird reports and sea duck surveys. Additional information was deemed necessary in order to produce the best population estimate possible since red-breasted mergansers are known to winter offshore in large flocks (e.g. Marquiss, 2007a). This value was multiplied by the proportion of relative abundance estimated to occur in Scotland based on *WA2010* (see section 3.3.2) in order to derive the Scotland population estimate**.** Hence the wintering population estimates for red-breasted mergansers relate to the winters 2004/05 to 2008/09.

Goosander: The British wintering population estimate was taken from Musgrove *et al.* (2011), also later cited in Musgrove *et al.* (2013) and was derived using WeBS data extrapolated by a factor of 2.95 (calculated as the proportion of the population uncounted by WeBS). This value was multiplied by the proportion of relative abundance estimated to occur in Scotland based on *WA2010* (see section 2.3.2) in order to derive the Scotland population estimate. Hence the wintering population estimates for goosanders relate to the winters 2004/05 to 2008/09.

Cormorant: The British wintering population estimate was taken from Musgrove *et al.* (2011), also later cited in Musgrove *et al.* (2013) and was derived using WeBS data extrapolated by a factor of 1.6 (calculated as the proportion of the population uncounted by WeBS). This value was multiplied by the proportion of relative abundance estimated to occur in Scotland based on *WA2010* (see section 2.3.2) in order to derive the Scotland population estimate. Hence the wintering population estimates for cormorants relate to the winters 2004/05 to 2008/09.

Grey heron: The British wintering population estimate was produced following the approach taken by Musgrove *et al.* (2011), also later cited in Musgrove *et al.* (2013) but was updated to the years 2008/09 to 2011/12 to coincide with most recent winter atlas period of WA2010[7]. It was noted that this value represented an estimate of the number of birds present at the start of the wintering period. A similar approach was used here in order to derive a wintering population estimate for Scotland.

2.5.3 SEPA river basin planning regions (breeding and wintering)

For all species, the SEPA river basin planning regional population estimates were carried out in the same way – the Scottish population estimate was multiplied by the proportion of relative abundance estimated to occur in each of these regions using *BA2010* and *WA2010* (see section 2.3.2.for explanation). Confidence limits presented for the regional population estimates are approximate. Precise values are not possible owing to a lack of knowledge of the covariance of two factors: the confidence limits around the Scottish population estimates; and the confidence limits around the proportion of the Scottish population present within each SEPA region.

[7] This entailed first calculating a 4-year average (2008–11) breeding population estimate of 11,502 pairs. In order to calculate the wintering estimate the following calculation was then applied: At the start of the winter it was assumed there would be a total of 23,004 breeding adults (11,502 × 2) + 23,004 fledged young (assuming productivity of 2 per pair) and 7,131 (23,004 × 0.31) 1-yr old non-breeders that had survived this long to give a total of 53,139 individuals. Estimates of survival and breeding success used were based on expert opinion of the APEP.

2.6 Red-breasted merganser species account

2.6.1 Current breeding status

Scottish breeding population estimate = 1432 (1252, 1612)
British breeding population estimate =1565 (1373, 1754)

Of the total British breeding population of red-breasted mergansers, 84% of the overall breeding range and, based on the distribution of relative abundance measures, 92% (CLs =88.5-94.0%) of the population is estimated to occur in Scotland (Table 1).

Table 1. Distribution (a) and relative abundance (b) information for red-breasted merganser in SEPA regions and Scotland in breeding seasons 2008–11. Numbers of hectads with only presence are excluded from the breeding range size and percentage figures. For the "% contribution" columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland.

(a)

a) **Region**	**Distribution**						
	Number of occupied hectads						
	Present	**Possible breeding**	**Probable breeding**	**Confirmed breeding**	**Breeding range size**	**% of region occupied**	**% contribution to parent region**
North East Scotland	**15**	**4**	**8**	**7**	**19**	**17**	**4**
Tay	**17**	**8**	**17**	**5**	**30**	**32**	**7**
Forth	**27**	**0**	**5**	**2**	**7**	**12**	**2**
Tweed	0	1	0	0	1	2	0
Solway	10	4	5	4	13	15	3
Clyde	5	6	17	16	39	41	9
Argyll	7	15	53	39	107	70	24
West Highland	18	15	45	51	111	54	25
North Highland	15	16	40	19	75	46	17
Orkney and Shetland	10	7	21	19	47	50	10
Scotland	**124**	**76**	**211**	**162**	**449**	**41**	**84**

b)

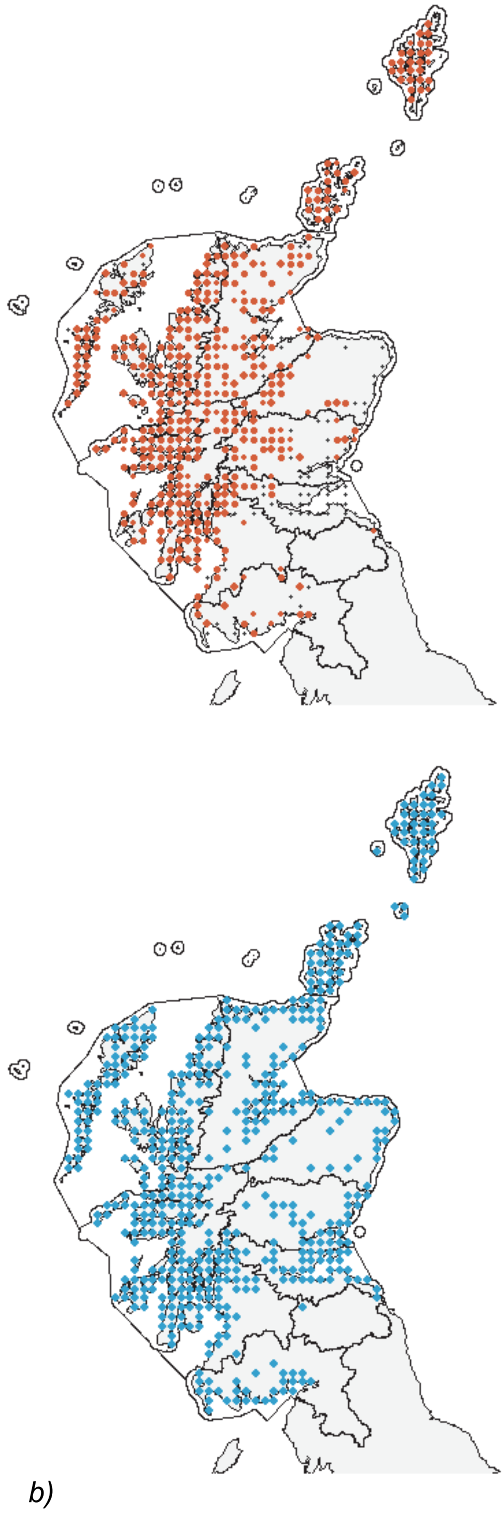
Region	**Relative abundance**	
	% contribution to parent region	**95% confidence limits**
North East Scotland	**0.6**	**0.3, 1.0**
Tay	**3.3**	**2.1, 4.2**
Forth	**0.6**	**0.2, 1.2**
Tweed	0.0	0.0, 0.0
Solway	4.1	0.5, 8.3
Clyde	9.4	6.7, 13.3
Argyll	30.6	24.0, 35.9
West Highland	24.8	21.3, 29.2
North Highland	15.8	10.9, 20.7

Orkney and Shetland	10.2	8.0, 13.4
Scotland	**92**	**88.5, 94.0**

The current distribution of breeding red-breasted mergansers in Scotland is noticeably concentrated in the west (Figure 2a). This may partially reflect habitat preference since breeding red-breasted mergansers in Scotland are predominantly located on sheltered sea lochs and estuaries – although some will nest on the lower reaches of rivers and large meso-trophic freshwater lochs and reservoirs (Marquiss, 2007a). In terms of SEPA regions, the following support approximately 80% of the Scottish range (in decreasing order of importance: West Highland, Argyll, North Highland and, Clyde (See Table 1a). The SEPA region of the Tweed is of note as there is an apparent lack of breeding red-breasted mergansers. A very similar pattern is evident for relative abundance and, consequently, the population estimates for the SEPA regions (Table 1 Table 2).

Table 2. Current breeding population estimates (number of breeding pairs) with lower and upper confidence limits for red-breasted merganser for the SEPA planning regions, Scotland and Britain (see section 2.5.1 for more details on how were derived). Figures given can only be regarded as minima. Dates of estimates are 2008-2011; Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	**Number of breeding pairs**
North East Scotland	8 (3,14)
Tay	47 (31,62)
Forth	8 (1,15)
Tweed	0 (0,0)
Solway	58 (2,114)
Clyde	134 (84,184)
Argyll	438 (336,540)
West Highland	355 (283,427)
North Highland	225 (150,301)
Orkney and Shetland	146 (103,188)
Scotland	**1432 (1252,1612)**
Britain	**1565 (1373,1754)**



a)

b)

Figure 2. Distribution maps for breeding (a) and wintering (b) red-breasted merganser in Scotland for the SEPA river basin planning regions (data truncated at the Scottish border). On breeding-season maps, orange dots show the breeding range, with increasing dot size indicating increasing evidence of breeding. Black dots show hectads where birds were recorded during the breeding season but no evidence of breeding was noted

2.6.2 Breeding population trends

Red-breasted mergansers are thought to have colonised Britain at some point during the Neolithic period. During the first half of the nineteenth century they were found in northern and central Scotland, their most southern limit reaching Loch Awe, Argyll. They continued to expand their range throughout the Scottish mainland into the latter half of the nineteenth century (Holloway, 1996). Based on comparisons between *BA1970* and *BA2010* (Table 18 in Section 11), the red-breasted merganser has undergone a statistically significant breeding range contraction throughout Scotland and these losses have been particularly evident in SEPA regions of the Forth, Solway, West Highland and North Highland. More recent losses in breeding ranges have become apparent in the Tay and Argyll regions between *BA1990* and *BA2010*. In terms of changes in relative abundance between *BA1990* and *BA2010*, statistically significant losses are shown for Scotland as a whole of -24.1% (CLs = -33.7, 14.4%) and the SEPA regions of North East Scotland, Tay, Solway, and North Highland (Table 18 in Section 11).

2.6.3 Current wintering status

Scottish wintering population estimate = 6261 (5926, 6541)
British wintering population estimate = 8440 (no CLs)

Of the total British wintering population 55% of the overall range and, based on the distribution of relative abundance measures, 74% (CLs = 70.0–77.5%) of the population is estimated to occur in Scotland (Table 3). During the winter period, migrants, notably breeders from Iceland, join the resident Scottish population (Toms, 2002) and this is reflected in a higher wintering population estimate compared with the breeding one (Tables 4 and 2 respectively).

Table 3. Distribution and relative abundance information for red-breasted merganser in SEPA regions and Scotland in winters 2007/08–2010/11. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland.

	Distribution			Relative abundance	
Region	**Winter range size**	**% of region occupied**	**% contribution to parent region**	**% contribution to parent region**	**95% confidence limits**
North East Scotland	30	28	5	1.6	1.2, 2.3
Tay	32	34	6	1.6	1.0, 2.3
Forth	35	59	6	4.6	3.1, 5.9
Tweed	2	4	0	0.1	0.0, 0.1
Solway	29	33	5	2.2	1.5, 3.1
Clyde	48	50	9	6.7	4.9, 8.2
Argyll	108	71	20	21.5	18.3, 24.0
West Highland	123	60	22	28.7	25.2, 31.8
North Highland	71	44	13	5.8	4.0, 7.3
Orkney and Shetland	71	76	13	27.3	21.8, 32.9
Scotland	**549**	**50**	**55**	**74**	**70.0, 77.5**

Table 4. Current wintering population estimates (number of individual birds) with lower and upper confidence limits for red-breasted merganser for the SEPA planning regions, Scotland and Britain (see section 2.5.2 for more details). Dates of estimates are 2004/2005-2008/209 Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	**Number of individual birds**
North East Scotland	101 (66,136)
Tay	99 (59,139)
Forth	287 (200,374)
Tweed	3 (0,7)
Solway	138 (87,188)
Clyde	419 (316,521)
Argyll	1348 (1158,1538)
West Highland	1795 (1570,2021)
North Highland	364 (261,467)
Orkney and Shetland	1708 (1351,2064)
Scotland	**6261 (5926,6541)**
Britain	**8440 (no CLs))**

As for the breeding population, the current distribution of wintering red-breasted merganser in Scotland tends to be located more to the west of the country although there are records along the whole of the eastern coast (Figure 2b). With respect to the SEPA regions, the following support over three quarters of the Scottish range: Argyll, West Highland and to a lesser extent, North Highland and Orkney & Shetland (Table 3). With the exception of North Highland, the same regions are also important for relative abundance and, hence, population estimates (Tables 3 and Table 4).

2.6.4 Wintering population trends

Wintering red-breasted mergansers do not appear to have significantly changed their Scottish long-term range (based on changes between *WA1980* and *WA2010*) (Table 18 in Section 11) although there is an apparent significant range expansion shown for the SEPA region of West Highland.

Long-term annual wintering population trends for Scotland have shown fluctuations in numbers since the mid-1960s, reaching a peak in the mid-1990s followed by a period of decline - see Figure 3. This pattern is broadly similar to that observed for Britain although the numbers are only just higher than when records began and the changes have been slightly less variable (Austin *et al.,* 2014).

