British Trust for Ornithology

The 1997 Breeding Sawbill Survey

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EXECUTIVE SUMMARY

1. Fish-eating birds are considered a cause for concern in Britain. Anglers and fisheries managers accuse them of causing damage to fish stocks, while conservationists argue that there is no evidence of this.

2. The 1997 Sawbill Survey addresses the question of changes in the density and range of two piscivorous bird species, goosanders *Mergus merganser* and red-breasted mergansers *Mergus serrator*, since the last national survey in 1987 and since the surveys conducted for the *New Breeding Atlas* in 1988-91. Change in density was assessed by repeating surveys on a sample of river stretches covered in 1987. Expansion or contraction in range was assessed using a questionnaire sent to all BTO Regional Representatives requesting information on the breeding status of sawbills in all 10 km squares in Britain.

3. Of the 300 river stretches selected for re-survey in 1997, 74% were actually surveyed, giving a percentage relative precision of *ca* 22.5%. The breeding status of sawbills was known in 54% of 10 km squares in Britain.

4. There was a significant increase (of 64% overall) in the density of goosanders between 1987 and 1997 (males and redheads: 1987 mean=0.430±0.023, 1997 mean=0.706±0.038; $F_{1,6263}$=32.12, P<0.001; males only: 1987 mean=0.178±0.010, 1997 mean=0.295±0.017; $F_{1,6263}$=30.69, P<0.001) and significant variation among regions (males and redheads: $F_{10,6254}$=15.21, P<0.001; males only: $F_{1,6254}$=11.81, P<0.001). The highest densities were recorded in north-west England and the Borders and southern uplands, the lowest in northern and western Scotland.

   There was no significant change in the density of mergansers, although there were regional differences between the two surveys ($F_{10,6254}$=5.10, P<0.001), possibly suggesting a change in distribution.

5. The most significant increase in goosanders occurred in Wales where density increased by 150%, although it continued to be lower than in northern England and Scotland (density of males and redheads: England: 1987 mean=0.520±0.048, 1997 mean=0.856±0.071; Scotland: 1987 mean=0.451±0.034, 1997 mean=0.654±0.052; Wales: 1987 mean=0.232±0.029, 1997 mean=0.582±0.074).

6. Thirty-two percent of 10 km squares adjacent to those occupied by goosanders in 1987-91 had been newly colonised by 1995-97, compared to 19% for mergansers. In 23 10 km squares, goosanders were absent in 1995-97 where they had previously been recorded in 1987-91, compared to 36 10 km squares for mergansers.

   Goosanders appear to have continued an eastward expansion from Wales into parts of Shropshire, Herefordshire and Gloucestershire. There were no confirmed breeding records from Cornwall, but there was a new breeding record from Exmoor. A number of newly occupied squares were recorded in parts of the southern uplands.

   For red-breasted mergansers, there was a concentration of newly occupied squares around Cumbria (although many of these refer to birds of unknown status only). A number of newly occupied squares on the southern edge of the population found north of

the central lowlands may represent a southward expansion from that population.

7.   Cormorants, herons and kingfishers were also recorded during the river surveys. The densities of cormorants and herons were significantly higher in 1997 than in 1987 (cormorants: 1987 mean=0.053±0.009, 1997 mean=0.104±0.034, $F_{1,6263}$=4.12, $P<0.05$; herons: 1987 mean=0.081±0.007, 1997 mean=0.121±0.011, $F_{1,6263}$=11.56, $P<0.001$). Heron density increased most in Scotland.

The density of Kingfishers recorded on surveyed river sections in northern England in 1997 was lower by 64% than in 1987 (1987 mean=0.025±0.005, 1997 mean=0.009±0.004).

8.   This survey was not designed specifically to estimate changes in cormorant, heron and kingfisher populations and therefore the results for these species must be treated with caution. National surveys to monitor the populations of these species in riverine systems are strongly recommended.

1.   INTRODUCTION

Two sawbilled ducks breed in Britain: the goosander *Mergus merganser* and the red-breasted merganser *Mergus serrator*. Red-breasted mergansers are smaller and slighter than goosanders, although their diet and feeding methods are similar. The diet consists mainly of small fish, including trout and salmon parr (Mills 1962). The goosander is a typical breeding bird of upland rivers, nesting in holes, either in trees or on the ground. It is also known to breed on some meandering lowland reaches and moorland tarns. Red-breasted mergansers nest on the ground, breeding near both fresh and tidal water (Cramp & Simmons 1977).

1.1   The Distribution and Expansion of Goosanders

The first confirmed British breeding records of goosander were in 1871 in Perthshire and Argyll, although breeding had been suspected earlier on the Northern and