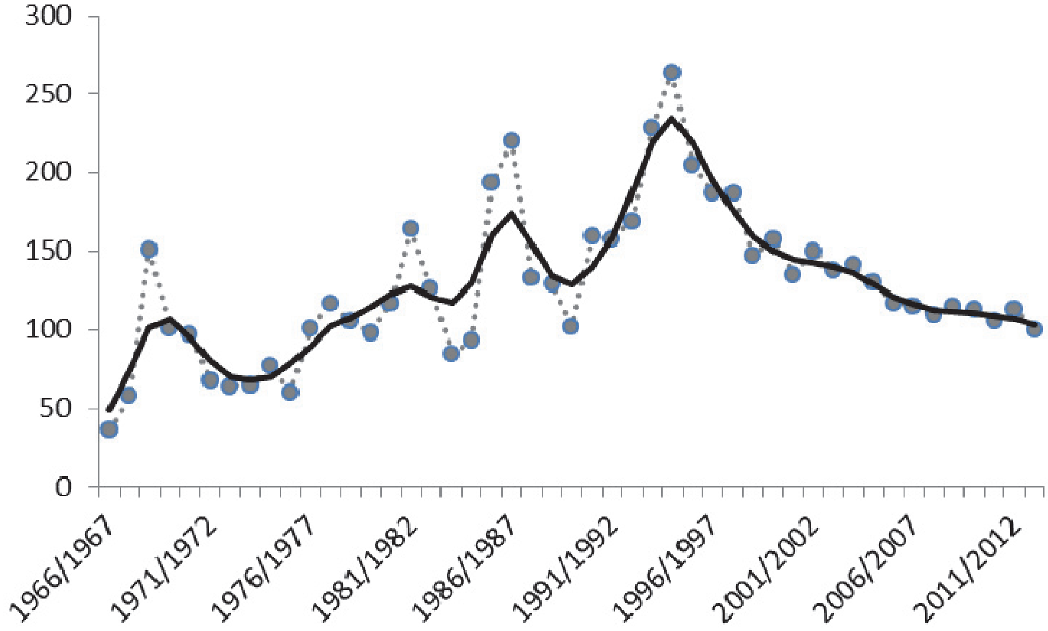


Figure 3. Annual indices and trend for red-breasted merganser in Scotland over the time period of winter 1966/1967 to the winter of 2012/2013 based on WeBS data (solid line = index; dotted line = smoothed trend).

2.7 Goosander species account

2.7.1 Current breeding status

Scottish breeding population estimate = 1991 (1751, 2232)
British breeding population estimate = 3455 (3070, 3804)

Fifty-one per cent of the British breeding range and, based on the distribution of relative abundance measures, 58% (CLs =54.0–61.0%) of the population is estimated to occur in Scotland (5).

Table 5. Distribution (a) and relative abundance (b) information for goosander in SEPA regions and Scotland in breeding seasons 2008–11. Numbers of hectads with only presence are excluded from the breeding range size and percentage figures. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland

a)

Region	Distribution						
	Number of occupied hectads						
	Present	Possible breeding	Probable breeding	Confirmed breeding	Breeding range size	% of region occupied	% contribution to parent region
North East Scotland	15	16	19	17	52	48	12
Tay	11	14	23	21	58	61	13
Forth	16	4	15	18	37	63	8
Tweed	1	10	8	21	39	87	9
Solway	11	15	8	20	43	49	10
Clyde	4	11	26	20	57	59	13
Argyll	13	16	21	13	50	33	11
West Highland	17	7	16	8	31	15	7
North Highland	12	24	30	20	74	45	17
Orkney and Shetland	19	0	0	0	0	0	0
Scotland	**119**	**117**	**166**	**158**	**441**	**40**	**51**

b)

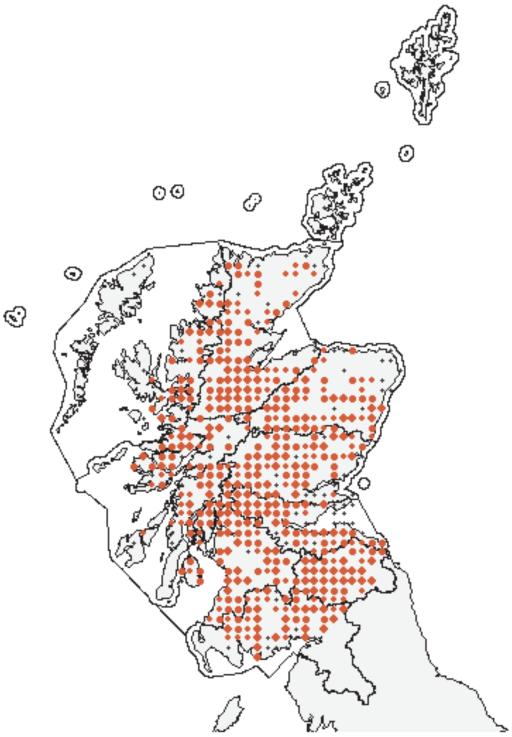
Region	*Relative abundance*	
	% contribution to parent region	***95% confidence limits***
North East Scotland	12.7	*9.4, 16.3*
Tay	15.8	*12.0, 19.6*
Forth	8.4	*5.6, 10.8*
Tweed	10.0	*6.6, 13.0*
Solway	11.1	*8.3, 13.8*
Clyde	13.0	*10.0, 16.1*
Argyll	10.0	*8.1, 12.2*
West Highland	3.2	*2.3, 4.3*

North Highland	15.5	*11.4, 18.9*
Orkney and Shetland	0.0	*0.0, 0.0*
Scotland	**58**	***54.0, 61.0***

The current distribution of breeding goosanders in Scotland is relatively uniformly spread across the country but with a notable absence from Orkney and Shetland and some of the western islands (Figure 3a). Goosanders tend to show much more preference for running water and nesting in the upper reaches of rivers, often close to tributary streams (Marquiss, 2007b), than red-breasted mergansers do. This distribution is reflected in the SEPA regions, with the exception of Orkney and Shetland, the Scottish breeding range is relatively equally spread across all of the other nine regions (Table 5) although values for the Forth, Tweed and West Highland are slightly lower. A very similar pattern is evident for relative abundance and hence the population estimates for the SEPA regions (Table 5 and Table 6) although the importance of West Highland appears to diminish further.

Table 6 Current breeding population estimates (number of breeding pairs) with lower and upper confidence limits for goosander for the SEPA planning regions, Scotland and Britain (see section 2.5.1 for more details on how these were derived). Figures given can only be regarded as minima. Date of the estimates is 2009. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	**Number of breeding pairs**
North East Scotland	252 (176,327)
Tay	314 (229,399)
Forth	166 (111,222)
Tweed	199 (131,268)
Solway	220 (159,280)
Clyde	259 (190,328)
Argyll	199 (151,247)
West Highland	64 (42,85)
North Highland	308 (225,391)
Orkney and Shetland	0 (0,0)
Scotland	**1991 (1751,2232)**
Britain	**3455 (3070,3804)**



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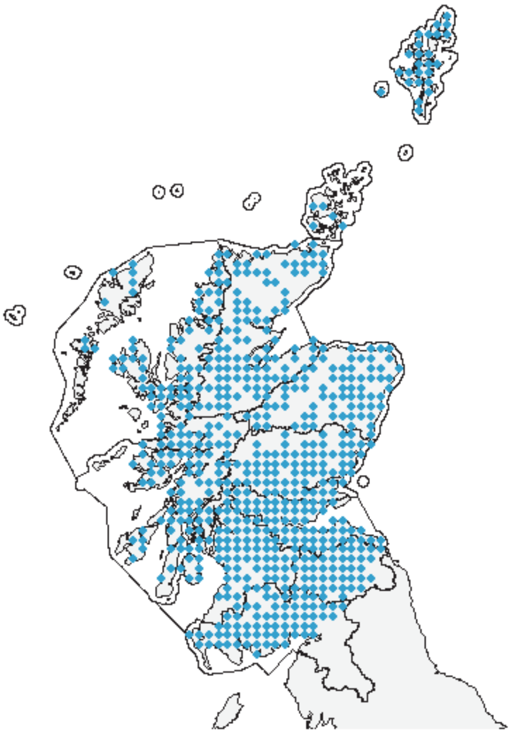


b)

Figure 4 Distribution maps for breeding (a) and wintering (b) goosander in Scotland for the SEPA river basin planning regions (data truncated at the Scottish border). On breeding-season maps, orange dots show the breeding range, with increasing dot size indicating increasing evidence of breeding. Black dots show hectads where birds were recorded during the breeding season but no evidence of breeding was noted.

2.7.2 Breeding population trends

The goosander was first confirmed as breeding in Britain in 1871 in Perthshire and Argyll (Holloway, 1996). In the nineteenth century, it was documented in Argyll, the north-west Highlands, the Moray Basin and Tay and by the early part of the twentieth, goosanders had spread slowly south into Aberdeenshire and Dumfriesshire (Armitage *et al.,* 1997). Based on comparisons between *BA1970* and *BA2010,* goosanders have shown a significant breeding range expansion for the whole of Scotland and this has also been observed for a number of the SEPA regions: Tay, Forth, Tweed, Clyde and North Highland (Table 19 in Section 11).

In terms of relative abundance, there was a suggestion of a decrease for Scotland between *BA1990* and *BA2010* but this was not statistically significantly (Table 19 in Section 11). Among the regions Forth showed a statistically significant increase in abundance and Solway a statistically significant decrease. Scottish breeding males are known to moult in northern Scandinavia over the period of June to October but will eventually return to spend the winter here (Marquiss 2007b); Little & Marchant, 2002).

2.7.3 Current wintering status

Scottish wintering population estimate = 5296 (4899, 5658)
British wintering population estimate = 11870 (no CLs)

Of the total British wintering population 34% of the overall range and, based on the distribution of relative abundance measures, 45% (CLs = 41.5–47.5%) of the population is estimated to occur in Scotland (Table 19). During the winter period, birds breeding in north-east Europe arrive into Britain - notably into southern England (Little & Marchant, 2002). This western movement of birds is also likely to account for the higher Scottish wintering population estimate compared with the breeding one (Table 8 and 6 respectively).

The current distribution of wintering goosander in Scotland, as for the breeding population is fairly equally spread across the country (Figure 3b). This is also reflected by the SEPA regions, with the breeding range being fairly even spread although Forth, Tweed and Orkney & Shetland have lower percentages. More differences are apparent with respect to the relative abundance and population estimates with the Solway supporting nearly a quarter of the overall population (Tables 7 and Table 8).

Table 7. Distribution and relative abundance information for goosander in SEPA regions and Scotland in winters 2007/08–2010/11. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland.

	Distribution			Relative abundance	
Region	**Winter range size**	**% of region occupied**	**% contribution to parent region**	**% contribution to parent region**	**95% confidence limits**
North East Scotland	71	65	11	13.3	10.8, 16.0
Tay	69	73	11	13.5	10.1, 17.3
Forth	51	86	8	7.9	5.5, 10.1
Tweed	42	93	7	8.2	5.8, 10.6
Solway	65	74	10	23.9	17.1, 31.1
Clyde	71	74	11	16.9	13.0, 21.1
Argyll	74	48	12	4.6	3.5, 5.5
West Highland	64	31	10	3.2	2.4, 3.8
North Highland	93	57	15	8.2	6.4, 10.0
Orkney and Shetland	30	32	5	0.2	0.1, 0.4
Scotland	**630**	**57**	**34**	**45**	**41.5, 47.5**

Table 8. Current wintering population estimates (number of individual birds) with lower and upper confidence limits for goosander for the SEPA planning regions, Scotland and Britain (see section 2.5.2 for more details). Dates of estimates are 2004/2005-2008/2009. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	Number of individual birds
North East Scotland	706 (559,852)
Tay	716 (517,914)
Forth	417 (291,542)
Tweed	436 (306,566)
Solway	1267 (885,1649)
Clyde	893 (669,1116)
Argyll	242 (188,296)
West Highland	167 (129,206)
North Highland	433 (333,533)
Orkney and Shetland	10 (0,20)
Scotland	**5296 (4899,5658)**
Britain	**11870 (no CLs)**

2.7.4 Wintering population trends

The wintering goosander population has undergone large and significant range expansions for the whole of Scotland and for most of the SEPA regions based on changes between *WA1980* and *WA2010* (Table 19 in Section 11).

Long-term annual population trends for Scotland have also shown fluctuations in numbers since the 1960s with a peak occurring in the mid-1980s - see Figure 5. Similarly numbers at the UK level have been variable but the peak occurred in the mid-1990s and has been followed by a period of decline as observed for the red-breasted merganser (Austin *et al.*, 2014).

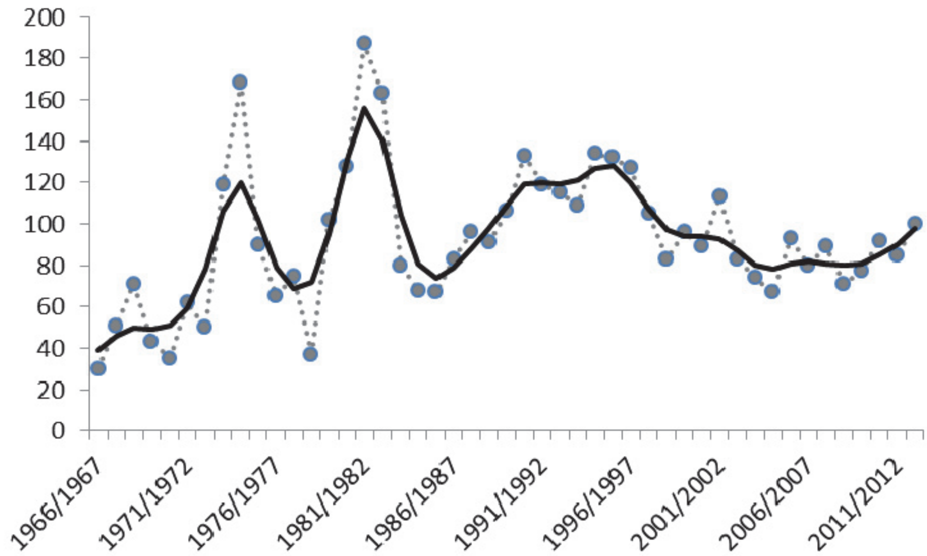


Figure 5. Annual indices and trend for goosander in Scotland over the time period of winter 1966/1967 to the winter of 2012/2013 based on WeBS data (solid line = index; dotted line = smoothed trend).

2.8 Cormorant species account

2.8.1 Current breeding status

Scottish breeding population estimate = 3626 (no CLs)
British breeding population estimate = 8355 (no CLs)

Twenty-four per cent of the British breeding range and, based on the distribution of relative abundance measures, 24% (CLs = 18.0–29.0%) of the population is estimated to occur in Scotland (Table 9).

Table 9. Distribution (a) and relative abundance (b) information for cormorant in SEPA regions and Scotland in breeding seasons 2008–11. Numbers of hectads with only presence are excluded from the breeding range size and percentage figures. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland

a)

Region	Distribution						
	Number of occupied hectads						
	Present	**Possible breeding**	**Probable breeding**	**Confirmed breeding**	**Breeding range size**	**% of region occupied**	**% contribution to parent region**
North East Scotland	29	0	0	9	9	8	7
Tay	42	0	0	3	3	3	2
Forth	46	2	1	4	7	12	5
Tweed	16	0	0	1	1	2	1
Solway	26	11	1	19	31	35	24
Clyde	53	4	2	5	11	11	9
Argyll	100	6	2	8	16	10	12
West Highland	105	12	0	14	26	13	20
North Highland	68	4	0	5	9	6	7
Orkney and Shetland	44	4	0	12	16	17	12
Scotland	**529**	**43**	**6**	**80**	**129**	**12**	**24**

b)

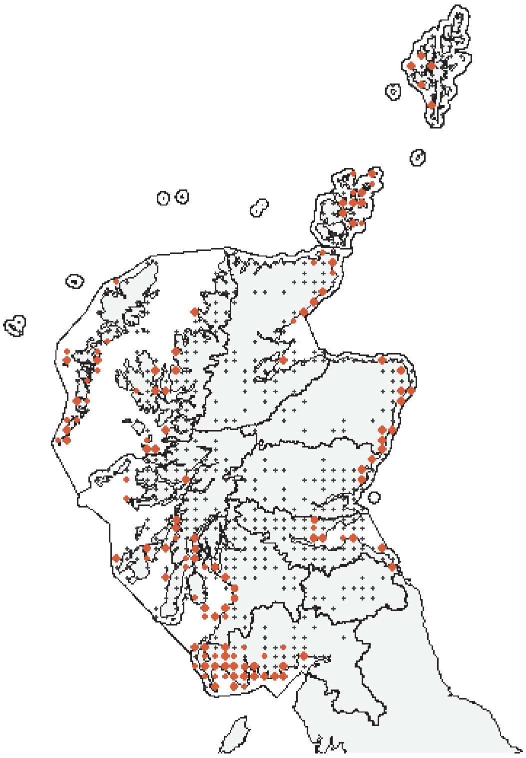
Region	Relative abundance	
	% contribution to parent region	**95% confidence limits**
North East Scotland	11.8	4.6, 17.5
Tay	3.0	1.1, 4.7
Forth	18.4	3.0, 34.0
Tweed	0.5	0.1, 0.9
Solway	38.5	24.0, 50.4
Clyde	4.9	2.3, 10.4
Argyll	1.8	0.9, 3.0
West Highland	8.6	6.5, 11.9
North Highland	5.6	1.7, 9.6
Orkney and Shetland	5.8	3.3, 9.0
Scotland	**24**	**18.0, 29.0**

At one time, cormorants were regarded as being an exclusively coastal breeder in Scotland – based on the definition of breeding within 5 km of the mean high water mark (Carss, 2007). The current breeding distribution of cormorant in Scotland is still associated with coastal areas but there is more evidence of inland breeding in Dumfries and Galloway. There are also numerous records of presence for inland regions across Scotland. These are important as they indicate areas with additional potential predation pressure which are not reflected in the breeding population estimates (Figure 4a). In terms of the SEPA regions, the highest percentage of Scottish breeding range occurs in the Solway and West Highland (Table 9) and the lowest in the Tay, Forth and the Tweed (all ≤ 5%). A broadly similar pattern was shown for relative abundance and the population estimates for the SEPA regions, although West Highland was of lower importance (Tables 9 and Table 10).

Table 10. Current breeding population estimates (number of breeding pairs) with lower and upper confidence limits for cormorant for the SEPA planning regions, Scotland and Britain (see section 2.5.1 for more details on how were derived). Dates of estimates 1998-2002. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	Number of breeding pairs
North East Scotland	429 (195,662)
Tay	109 (45,173)
Forth	666 (104,1228)
Tweed	16 (1,31)
Solway	1394 (916,1872)
Clyde	179 (32,326)
Argyll	64 (26,101)
West Highland	313 (215,411)
North Highland	202 (61,344)
Orkney and Shetland	210 (107,313)
Scotland	**3626 (3626,3626)***
Britain	**8355 (no CLS)***

* based on absolute count



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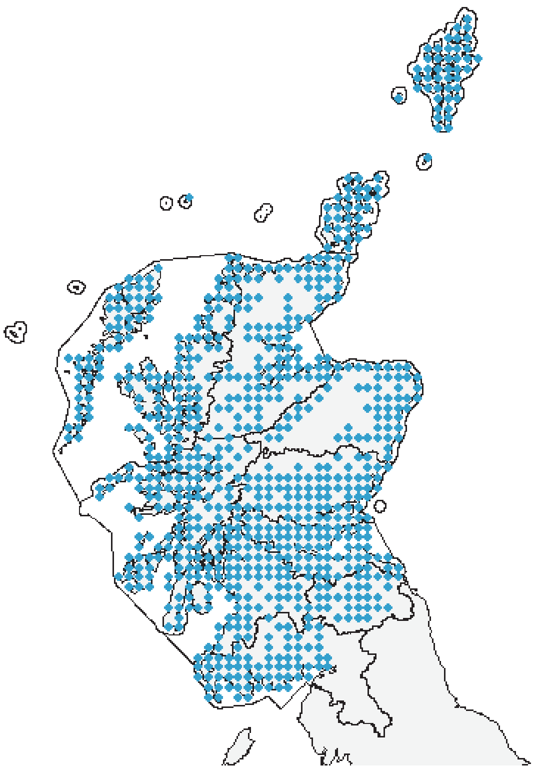


b)

Figure 6. Distribution maps for breeding (a) and wintering (b) cormorant in Scotland for the SEPA river basin planning regions (data truncated at the Scottish border). On breeding-season maps, orange dots show the breeding range, with increasing dot size indicating increasing evidence of breeding. Black dots show hectads where birds were recorded during the breeding season but no evidence of breeding was noted.

2.8.2 Breeding population trends

Based on comparisons between *BA1970* and *BA2010,* the breeding population of cormorants has shown a significant range contraction for the whole of Scotland and in a number of SEPA regions: Arygll, West Highland and North Highland. The recent colonisation of North East Scotland is noteworthy however, albeit based on a small number of hectads (Table 20 in Section 11). Significant declines in abundance were noted for Scotland as a whole and for the regions of Forth, Clyde, Argyll, West Highland and North Highland (Table 20 in Section 11).

For Scotland as a whole there was no evidence that there had been a significant change in relative abundance between *BA1990* and *BA2010.* There was a significant increase in relative abundance for North East Scotland, and significant decreases in Solway and West Highland.

2.8.3 Current wintering status

Scottish wintering population estimate = 8232 (7319, 9122)
British wintering population estimate = 35415 (35415, 35415)

Of the total British wintering population 34% of the overall range and, based on the distribution of relative abundance measures, 23% (CL = 21.0–26.0%) of the population is estimated to occur in Scotland (Table 11).

The current distribution of wintering cormorant in Scotland is relatively evenly spread although there are gaps for inland north-eastern and northern parts of the country (see Figure 4b). This is broadly confirmed by the breeding range, abundances and population estimates for the SEPA regions - although the Tweed is notably lower compared with the other regions with respect to the latter two parameters. This may reflect the lack of nearby adjacent coastline (Tables 11and Table 12).

Table 11 Distribution and relative abundance information for cormorant in SEPA regions and Scotland in winters 2007/08–2010/11. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland.

	Distribution			Relative abundance	
Region	**Winter range size**	**% of region occupied**	**% contribution to parent region**	**% contribution to parent region**	**95% confidence limits**
North East Scotland	55	50	7	8.6	5.7, 11.2
Tay	72	76	9	10.4	8.6, 12.7
Forth	58	98	7	10.2	7.6, 12.7
Tweed	32	71	4	1.5	1.0, 2.1
Solway	67	76	8	13.6	11.2, 16.2
Clyde	77	80	10	15.3	11.3, 19.5
Argyll	116	76	15	11.9	10.1, 13.5
West Highland	135	66	17	11.0	8.7, 13.1
North Highland	106	65	13	8.1	6.8, 9.5
Orkney and Shetland	75	80	9	9.1	6.4, 11.8
Scotland	**793**	**72**	**34**	**23**	**21.0, 26.0**

Table 12 Current wintering population estimates (number of individual birds) with lower and upper confidence limits for piscivorous birds for the SEPA planning regions, Scotland and Britain (see section 2.5.2 for more details). Dates of estimates are 2004/2005-2008/2009. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	Number of individual birds
North East Scotland	709 (470,948)
Tay	859 (668,1050)
Forth	840 (612,1067)
Tweed	122 (73,170)
Solway	1116 (876,1356)
Clyde	1256 (892,1619)
Argyll	978 (803,1152)
West Highland	908 (701,1115)
North Highland	664 (531,797)
Orkney and Shetland	750 (514,985)
Scotland	**8232 (7319,9122)**
Britain	**35415 (35415,35415)**

2.8.4 Wintering population trends

The wintering cormorant population has undergone large and significant range expansions for the whole of Scotland and for most of the SEPA regions based on changes between *WA1980* and *WA2010* (Table 20 in Section 11).

Annual wintering population trends for Scotland showed increases over the period from the late 1980s, when records began, to the early 1990s but this was followed by a gradual decline until the present day. The most recent numbers are similar to those reported when recording first began (see Figure 7). This is in contrast to the whole of Britain which has shown steady increases over the same period although the trends appeared to have levelled off since the mid-2000s (Austin *et al.,* 2014). Although the English inland breeding cormorant population was established and initially colonised by birds belonging to the continental race *P. carbo sinensis*, it is apparent that these inland colonies are now made up of both races (Newson *et al.,* 2013).

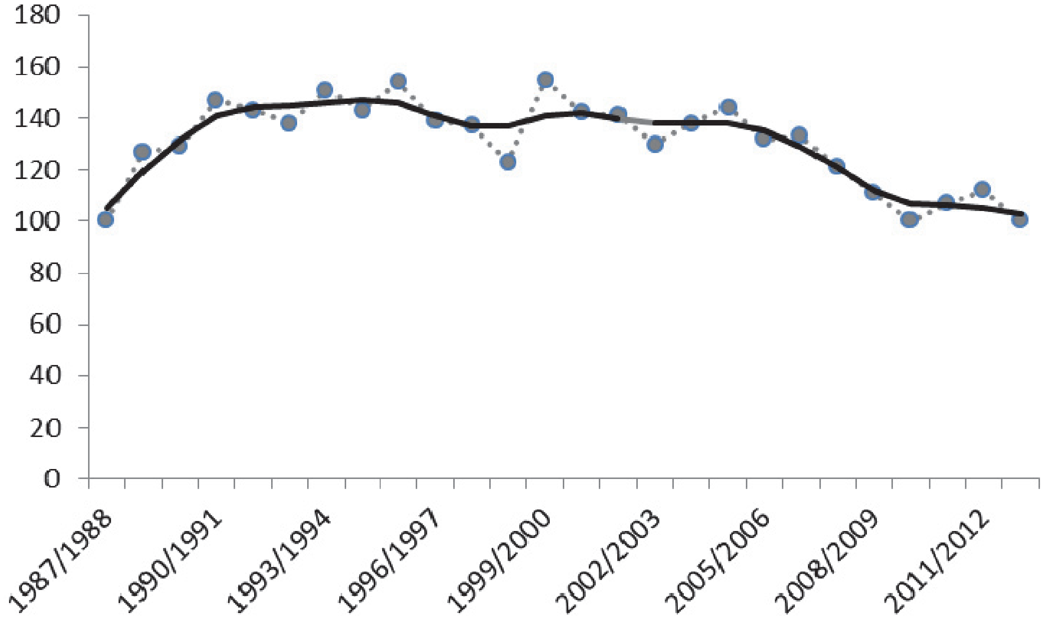


Figure 7. Annual indices and trend for cormorant in Scotland over the time period of winter 1987/1888 to the winter of 2012/2013 based on WeBS data (solid line = index; dotted line = smoothed trend

2.9 Grey heron species account

2.9.1 Current breeding status

Scottish breeding population estimate = 4029 (3182, 4843)
British breeding population estimate = 11502 (11023, 12051)

Thirty-four per cent of the British breeding range and, based on the distribution of relative abundance measures, 31% (CLs = 30–32.0%) of the population is estimated to occur in Scotland (Table 13).

Table 14. Distribution (a) and relative abundance (b) information for grey heron in SEPA regions and Scotland in breeding seasons 2008–11. Numbers of hectads with only presence are excluded from the breeding range size and percentage figures. For the '% contribution' columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland

a)

Region	Distribution						
	Number of occupied hectads						
	Present	Possible breeding	Probable breeding	Confirmed breeding	Breeding range size	% of region occupied	% contribution to parent region
North East Scotland	21	36	4	38	78	72	12
Tay	28	29	4	26	59	62	9
Forth	6	26	4	23	53	90	8
Tweed	3	17	7	17	41	91	6
Solway	26	26	9	21	56	64	8
Clyde	9	31	9	42	82	85	12
Argyll	35	50	16	38	104	68	16
West Highland	57	47	4	43	94	46	14
North Highland	44	71	6	22	99	61	15
Orkney and Shetland	46	0	0	0	0	0	0
Scotland	**275**	**333**	**63**	**270**	**666**	**60**	**34**

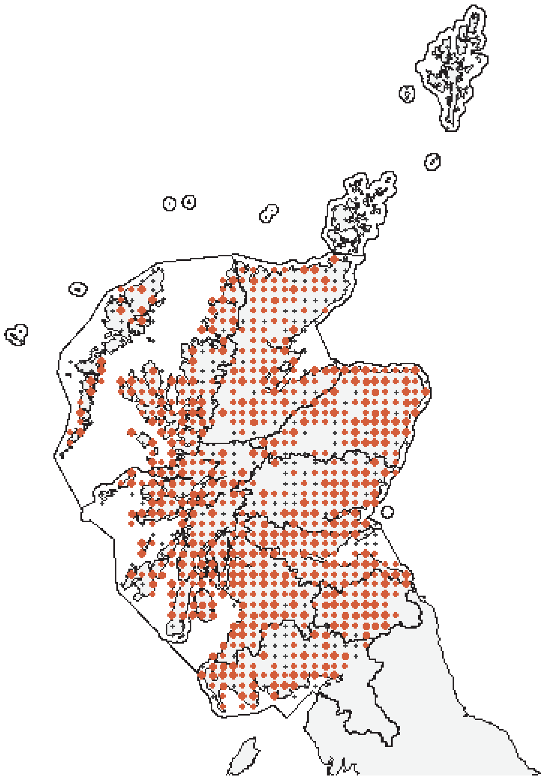
b)

Region	Relative abundance	
	% contribution to parent region	95% confidence limits
North East Scotland	9.3	8.3, 10.2
Tay	8.3	7.2, 9.3
Forth	7.8	6.5, 8.9
Tweed	7.0	5.9, 8.7
Solway	9.9	8.8, 11.0
Clyde	14.9	13.6, 16.5
Argyll	16.3	15.3, 17.9
West Highland	12.3	10.8, 13.9
North Highland	14.0	12.4, 15.6
Orkney and Shetland	0.0	0.0, 0.0
Scotland	**31**	**30.0, 32.0**

The current breeding distribution of grey heron in Scotland shows a fairly uniform spread across the country with the notable exceptions of Orkney and Shetland (there have been no breeding records since 2005 according to BTO Heronries Census data). There are also notable small gaps for the extensive mountain regions, e.g. Cairngorms (Figure 8). There are, however, a reasonable number of presence records for Orkney and Shetland which indicate the strong likelihood of piscivorous predation in these areas, despite the apparent lack of breeding birds. The same patterns are also evident for the SEPA regions with respect to the breeding range, relative abundance and population estimates (Table 14 and Table 15).

Table 15. Current breeding population estimates (number of breeding pairs) with lower and upper confidence limits for grey heron for the SEPA planning regions, Scotland and Britain (see section 2.5.1 for more details on how these were derived). Date of estimates 1998-2002. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	**Number of breeding pairs**
North East Scotland	374 (288,460)
Tay	333 (253,413)
Forth	313 (233,393)
Tweed	282 (201,363)
Solway	399 (306,492)
Clyde	599 (463,736)
Argyll	656 (511,801)
West Highland	493 (374,612)
North Highland	563 (430,697)
Orkney and Shetland	0 (0,0)
Scotland	**4029 (3182,4843)**
Britain	**11502 (11023,12051)**



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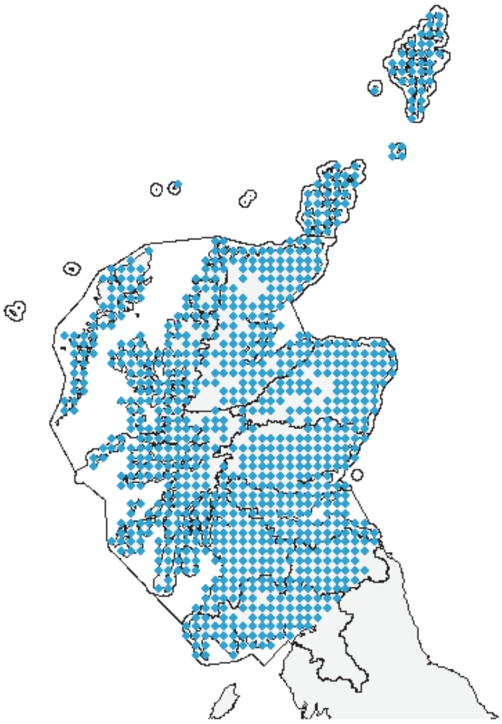

b)

Figure 8. Distribution maps for breeding (a) and wintering (b) grey heron in Scotland for the SEPA river basin planning regions (data truncated at the Scottish border). On breeding-season maps, orange dots show the breeding range, with increasing dot size indicating increasing evidence of breeding. Black dots show hectads where birds were recorded during the breeding season but no evidence of breeding was noted.

2.9.2 Breeding population trends

Based on comparisons between *BA1970* and *BA2010,* the breeding population has shown a range contraction for the whole of Scotland and in a number of SEPA regions: Tay, Argyll, West Highland and Orkney & Shetland (Table 21 in Section 11). There was an increase in one SEPA region (the Forth), however, over the same timescale. More recent declines have also become apparent for the Solway and North Highland between *BA1990* and *BA2010* (Table 21 in Section 11). There was, however, range expansion in six regions during the earlier period of *BA1970–BA1990* and this resulted in an overall increase for Scotland (Table 21 in Section 11). Therefore the long-term trend of a range contraction could indicate major losses during the period *BA1990–-BA2010*. Problems with gaining a clear pattern for grey heron trends based on Atlas data may be related to issues outlined under section 2.3.3.

Despite clear fluctuations in the annual Scottish breeding population since the 1930s, the long-term trend based on the Heronries Census appears to be that of a relatively stable one despite wide confidence limits (Figure 9).

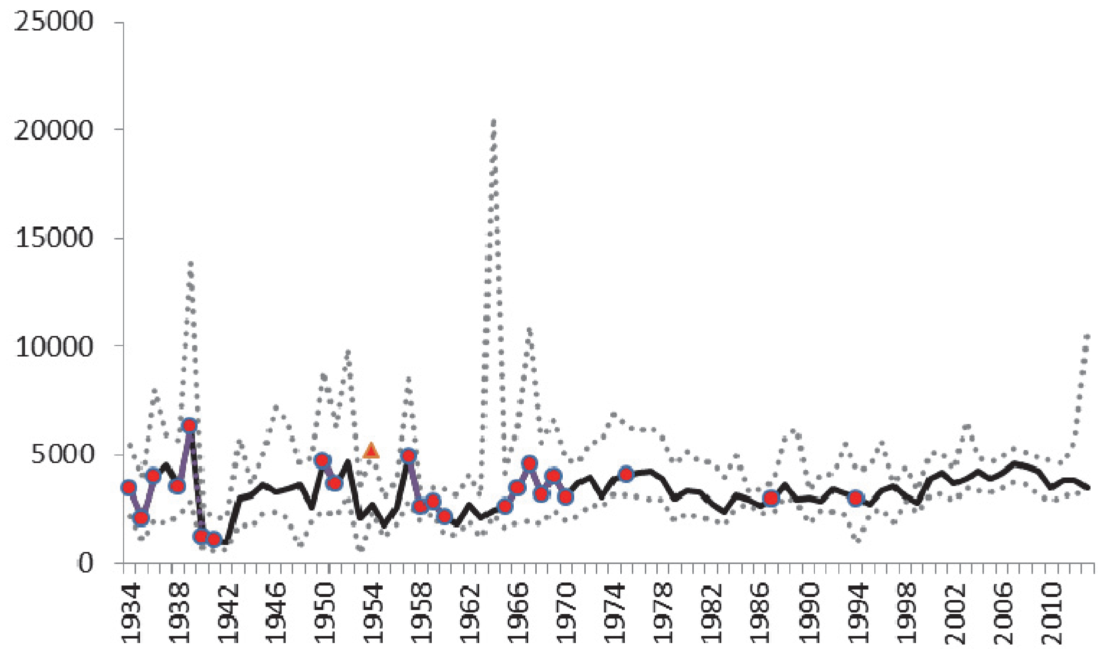

Figure 9. Total number of estimated breeding pairs of grey heron In Scotland (black line) with upper and lower confidence limits =grey dotted lines). Values that have been generated by interpolation are shown in red (see section 3.4.2).

This is in contrast with overall UK trends which suggest an increase, with the species being more abundant in the early 2000s than at any time in the last 80 years. Fluctuations in the population trends appear to be largely due to the effects of harsh winters which result in high mortality for the heron (Besbeas *et al.,* 2002). The long-term increase is thought to be a result of reduced persecution, improvements in water quality, the provision of new habitat as new lakes and gravel pits mature, and increased feeding opportunities at freshwater fisheries (Gibbons *et al.,* 1993, Marchant *et al.,* 2004). The Scottish BBS trend from 1994 for the heron appears to be broadly similar to that shown by the Heronries Census.

2.9.3 Current wintering status

Of the total British wintering population 36% of the overall range and, based on the distribution of relative abundance measures, 23% (21.0–26.0%) of the population is estimated to occur in Scotland. During the winter period, birds breeding in north-east Europe (notably Norway but also from Denmark, the Netherlands and Sweden) arrive into Britain and the ringing recoveries appear to indicate that the British breeding population tends to be largely resident (Marquiss, 2002). This is likely to account for the higher Scottish wintering population estimate compared with the breeding one (Tables 16 and 15 respectively).

The current distribution of wintering grey herons in Scotland is relatively evenly spread – although the small gaps evident are similar to those observed during the breeding season (see Figure 8b). This is broadly confirmed by the wintering ranges, relative abundances and population estimates for the SEPA regions (Table 16, Table 17 & Table 21 in Section 11).

Table 16. Distribution and relative abundance information for grey heron in SEPA regions and Scotland in winters 2007/08–2010/11. For the "% contribution" columns the figures for SEPA regions indicate the percentage of the Scottish range (or overall abundance) found in each region. Similarly, figures for Scotland indicate the percentage of the Great Britain totals found in Scotland.

	Distribution			Relative abundance	
Region	**Winter range size**	**% of region occupied**	**% contribution to parent region**	**% contribution to parent region**	**95% confidence limits**
North East Scotland	90	83	10	7.7	6.8, 8.7
Tay	84	88	9	8.6	7.8, 9.4
Forth	59	100	6	6.3	5.5, 7.1
Tweed	44	98	5	5.2	4.6, 6.1
Solway	81	92	9	8.5	7.8, 9.5
Clyde	92	96	10	12.0	11.0, 13.0
Argyll	130	85	14	18.7	17.3, 20.4
West Highland	150	73	16	16.5	14.8, 17.8
North Highland	134	82	14	10.6	9.6, 11.8
Orkney and Shetland	73	78	8	5.6	4.5, 6.8
Scotland	**937**	**85**	**36**	**37**	**36.0, 38.0**

Table 17. Current wintering population estimates (number of individual birds) with lower and upper confidence limits for piscivorous birds for the SEPA planning regions, Scotland and Britain (see section 2.5.2 for more details). Dates of estimates are 2008/2009-2011/2012. Please see text for caveats associated with the use of these estimates in particular when this relates to uncertainty over their likely accuracy.

Scale	**Number of individual birds**
North East Scotland	1432 (1086,1779)
Tay	1607 (1241,1973)
Forth	1169 (889,1450)
Tweed	970 (729,1211)
Solway	1589 (1224,1954)
Clyde	2233 (1736,2730)
Argyll	3483 (2707,4258)
West Highland	3069 (2377,3761)
North Highland	1970 (1516,2423)
Orkney and Shetland	1049 (746,1352)
Scotland	**18613 (14700,22374)**
Britain	**53139 (50926,55675)**

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2.9.4 Wintering population trends

Scottish wintering population estimate = 18613 (14700, 22374)
British wintering population estimate = 53139 (50926, 55675)

The wintering grey heron population has undergone significant range expansion for the whole of Scotland and this appears to be largely driven by increases in North Highland based on changes between *WA1980* and *WA2010* (Table 21 in Section 11).

Annual wintering population trends are only available from the mid-1990s and show a steady increase in Scotland until the mid to late 2000s which was thereafter followed by a decline (Figure 10). In contrast, for the whole of Britain there has been very little variation in numbers (Austin *et al.,* 2014).

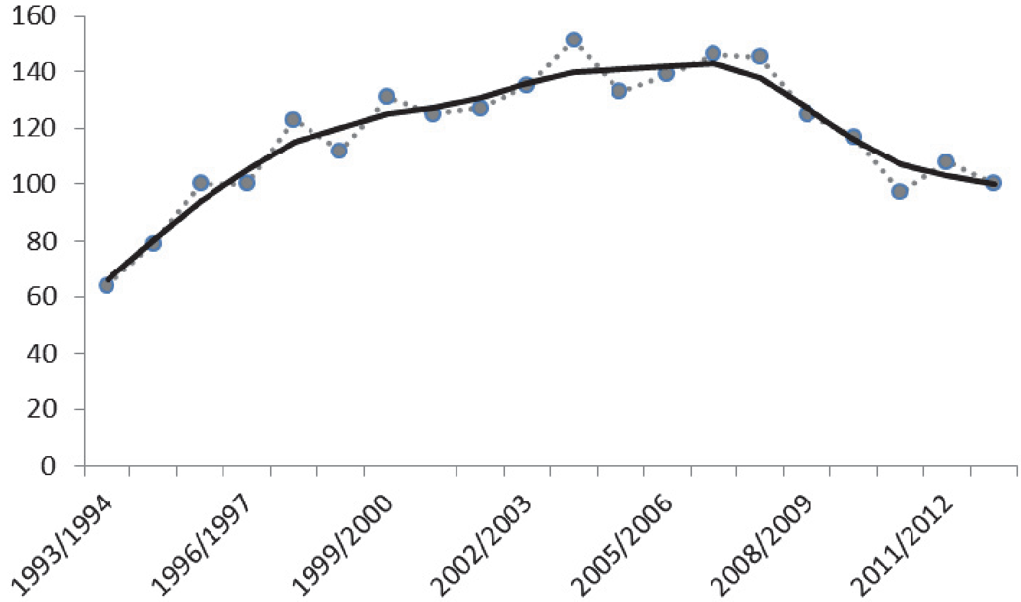

Figure 10. Annual indices and trend for grey heron in Scotland over the time period of winter 1993/1994 to the winter of 2012/2013 based on WeBS data (solid line = index; dotted line = smoothed trend).

3. STATUS OF SCOTLAND'S FRESHWATER FISHERIES – WITH A FOCUS ON ANADROMOUS SPECIES

This section only discusses population trends of fish species for which sufficient data are available. These are the anadromous species (those which spawn in fresh water but move out to sea where they will undergo most of their growth): Atlantic salmon and sea trout (brown trout).

3.1 Life cycles /histories – setting the context for identifying management for freshwater fisheries

Unless otherwise indicated, much of the following information relating to the life cycles and life histories of these salmonid populations has been adapted from information on Marine Scotland's webpages.

3.1.1 Atlantic salmon

Spawning occurs between November and December but in some localities, particularly in larger rivers, this may extend from October to late February. They show a preference for swift flowing rivers and streams. Eggs are laid by female fish in gravel depressions called 'redds'. As the eggs are released by the female, they are immediately fertilised by an accompanying adult male, and often by mature juvenile males (often referred to as 'precocious' parr). The fertilised eggs are then covered with gravel by the female. Most, but not all, fish die after spawning and survivors may return to the river to spawn again. The time taken for eggs to hatch (or the 'incubation time') depends on the water temperature. Generally speaking, eggs usually hatch during early spring. These young fish, which still have a yolk sac attached, are called 'alevins'. These fish remain in the redd for a few weeks and emerge from the gravel in April or May, when they have absorbed the yolk sac and are about 3 cm in length. These fish establish territories and compete with each other to feed on a range of items within the stream.

As these 'fry' get larger, they develop prominent markings on their sides and are then known as 'parr'. Depending on the water temperature and the availability of food, these fish will live in the river for two to three years. Once they reach a size of approximately 12 cm, the parr undergo a physiological transformation which allows them to survive in marine environments. The young fish, now called 'smolts', change in physical appearance, becoming silver. The smolts will then move down river to reach the sea, in Scotland this ranges from April to June (Todd *et al.,* 2012) but there is evidence that the timing of smolt migration is related to genetic differences.

These fish remain in the ocean from just over a year to three or four years. Fish which spend only one year at sea (usually around the Faroe Islands and the southern Norwegian Sea) before coming back to Scottish rivers at a size of 2-3 kg are called 'grilse'. Other fish may stay at sea for two or three years before coming back to Scotland. These are referred to as multi-sea-winter fish or 'salmon' and, because they have spent more time feeding in marine environments (usually off Greenland), are larger than grilse. If these fish return to Scottish rivers between the months of January-June, they are referred to as 'spring salmon'. Salmon may, of course, enter Scotland's rivers at all times of the year. This is in contrast with the migratory patterns observed elsewhere for this species within their global range and is one of the factors that make Scottish populations so important from a biodiversity perspective. Eventually they will return back to spawn at a site where they spent time as a parr. This means that some stock components in individual rivers (grilse; spring, summer and autumn salmon) may be supported by several genetically discrete populations, all of which spawn in particular locations within the river catchment. The timing of the onset and the duration of the salmon run upstream can be rather complex since it can start up to a year prior to spawning (Jonsson & Jonsson, 2011; Todd *et al.,* 2012). Spring salmon can, for example, enter the river in January of the year in which they eventually spawn. This means that they may be present within a river for 12 months prior to spawning.

3.1.2 Sea trout/Brown trout

The brown trout is highly variable with respect to its morphology, ecology and life history strategies (Fergusson, 1989). They can occur in streams, rivers, lochs or estuaries and migrate freely between these habitats during different phases of their life history (Jonsson & Jonsson, 2006). Sea trout, as the name suggests, spend a significant proportion of their time in estuarine and coastal marine habitats but, despite being treated by some as a separate species, are simply an anadromous form of *Salmo trutta*. The wide range of morphological variation exhibited by trout has led in the past to the taxonomic classification of up to 50 different species or subspecies of ‘trout’ (Behnke, 1989). These morphological variants are now also considered to be *Salmo trutta*, although significant levels of genetic differentiation may exist between populations.

Trout, including sea trout, spawn from autumn onwards. The timing and duration of spawning may be determined by environmental and genetic factors. Once on the spawning grounds, sea trout, like Atlantic salmon, lay their eggs in gravel pockets or 'redds' that have been excavated by the female fish. Once the eggs have been fertilised the female then covers the fertilised eggs with gravel. The young trout will emerge from the gravel between mid-March and early May. Trout may spend 2-3 years in fresh water before a proportion of the parr population undergoes a physiological transformation which allows them to survive in marine environments. This ‘smoltification’ process, which is similar to that experienced by Atlantic salmon, allows the fish to adopt a silver, fusiform appearance. Generally speaking sea trout smolts are slightly larger than those of Atlantic salmon. Many of the spent adults, known as 'kelts', die, but a significant proportion of them survive and make their way back to the sea to recover and grow. Sea trout can spawn up to 13 times in their lifetime. Unlike Atlantic salmon, sea trout do not make extensive marine migrations to northern seas (Jonsson & Jonsson, 2006), but remain within estuarine and coastal areas. Some fish will make short migrations back into fresh water, usually restricting themselves to the lower reaches of rivers. These post-smolt fish are often locally referred to as finnock, but also as whitling or herling.

3.2 Data sources

Marine Scotland Science (MSS), publishes annual updates on the status of salmon and sea trout stocks in Scotland – the most recent of which are summarised up to and including the year 2013 (MSS, 2014). In addition, MSS also provides summary fishery statistics for salmon and sea trout stocks in the form of Topic Sheets– the most recent include data up to and including the year 2013 (MSS, 2014a, b). Data for both are largely compiled from two main sources of numbers of catch data: (1) rod & line (hereafter referred to as rod) and (2) net fisheries (MSS, 2012). They are described more extensively below.

The rod catches are compiled from mandatory returns to an annual questionnaire sent out by MSS to the proprietors or occupiers of salmon and sea trout fisheries. Data are then summarised according to one of the 109 districts which correspond to either a single catchment or groups of neighbouring river catchments together with the associated coastline. These were defined in the Salmon Fisheries (Scotland) Act 1868. These in turn are aggregated into 11 salmon fishery regions[8] although these are not defined by statute. An underlying assumption in using these data is that there is no consistent change in exploitation rate (the percentage of available salmon captured) whereas, in fact, it could vary according to a range of factors such as fishing effort, river flow and fishing efficiency.

[8] http://www.scotland.gov.uk/Publications/2012/09/5760

Although rod catches do not accurately measure fish abundance *per se,* as data are collected over the whole of Scotland this has been used as the main method of assessing stocks. Since 1994, the proportion of rod catch accounted for in by-catch and release has also been recorded for both salmon and sea trout.

Net fisheries catch data are collected using two methods: i) fixed engine, which are sited on open coast away from estuaries and; ii) net & coble, which are located in estuaries and the lower reaches of rivers. As well as providing information on the numbers caught, a measure of fishing effort is also provided (the maximum and minimum of people employed in the fishing operation and numbers of traps, for the latter method only). However information from the net fisheries is not used to help assess the status of salmonid stocks since both the numbers caught and fishing effort have declined very markedly (see later). In addition this technique intercepts fish bound for a range of rivers and not just the one they are closest to.

For the status of the fish stock reports, three distinct periods are identified with respect to run timings although there can be some annual variation: spring (February – May), summer (June – August) and Autumn (September – October). In terms of the run timing, the fishery statistics define the seasonal components as follows: spring salmon catch (multi sea-winter fish taken before 1 May), summer salmon catch (multi sea-winter fish taken on or after 1 May) and grilse (refers to one sea-winter salmon caught in the autumn). Despite these apparent differences in definitions, they do in effect refer to the same datasets.

There is limited information on population trends of salmon and sea trout at a regional level and, to date, two broad approaches are employed. First the regional rod catch statistics are used to compare the most recent catch data with the historic information. This is carried out by ranking the annual rod catch across the whole time series in order of size (from 1952 onwards, which gives 61 data points up to 2012). Only nine regions are reported since Orkney and Shetland do not support a notable wild fishery. There is an important (farmed) sea trout fishery present, but this is not managed by a DSFB. Therefore comparisons of catch sizes within regions can be carried out (see MSS, 2013a, b). Second, MSS has also developed the rod catch tool which uses data from 1994 onwards to assess whether changes in salmon catches are significant for all three seasonal stock components for each of the 109 fishery districts, when sample sizes permit. Essentially, it determines whether or not there is evidence of change using a simple rule-based system, with an 11% chance of a trend being identified by chance.

3.3 Population trends

3.3.1 Atlantic salmon

The adult salmon stock returning back to Scottish rivers is estimated by a combination of rod catch returns (retained and released), fish counters and fixed traps, the latter two being operated by Marine Scotland Science. Additional information to the rod catch data on the actual abundance of salmon is provided at key sites by fish counters and fixed traps. Additional data for Salmon is collected from fish counters located at three sites: two of which are on the North Esk - Logie which is located in the main stem water and a tributary called Westwater; and the other on the Helmsdale. Fixed traps are located at two sites only (two tributaries of the Dee called the Girnock and Baddoch burns). Although these methods are very restricted in terms of their locations, they provide critical checks of the rod catch data at these sites – any contrasting trends can help identify changes in other factors such as catch effort. Another benefit for fixed traps is that they can also pick up on juvenile emigrants and therefore it is possible to calculate the number of returning fish required in order to maintain the emigrant population for those rivers.

The total annual number of salmon caught using a rod on an annual basis over the period of 1952-2013 has increased - indicating that overall the number of salmon returning from the sea have risen despite reduced survival rates of salmon at sea (MSS, 2014a;). These increases may reflect reduction in the netting industry at sea as both the numbers of salmon caught and the associated fishing effort have shown a steady decline since 1952 - catches in 2013 were reported as 7% and 3% of the maximum reported within their respective time series (MSS, 2014a). There are however, important differences observed for the three different run times and hence the region from which the salmon originate: autumn catches have increased, summer catches have shown slight increases, whilst the spring catches have declined, although these trends all appear to have stabilised since the mid-1990s notably for spring (MSS, 2014a;). Given that the run timing of salmon is determined by the location of their origin (see section 4.1.1), there is potential to tease out environmental factors which could account for the declines in the spring stock of salmon. For example, it may be possible that the impacts of piscivorous birds could be more profound at this time of year. There has been a steady increase in numbers of salmon being caught and released with figures of 80% and 92% of the total catch 2013 for the annual and spring catches respectively (MSS, 2013a).

Comparisons of catches of salmon within the regions for 2012 (this information has not been presented for 2013), showed that the catches in five of the regions were ranked within the top 25% of their respective times series. Perhaps unsurprisingly, none of the regions reported catches in the lowest 25% of their times series given the overall increase reported in catch data for Scotland as a whole (MSS, 2013a). The results derived from the rod catch tool did not reveal any clear patterns. For spring run timings, only 30 districts had sufficient data to use the rod catch tool, the majority of which show no evidence of a trend (possibly reflecting the Scottish trend). The rod catch tool could be used to generate trends for 70 and 74 districts for summer and autumn run timings respectively with most showing no change or an increase, again broadly reflecting national trends for comparable times of years (MSS, 2014). Significant declines in summer and autumn catches have been reported at a fishery district level, however some of these may in part be accounted for by the failure to return fishery catches (and hence under-reporting may have occurred).

3.3.2 Sea trout

Sea trout abundance and population trends are assessed using rod catch data only. Unlike Atlantic salmon, there is a lack of distinct run timings in the structuring of sea trout stocks – hence information is collated on an annual basis only (MSS, 2013b). The number of rod-caught sea trout across all regions has decreased markedly over the period of 1952-2013 and in particular since the mid-1990s. There is a lack of long-term data in relation to the annual fishing effort associated with the rod catch data (MSS, 2013b) so the extent to which these declines reflect a true reduction is unknown. There has been a steady increase in numbers of sea trout being caught and subsequently released. In 2013 the numbers of catch and release accounted for 77% of the total rod catch and 90% of the finnock[9] rod catch. It has been proposed that the declines in rod catches indicate that the levels of spawning escapement (the size of the spawning stock) of sea trout may also be low (MSS, 2013b). Declines in netting have also been observed with the records of sea trout caught using fixed engine and net & coble fishery methods but this was associated with declines in fishing effort. Overall a steady decline has occurred since 1952, with catches in 2012 of 4% and 1% of the maximum reported within their respective time series.

Comparisons of catches of sea trout within the regions in 2012 showed that six regions ranked within the lowest 25% of their respective series (of these, two regions were ranked as

[9] Finnock are small sea trout in their first year after smolt migration which are often found in estuaries or lower areas of rivers.

joint first) again reflecting the declines shown at the Scottish level. This information has not been presented for 2013. In terms of the rod catch tool, there was sufficient data to show declines in 34 out of 82 districts. No changes were shown in the 39 districts and increases were shown in nine – it was not possible to derive trends for the remaining districts (MSS, 2013b). However, it is acknowledged that there are no other supporting data on actual fish abundance nor is there any information on juvenile immigrants held by MSS. There is the added complexity of sea and brown trout which have plasticity in their life history including whether or not they migrate.

4. QUANTIFYING THE IMPACTS OF PISCIVORES ON SALMONID POPULATIONS

One of the key findings of Harris *et al.* (2008) was that there was very little evidence that piscivorous bird predation had impacts on fish species at the population level or caused a direct economic loss in Scotland (see introduction for further details). There has been relatively little primary research published over the last five years or so which relates specifically to the impact of key species of piscivorous birds and the fish species considered by this review (see Table 22 in Section 2). Of those relevant studies, all have been carried out in the U.S.A or elsewhere in Europe and do not appear to have shown any new findings *per se*. Harris *et al. (*2008) reported that impacts of piscivorous birds in Scotland had mainly been studied by a combination of consumption rates and site level bird counts in order to quantify the numbers/amount of prey species consumed. Consumption rates have been estimated by information on diet (e.g. analyses of stomach contents (shot birds) or regurgitates; analyses of pellets; carrying out feeding observations) and extrapolations based on known energetic requirements of particular bird species (e.g. estimation of daily energy expenditure based on basic metabolic rate and time-activity-budget and measurements of daily energy expenditure in free living birds using doubly labelled water). Other methods for estimating consumption rates include using either a percentage of adult body weight, or balances in combination with stomach temperature tags (see Ridgeway (2010) but all relevant studies cited pre-date 2009). There are, however, a number of issues which have been raised in terms of reaching consensus on the *per capita* consumption rates and in particular how important variation in the values used will be (such prey assimilation efficiencies, prey energy densities and daily food intake) when scaled up to the population level (Ridgeway, 2010). This has also presented significant challenges when attempting to make comparisons between studies (Harris *et al.,* 2008). The lack of accurate assessments of fish consumption rates by piscivorous birds, in combination with the lack of evidence available for key parameters of fish populations (e.g. overall fish abundance and mortality rates caused by other factors), has hindered any attempts to demonstrate a reduction in numbers or productivity of fish species caused by piscivorous birds (Harris *et al.,* 2008).

Other methods of assessing the impacts of piscivorous birds upon fish populations have attempted to compare the numbers of fish that were potentially available with those which were actually consumed. This has included the use of passive integrated transponders (PIT tags), which is based on a comparison of the numbers of returning tagged fish that are detected by tag antennae systems, and with the recovery rates of tags from predated fish collected from breeding and/or roosting sites, for example. Frechette *et al.* (2012) looked at predation rates by breeding western gull, brown pelican and Brandt's cormorant on juvenile pacific salmonids in North America. Although PIT tags have been deployed to determine migration speeds of juvenile salmon in Scotland (e.g. Mackay & Smith, 2011), they do not appear to have been used to quantify predation rates. Similarly, Coded Wire Tags (CWT) and Carlin Tags have recently been used to look at the impact of cormorants on salmon and trout stocks in Norway (Boström *et al.,* 2009) and have previously been used in Scotland (see Park *et al.* (2005) for review).

It is worth noting that interest in conflicts between cormorants and fisheries has been particularly high, with two international research networks being formed, covering not only Europe but the Middle East as well: REDCAFE and INTERCAFE[10]. These projects have arisen largely as a result of dramatic increases across Europe in both numbers and range over the last three decades notably for the race *P. c. sinensis* (see Bregnballe *et al.* (2014) for further details). As part of this collaboration, a database characterising hydrological and ecological data of sites known to be used by cormorants has been produced (INTERCAFE's Water Systems Database – see Van Eerden *et al*., 2012). Overall nearly 100 species have been recorded as being taken at 117 sites across 26 countries and, broadly speaking, large-

[10] http://www.intercafeproject.net/

scale bodies tended to be favoured by the cormorant. In addition, although most data were based on measures of relative rather than absolute abundance, it was also suggested that the water bodies with the highest fish biomass attracted the greatest number of birds Another key output of this international research network, has been the production of standardised methods for studying cormorants, fishes and the interactions between them (Carss *et al.,* 2012). This should ultimately help develop a better understanding of the impacts of not only the cormorant, but also of other piscivorous birds, on fish populations.

5. OTHER FACTORS AFFECTING SCOTTISH GAME FISHERIES

Harris *et al.* (2008) identified a range of other factors which they considered to affect the Scottish salmonid fisheries (including both anadromous and, to a lesser extent, lacustrine populations) which were as follows: other predators (mammal and fish); habitat degradation through factors such as climate change and hydro-electric dams, although there was an acknowledged absence of studies from Scotland for the latter; (low) survival at sea and aquaculture (threats to genetic integrity; increase in parasites and potential competition). An emerging area of concern is the likely impact of marine renewables and telecommunications upon anadromous salmonid populations (Malcolm *et al.,* 2013; Marine Scotland 2014): (1) electromagnetic fields generated by subsea cables for renewables and telecommunications which could result in the disorientation of migrating fish; (2) underwater noise particularly during the construction period (if pile driving is used); (3) mortality caused by direct strike or indirectly (e.g. disorientation and predation).

In order to understand the likely impacts of offshore renewables, Malcolm *et al.* (2010) identified a number of key gaps in knowledge for Atlantic salmon and sea trout. These included a need to: describe and quantify swimming depths used by migrating post-smolt and adult fish; identify the offshore and inshore habitat use of Atlantic salmon; identify the marine migration routes of post-smolt and adult Atlantic salmon; identify patterns in phenology for migration for specific locations around the Scottish coast; gather information on the geographical distribution of post-smolt Atlantic salmon in the North Sea; and sea trout post-smolt habitat use. Progress in Scotland since 2010 was summarised by Malcom *et al.* (2013). This provided updated information on the use of satellite tags on smolt and adult salmon in the Pentland and Moray Firth areas. These tags can also collect depth data which will be combined with hydrographic and particle tracking models in order to identify likely migratory routes. A further two projects both of which are in an early phase will look at migration in sea trout but no other information has been provided.

6. HABITAT PREDICTORS OF PISCIVOROUS BIRDS OCCURRENCE AND DISTRIBUTION

There have been several studies which have used the national dataset of WBS/WBBS to look at habitat variables that can be used to predict occurrence and distribution of birds that occur near waterways. With respect to the piscivorous birds, however, there is only sufficient data for goosander, cormorant and grey heron. One study used the EA's River Habitat Survey to determine the relationship between bird species distribution and hydromorphology (Vaughan *et al.,* 2007). Both cormorant and grey heron showed a negative relationship with the variable rocky channel, a proxy for levels of bedrock, boulders and the frequency of high energy flow. Goosanders had a quadratic positive relationship with the level of tree cover, and a positive association with width of river. The authors concluded that the modelling approaches performed better in terms of generating predictions for the fast water upland species as opposed to lowland, slow water species. Moreover, they suggested the collection of additional habitat information relating to the wider riverine landscape and water chemistry. Similar analyses were carried out using the UK National River Flow data which showed distinct relationships between avian species occurrence and river flow regime attributes (Royan *et al.,* 2013). River flow is an important variable since it not only structures physical features, such as channel width and stability, but it also determines the physiochemical properties such as temperature and levels of dissolved oxygen which in turn influence productivity. Goosander presence had a positive quadratic relationship with high flows (where medium values indicate a medium stability in the magnitude of high flows), whereas grey heron occurrence was positively linked to low flow (where high values indicate greater stability in the magnitude of low flows and water depth). Both goosander and cormorant presence were also positively associated with high flow variation in April (where high values indicate greater flow variability), which coincided with the start of the breeding season).

7. IMPACTS OF CONTROL METHODS ON PISCIVOROUS BIRD POPULATIONS

Despite control measures being implemented to reduce the impact of freshwater piscivores on fish stocks, very little has been done in terms of demonstrating the impact of such measures on the piscivorous bird populations themselves. These could be mediated either directly through mortality (killing) of birds or indirectly through disturbance which displaces birds from key foraging habitats. The single exception to this is a study carried out based on annual WeBS data and the Dispersed Waterbird Survey of 2002 at the scale of England (Chamberlain *et al.,* 2013). It did not detect any relationship between the intensity of licensed shooting and the English wintering population trend for cormorant. Furthermore, there was no apparent relationship between the trajectory of numbers on sites and the intensity of control in the local area when considering sites from areas with little or no control through to sites from areas with a high degree of control. Reasons given for the lack of relationship included: the population may have reached a carrying capacity and density dependence factors may be operating, or there may be other factors which are influencing breeding success and survival or even immigration.

8. EMERGING POLICY ISSUES WITHIN SCOTLAND

The Wild Fisheries Review was completed in October 2014 (Thin *et al.,* 2014). Its main aims were to: i) develop and promote a modern, evidence-based management system for wild fisheries fit for purpose in the 21st century and capable of responding to the changing environment and; ii) to manage, conserve and develop our wild fisheries to maximise the sustainable benefit of Scotland's wild fish resources to the country as a whole and particularly to rural areas. The need for this review was driven by the recognition that the existing fisheries management system needed updating to meet the demands of the 21st century. It will build on the work carried out as part of the Aquaculture and Fisheries (Scotland) Act 2013 which set out the legislative framework and modernised the governance arrangements. A total of 53 recommendations have been set out and ministers are now currently considering the report in depth and will consult on proposals to implement a new management system[11]. As a direct result of one of the recommendations set out in the review, a consultation process was launched in February 2015 relating to the licensing of killing of wild salmon[12]. Current plans include new conservation measures which would seek to ban the killing of wild salmon except under licence, along with the introduction of a carcass tagging scheme in order to ensure compliance[13].

Scotland's National Marine Plan is also currently in its consultation draft stage. A number of key topics have been identified including Wild Salmon and Migratory Fish and the most relevant objectives in terms of this review are: i) ensuring that an appropriate management and regulatory framework is in place to sustainably manage salmon and migratory fish and fisheries resources to provide significant economic and social benefits for the people of Scotland, and ii) maintaining, and where possible, improving healthy salmon and migratory fish stocks in support of sustainable fisheries through sound science based management. This document also highlights the possible impacts of renewables on fish populations (see section 6 for further discussion).

Marine Scotland Science started a five year plan in 2014 to look at potential approaches for producing new conservation limits for salmon, and represents a value below which stock levels should not be permitted to fall. Current conservation limits are applied at the scale of the whole stock of salmon within a river system. Given the recognition that the sub spring stocks of salmon are doing less well, the current catch levels at this time of year may be unsustainable. Hence options for exploring conservation limits at a sub-river catchment level in order to manage spring fish more effectively are being developed[14] and will involve exploration of current data collected on fish statistics. Other work in the programme includes the use of electrofishing data to quantify carrying capacity of different habitat types, additional data collected from fish counters and DNA analyses in order to establish which rivers produce spring fish. This focus on the management of spring stocks should be borne in mind when considering the impacts of piscivorous birds on salmon populations as this sub stock may well be disproportionately influenced by predation compared with other sub stocks.

[11] http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/fishreview
[12] http://news.scotland.gov.uk/News/Licence-to-kill-15b7.aspx
[13] http://www.gov.scot/Resource/0046/00469573.pdf
[14] http://www.scotland.gov.uk/Topics/marine/Salmon-Trout-Coarse/Freshwater/Research/limits

9. DISCUSSION AND RECOMMENDATIONS

A number of limitations are associated with the population estimates presented in this report.

1. There was a lack of acceptable bespoke survey data for some species, in particular for breeding red-breasted mergansers, and hence the British and Scottish population estimates were based solely on Atlas data which were not collected by a method designed with this purpose in mind. Similarly, for some of the Scottish (breeding and wintering red-breasted mergansers and goosanders as well as wintering cormorants) and all of the SEPA population estimates for all species, atlas data were used as the basis of apportioning the number of birds. Again this was carried out in the full knowledge that there are notable limitations regarding appropriateness of the atlas survey methodology for these species.

2. A number of the population estimates were out-of-date. It was, therefore, necessary to use correction factors relating to either an annual population trend measure or changes in relative abundance between differing atlas periods. The former were used for breeding goosander at the level of Britain to correct for potential population changes since 1987 while the latter were used for the red-breasted merganser British population estimate; however, this added even further uncertainty due to the multiple use of atlas data. Similarly a correction factor based on the percentage of the population considered to be surveyed was applied to the estimates for wintering goosanders and cormorants.

3. The breeding cormorant population estimate for Britain and for Scotland was based on survey data from 1998-2002 and there was no measure of population trend over the intervening period. This would also have had implications for the wintering population estimates for cormorant.

4. There may be issues relating to the wintering population estimate of grey heron (Section 2.9.3) which is calculated by applying a very simple population model applied to the breeding estimate.

Extreme caution should be applied when using these population estimates and the associated confidence limits, particularly for the SEPA regions if they are to be used to assess the population level impacts of any licensed control activities. If these estimates are to be used as the basis of setting a regional bag limit, we would recommend a precautionary approach and that more weighting is given to the lower confidence limit reported.

The impacts of control measures should be monitored through regular monitoring of the populations regardless of whether the overall aim is to derive more accurate periodic population estimates or to generate annual population indices. This will be particularly critical if the overall aim is to manage populations of piscivorous birds using an approach which is based broadly on the principles of adaptive management. Here we set out a number of options to derive improved population estimates for piscivorous birds, more targeted monitoring of key salmonid rivers, and use of alternative population trends for piscivorous birds. We also discuss how salmon population trends could be compared with piscivorous bird population trends and the scope for developing our understanding of the impacts of control methods on piscivorous bird and fish populations.

9.1 More accurate assessment of population estimates

If robust population estimates are required by statutory nature conservation bodies such as SNH for Britain, Scotland and for the smaller scale such as the SEPA regions, then there is a need to consider funding well designed surveys from which more accurate measures of population numbers can be derived, or increasing the coverage achieved by existing surveys.

9.1.1 Breeding population estimates (MODERATE PRIORITY)

We do not consider it necessary to make recommendations for breeding cormorant since the upcoming national seabird census, likely to be starting in 2016/17, will provide the best possible breeding population estimate assuming reasonable inland coverage is achieved. Nevertheless there would be huge merit in increasing the amount of effort put into annual monitoring of the abundance of breeding cormorant through the Seabird Monitoring Programme (SMP). Similarly we consider that breeding grey heron are also sufficiently covered by the BTO's Heronries Census. We note, however, that neither the next national seabird census (based on previous methods) nor the Heronries Census will collect records of non-breeders (as was possible for atlas data). Furthermore cormorants, like other seabirds, can skip breeding seasons when conditions are poor. These are very important considerations if the likely levels of predation are based solely on breeding population sizes, particularly at a regional level.

There are practical difficulties, however, associated with coming up with a survey fit for purpose for red-breasted mergansers and goosanders, particularly during the breeding season. First, there are differences in breeding sites selection. Red-breasted mergansers tend to breed on sheltered sea lochs and estuaries with a few nesting inland on the lower reaches of rivers (slower moving) and large mesotrophic freshwater lochs and reservoirs (Gregory *et al.,* 1997; Marquiss*,* 2007a). In contrast, goosanders nest close to the upper reaches of rivers or tributary streams (Marquiss*,* 2007b). Some of these nesting sites are also located in remote areas, hence coverage by volunteers can be very difficult to achieve.

Second, there are a number of challenges in achieving complete coverage of potential nesting sites. It has been estimated that there are over 50,000km of rivers in Scotland (Scottish Government, 2008), although this latter figure does not include tributaries so the potential length of linear water features required to be covered would be even higher. Similar issues are also true for the wide range of freshwater/marine water bodies used by red-breasted merganser. A stratified approach by habitat type may deal with this issue partially although care would have to be given to ensuring that a sufficient sample size is achieved for each SEPA region.

Third, both of these species have highly concealed nests and therefore providing an estimate of the number of breeding pairs is extremely difficult. Red-breasted mergansers nest in rank vegetation, often on islands, and ducklings are reared in sheltered waters whereas goosanders nest in tree hollows or rock cavities (Marquiss , 2007a, b). An additional issue for the goosander is that nests are not always located immediately adjacent to waterways of interest (Marquiss*,* 2007b) which may make it harder to pick up breeding adults as they are not always located.

In order to obtain a reasonable British/Scottish population estimate for sawbills, therefore, it would be necessary to carry out a Britain/Scotland-wide stratified survey of rivers, sea lochs, estuaries and mesotrophic freshwater lochs. We recommend that pilot work would be necessary to: determine the most suitable survey methodology for the different sites: define what the robust index of population size is likely to be (e.g. males, females or apparent pairs in spring or pairs that rear young); and ascertain whether there is scope for habitat variables which could be collected as part of the surveys.

9.1.2 Wintering population estimates (LOW/MEDIUM PRIORITY)

In terms of wintering estimates, increased confidence in the population estimates could be achieved by augmenting the number of sites surveyed by WeBS to ensure there would be less error potentially with the corrections applied. It should be noted that WeBS is not designed to generate population numbers, rather the main aim is to generate population trends. It also covers still water rather than running water. This may not help in the case of grey heron, for which the wintering population estimate is based on the breeding population estimate with a simple population model applied. As there appears to be little evidence that grey heron are considered a major problem at this time of year, it is not a priority to develop a bespoke wintering survey for this species. Additional effort could be considered in commissioning seaduck surveys to pick up on red-breasted merganser but, given the extent of the coastline in Scotland, this is likely to be cost prohibitive and the use of shore-based surveys in this context has been questioned.

9.2 Targeted monitoring of key salmonid rivers (HIGH PRIORITY)

Harris *et al.* (2008) proposed that assessing the total population size of breeding or wintering populations of piscivorous birds was unnecessary. There are clearly a number of logistical issues which may render a complete survey (or even stratified surveys) of breeding or wintering piscivorous birds highly problematic and difficult to fund. It may be more realistic to consider the option of carrying out more intensive and localised monitoring of piscivorous birds along important salmon rivers at key times of year (e.g. during the main spawning periods when the greatest impacts of piscivore birds are reported by the DSFB (Colin Bean *pers. comm.*)). This would be a much better measure of the true likely use of the rivers by fish-eating birds. We therefore advocate working closely with those DSFBs which make applications to SNH for licensed control, to determine which species are considered to be the problem and at what time of year they have the most impact. There may also be scope to make use of local atlas data in these contexts.

9.3 Alternative population trends for piscivorous birds

9.3.1 DSFB count data as used for licensing purposes (HIGH PRIORITY)

There may be scope to work with the 15 DSFB's in order to use existing data collected by a number of districts (see section 3.2.2.) as part of their application for licences to carry out either lethal or non-lethal control (when shooting is used as an aid to scaring). It is worth noting that this represents a relatively small proportion of the total number of DSFBs. This was also recommended by Park *et al.* (2005) who suggested that these data could potentially be used to characterise piscivorous birds' spatial and temporal variation in abundance and would inform the design of potential bespoke Scotland-wide river surveys. We reiterate the need to carry out a review of the existing data (assuming permission could be sought from the relevant DSFBs) to examine the extent to which the database in its current form could be used to meet this objective. This would include looking at how variable counts were within and between sites over the time series. Such information could point to the likely drivers underlying such variability (e.g. time of year, physical features of the water body). As part of this review, consideration would be given to the range in methods of counts and the timing of such counts in terms of how they may influence the abundance. There may also be scope to make recommendations for additional counts to be carried out in order to supplement the existing database, although this may have to be carried out by professional field workers rather than staff working for the DSFBs.

9.3.2 WeBS data (HIGH PRIORITY)

There may be scope to generate wintering population indices for each of the SEPA regions using WeBS data (see Table 23 a-d in Section 13)

Furthermore it may also be possible to differentiate between coastal and inland population trends. However, there are a number of caveats associated with this dataset. Consideration would have to be given to those SEPA regions which have a low number of sites and whether these sites can be considered representative of all the potential sites within that region. If these sites only hold small numbers of birds, then it is questionable as to how representative these indices are. Related to this, the index also will be biased by those sites which hold the greatest proportion of birds and this would be compounded in regions with small numbers of sites. There could be potential for funding a professional element of the work in order to increase coverage. It is also worth noting that WeBS are actively requesting roost counts for mergansers in addition to the core counts (Austin *et al.,* 2014) which would further improve the reliability of the population trends.

9.3.3 WBBS data (LOW PRIORITY)

At present there are only sufficient data to be able to derive population trends for Scotland using WBBS for the most common species and not the piscivorous species being considered here. The methodology of WBBS is such that it is unlikely to pick up on breeding heron or cormorant, and any records are likely to be non-breeders (however, concern for either of these species is not considered particularly high during the breeding season). Based on the current coverage achieved by volunteers (see Table 24 in Section 14), it would take more than double the number of surveys currently carried out in which goosander is recorded in order to achieve the minimum number of sites, sufficient to generate an index. This effort would have to be maintained consistently over a number of years. For red-breasted merganser, any increased effort would have to be an order of magnitude higher. We do not, therefore, suggest that improved monitoring could be achieved using the WBBS.

9.4 Comparisons of population trend for salmon and piscivores (MEDIUM PRIORITY)

At present MSS generates trends for salmon catch data using the rod catch tool at the scale of salmon fishery districts using data from 1994 onwards. It would be entirely possible to use the rod catch tool for different scales (e.g. salmon fishery regions[15], SEPA regions) and based on catch statistics that predate 1994 (Julian Maclean (MSS) *pers. comm*). Although we have advised caution in terms of the use of the population estimates for piscivorous birds, there may still be merit in comparing broad trends between salmon and piscivores population estimates for individual SEPA or salmon fishery regions. This could potentially tie in with another recommendation arising from Harris *et al.* (2008) which called for review of existing demographic data for fish populations.

9.5 Understanding impacts of control methods

9.5.1 Understanding movement between sites in response to shooting (HIGH PRIORITY)

Chamberlain *et al.* (2013) stated that future research needs included better understanding of how cormorants use sites and what the movements of individuals are. A similar point was made by Marzano *et al.* (2013) who highlighted the lack of knowledge relating to the dispersal and migratory behaviour of cormorants (including identifying breeding and wintering areas but this is probably less true for the UK due to the existence of atlas data). This principle is also true for the other piscivorous bird species'. Some work has already been carried out on breeding on the River Wye for goosanders using ring-recovery recorded to determine non breeding movements (Mitchell *et al.,* 2008). Furthermore, it is also important to establish how birds respond to disturbance arising from control measures through either mark-resighting programmes (e.g. colour ringing) or the use of devices which provide the locations of birds such as GPS or satellite tags. This would involve working with

[15] http://www.scotland.gov.uk/Publications/2014/09/9467/1

those DSFBs who apply for licences to control piscivorous bird numbers in order to obtain information on the intensity and frequency of shooting effort.

9.5.2 Impacts of control methods on piscivore populations (HIGH PRIORITY)

Regular monitoring of red-breasted merganser and goosander populations have been recommended in order to understand the impacts on the Scottish population of culling. For cormorant there have also been calls to quantify levels of legal and illegal methods of killing adults (Forrester *et al.,* 2007). It is unlikely that levels of illegal killing will be easily quantified, however. SNH, as administrator of the licensing scheme, holds information on the numbers of birds that were licensed to be shot on an annual basis (the bag limit) and the numbers of birds actually shot, based on return forms. This information could potentially be related to piscivorous bird population trends post shooting (noting that the salmon fishery districts are markedly smaller than the either the SEPA or salmon fishery region).

9.5.3 Testing impacts of control methods (for piscivores) on fish populations (MEDIUM PRIORITY)

There have been repeated calls to adopt what is known as "the model-field experiment remodel" – a combination of modelling, field observations and experimentation in order to demonstrate impacts (Marquiss *et al.,* 1998; Park *et al.,* 2005; Harris *et al.;* 2008). We reiterate the need for such an approach. Due to the issues with providing evidence for impacts of piscivorous birds on salmonid populations, it has not yet been demonstrated whether control measures such as licensed shooting are effective at reducing population level effects.

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11. REGIONAL AND SCOTLAND-LEVEL CHANGE STATISTICS FOR PISCIVOROUS BIRDS

Regional and Scotland-level change statistics for piscivorous birds. For each change period (i.e. between each pair of atlases) we present the number of hectads showing apparent loss, stability or gain (- / = / +) and the percentage change in range size over the period (+∞ indicates apparent colonisation). Highlighted cells indicate statistically significant changes. For BA1990–BA2010 we also give an estimate of change in relative abundance based on change in the proportional occupancy of tetrads within hectads. This is expressed as a percentage (with 95% confidence limits) and is based on tetrad-resolution data which are available only for these two atlases. Empty cells indicate where a species did not occur in a region in either atlas period.

Table 18. Red-breasted Merganser

Region	***BA1970–BA1990* (first 20 years)**		***BA1990–BA2010* (recent 20 years)**			***BA1970–BA2010* (40 years)**		***WA1980–WA2010* (c30 years)**	
	- / = / +	**% change in range size**	**- / = / +**	**% change in range size**	**% change in relative abundance**	**- / = / +**	**% change in range size**	**- / = / +**	**% change in range size**
North East Scotland	-12/=17/+8	-14	-10/=15/+4	-24	-74.9 (-94.5, -33.7)	-16/=13/+6	-34	-4/=15/+13	+47
Tay	-15/=28/+19	+9	-25/=22/+8	-36	-50.4 (-71.2, -18.7)	-22/=21/+9	-30	-5/=16/+14	+43
Forth	-10/=6/+11	+6	-13/=4/+3	-59	-58.2 (-100.0, 58.3)	-11/=5/+2	-56	-4/=25/+8	+14
Tweed	-1/=3/+0	-25	-3/=0/+1	-67	-100.0 (0.0, -100.0)	-4/=0/+1	-75	-1/=1/+1	0
Solway	-24/=14/+5	-50	-16/=3/+10	-32	-64.2 (-92.2, -4.0)	-30/=8/+5	-66	-6/=21/+6	0
Clyde	-8/=36/+11	+7	-12/=35/+4	-17	-9.8 (-42.3, 36.4)	-15/=30/+9	-13	-8/=38/+8	0
Argyll	-11/=109/+14	+3	-27/=96/+11	-13	-19.8 (-36.6, 0.9)	-22/=98/+9	-11	-7/=96/+8	+1
West Highland	-30/=105/+19	-8	-27/=97/+14	-10	6.0 (-18.2, 38.9)	-40/=95/+16	-18	-12/=84/+33	+22
North Highland	-21/=82/+28	+7	-48/=62/+13	-32	-45.3 (-60.6, -25.6)	-49/=54/+21	-27	-6/=47/+23	+32
Orkney and Shetland	-14/=42/+8	-11	-11/=39/+8	-6	-0.9 (-36.1, 53.4)	-16/=40/+7	-16	-5/=57/+11	+10
Scotland	**-146/=442/+123**	**-4**	**-192/=373/+76**	**-21**	**-24.1 (-33.7, -14.4)**	**-225/=364/+85**	**-24**	**-58/=400/+125**	**+15**

Table 19. Goosander

Region	*BA1970–BA1990* (first 20 years)		*BA1990–BA2010* (recent 20 years)			*BA1970–BA2010* (40 years)		*WA1980–WA2010* (c30 years)	
	- / = / +	% change in range size	- / = / +	% change in range size	% change in relative abundance	- / = / +	% change in range size	- / = / +	% change in range size
North East Scotland	-16/=35/+11	-10	-13/=33/+19	+13	-25.1 (-52.8, 12.0)	-13/=38/+14	+2	-13/=45/+21	+14
Tay	-15/=29/+21	+14	-13/=37/+21	+16	13.3 (-25.1, 71.2)	-13/=31/+27	+32	-11/=43/+24	+24
Forth	-2/=9/+12	+91	-0/=21/+16	+76	233.9 (55.2, 849.1)	-1/=10/+27	+236	-1/=33/+18	+50
Tweed	-2/=17/+22	+105	-5/=34/+5	0	-30.0 (-57.4, 8.8)	-1/=18/+21	+105	-3/=35/+6	+8
Solway	-10/=44/+2	-15	-12/=34/+9	-7	-40.4 (-61.1, -10.7)	-16/=38/+5	-20	-1/=40/+22	+51
Clyde	-5/=13/+29	+133	-9/=33/+24	+36	35.8 (-12.9, 120.4)	-5/=13/+44	+217	-7/=33/+35	+70
Argyll	-24/=24/+18	-13	-17/=25/+25	+19	27.8 (-23.1, 122.0)	-23/=25/+25	+4	-13/=28/+42	+71
West Highland	-23/=16/+12	-28	-12/=16/+15	+11	-6.1 (-56.8, 89.7)	-22/=17/+14	-21	-11/=14/+45	+136
North Highland	-16/=39/+35	+35	-23/=51/+23	0	-9.4 (-40.5, 33.4)	-14/=41/+33	+35	-14/=38/+50	+69
Orkney and Shetland	-	-	-	-	-	-	-	-2/=8/+22	+200
Scotland	**-113/=226/+162**	**+14**	**-104/=284/+157**	**+14**	**-3.4 (-17.3, 14.3)**	**-108/=231/+210**	**+30**	**-76/=317/+285**	**+53**

Table 20. Cormorant

Region	*BA1970–BA1990* (first 20 years)		*BA1990–BA2010* (recent 20 years)			*BA1970–BA2010* (40 years)		*WA1980–WA2010* (c30 years)	
	- / = / +	**% change in range size**	**- / = / +**	**% change in range size**	**% change in relative abundance**	**- / = / +**	**% change in range size**	**- / = / +**	**% change in range size**
North East Scotland	-0/=1/+1	+100	-1/=1/+8	+350	-5.0 (-63.0, 131.5)	-0/=1/+8	+800	-3/=33/+20	+47
Tay	-0/=0/+1	+∞	-0/=1/+2	+200	35.2 (-64.9, 614.8)	-0/=0/+3	+∞	-2/=37/+31	+74
Forth	-0/=2/+3	+150	-2/=3/+2	0	-72.0 (-93.2, -34.9)	-0/=2/+3	+150	-0/=49/+8	+16
Tweed	-	-	-0/=0/+1	+∞	200.0 (0.0,∞)	-0/=0/+1	+∞	-0/=9/+21	+233
Solway	-4/=10/+1	-21	-2/=9/+11	+82	-23.1 (-47.1, 7.9)	-3/=11/+9	+43	-6/=35/+24	+44
Clyde	-2/=0/+0	-100	-0/=0/+7	+∞	-69.8 (-87.8, -40.8)	-2/=1/+6	+133	-6/=56/+20	+23
Argyll	-20/=5/+7	-52	-10/=2/+8	-17	-79.5 (-91.7, -62.5)	-22/=3/+7	-60	-14/=92/+20	+6
West Highland	-24/=20/+9	-34	-24/=6/+8	-53	-71.0 (-81.8, -55.8)	-35/=7/+7	-67	-12/=85/+40	+29
North Highland	-7/=8/+1	-40	-5/=4/+1	-44	-81.8 (-93.7, -61.2)	-12/=3/+2	-67	-6/=65/+37	+44
Orkney and Shetland	-10/=11/+4	-29	-6/=9/+3	-20	-35.8 (-71.1, 25.0)	-12/=9/+3	-43	-4/=65/+8	+6
Scotland	**-67/=57/+27**	**-32**	**-50/=35/+51**	**+1**	**-56.3 (-64.9, -47.1)**	**-86/=37/+49**	**-30**	**-53/=526/+229**	**+30**

Table 21. Grey Heron

Region	***BA1970–BA1990* (first 20 years)**		***BA1990–BA2010* (recent 20 years)**			***BA1970–BA2010* (40 years)**		***WA1980–WA2010* (c30 years)**	
	- / = / +	**% change in range size**	**- / = / +**	**% change in range size**	**% change in relative abundance**	**- / = / +**	**% change in range size**	**- / = / +**	**% change in range size**
North East Scotland	-22/=66/+11	-13	-18/=59/+19	+1	32.2 (3.5, 69.0)	-21/=67/+11	-11	-7/=78/+10	+4
Tay	-7/=68/+13	+8	-26/=55/+4	-27	19.0 (-6.7, 54.0)	-23/=52/+7	-21	-6/=71/+7	+1
Forth	-0/=39/+16	+41	-3/=52/+1	-4	8.6 (-14.8, 41.1)	-2/=37/+16	+36	-0/=54/+4	+7
Tweed	-1/=35/+9	+22	-4/=40/+1	-7	-17.3 (-34.5, 5.5)	-3/=33/+8	+14	-2/=42/+1	-2
Solway	-6/=54/+21	+25	-25/=50/+6	-25	-19.2 (-33.1, -1.8)	-19/=41/+15	-7	-5/=64/+11	+9
Clyde	-2/=71/+16	+19	-9/=78/+4	-6	6.2 (-12.2, 26.9)	-5/=68/+14	+12	-0/=85/+7	+8
Argyll	-18/=101/+18	0	-26/=93/+10	-13	15.2 (-4.2, 39.2)	-27/=92/+11	-13	-5/=112/+17	+10
West Highland	-18/=112/+26	+6	-57/=81/+13	-32	-21.6 (-35.5, -5.3)	-45/=85/+9	-28	-9/=113/+26	+14
North Highland	-13/=78/+42	+32	-43/=77/+22	-18	2.8 (-16.4, 24.2)	-25/=66/+33	+9	-15/=85/+41	+26
Orkney and Shetland	-1/=2/+18	+567	-20/=0/+0	-100	-100.0 (-100.0, -100.0)	-3/=0/+0	-100	-5/=57/+8	+5
Scotland	**-88/=626/+190**	**+14**	**-231/=585/+80**	**-19**	**-0.3 (-6.9, 7.1)**	**-173/=541/+124**	**-7**	**-54/=761/+132**	**+10**

12. IMPACT STUDIES TABLES

Table 22. Impact studies for piscivorous birds on salmonid populations (update of Park et al. 2005)

Species /Reference	**Methodological approach and parameters collected**	**River/stocked river or still water fisheries/fish farm**	**Fish species**	**Impacts on population**	**Impact on the economy**	**Limitations of study**
Goosander/ Frechette *et al.* 2013.	Transect based counts of birds Bioenergetic modelling (using Monte Carlo simulations to account for uncertainty in the estimates)	River system located in coastal watershed (Scott Creek, Santa Cruz County, USA)	Juvenile salmonid (Steelhead)	Estimates of 5-54% of annual steel head production taken.		Lack of real data on piscivore diet composition Abundance of fish estimated (no counts of fish carried out)
Goosander/ Wiese *et al.* 2008*	Analyses of stomach contents Boat based counts of birds Bioenergetic modelling	Stocked river (Columbia River Basin, Washington, USA)	Range of juvenile salmonids (some wild) (Chinook, Steelhead, Coho, Sockeye, Chum,)	44,830 -109,209 salmonids removed on an annual basis by six piscivorous species (highest levels between end March and mid June)		Possible bias in timing of shooting (06:30 – 14.00) No evidence that double counting was accounted for in the counts Lack of species breakdown for prey consumption provided`
Goosander/ Svennning *et al.* 2005*	Analyses of stomach contents (during the smolt run) Bird counts	River estuary – (River Tana estuary, Norway)	Atlantic Salmon smolts	Two otoliths identified (rest of prey were sandeel spp.)		Time of day birds shot not reported Birds were shot solely in the tidal areas (not freshwater) No details of the bird count methods provided
Cormorant/ Boström *et al.* 2009	Insertion of CWT and Carlin tags into fish Collection of pellets, nest material and soil	River estuary (delta of the Daläven River, Sweden)	Trout spp. and salmon (stocked salmon) smolt	No salmon tag retrieved One tag found in pellet = 1.9% predation rate Four tags found in soil= 2.3% predation rate		Incomplete recoveries of ingested tags (degradation, eaten by other species) Immature cormorants not sampled

* These studies pre-date Harris *et al.* 2009 but were not included in that revie

13. WEBS TABLE FOR SCOTLAND AND SEPA REGIONS

Table 23. Number of WEBS sites per SEPA region that have been visited on at least 50% of designated monthly count dates (from September to March) over the entire time series for the four piscivorous species (see Underhill and Prys-Jones 1994 for justification). The coastal/inland split is also shown.

a) Red-breasted merganser

Region	Total number of sites	Coastal sites	Inland sites
North East Scotland	13	4	9
Tay	22	4	18
Forth	38	3	35
Tweed	6	0	6
Solway	11	5	6
Clyde	32	9	23
Argyll	7	6	1
West Highland	0	0	0
North Highland	15	6	9
Orkney and Shetland	31	4	27
Total	**175**	**41**	**134**

b) Goosander

Region	Total number of sites	Coastal sites	Inland sites
North East Scotland	14	4	10
Tay	29	4	25
Forth	48	3	45
Tweed	23	0	23
Solway	13	4	9
Clyde	37	5	32
Argyll	6	5	1
West Highland	0	0	0
North Highland	11	6	5
Orkney and Shetland	20	1	19
Total	**201**	**32**	**169**

c) Cormorant

Region	Total number of sites	Coastal sites	Inland sites
North East Scotland	17	6	11
Tay	51	5	46
Forth	113	4	109
Tweed	21	0	21
Solway	16	6	10
Clyde	115	10	105
Argyll	24	15	9
West Highland	2	1	1
North Highland	25	8	17
Orkney and Shetland	37	7	30
Total	**421**	**62**	**359**

d) Grey heron

Region	Total number of sites	Coastal sites	Inland sites
North East Scotland	17	5	12
Tay	70	6	64
Forth	139	5	134
Tweed	29	0	29
Solway	19	6	13
Clyde	140	9	131
Argyll	22	11	11
West Highland	9	3	6
North Highland	27	9	18
Orkney and Shetland	67	16	51
Total	**539**	**70**	**469**

14. WBBS TABLES

Table 24. Number of WBBS sites in Scotland in which the four piscivorous species have been recorded each year since the start of the survey.

Number of sites	Red-breasted Merganser	Goosander	Cormorant	Grey Heron
1998	2	9	2	9
1999	3	9	3	15
2000	3	10	1	17
2001	0	2	0	4
2002	5	14	3	20
2003	1	15	1	19
2004	4	16	2	26
2005	5	10	0	21
2006	1	17	1	22
2007	3	15	1	28
2008	0	12	3	21
2009	3	13	2	18
2010	0	13	4	24
2011	1	15	3	21
2012	0	15	4	24
2013	2	15	3	23

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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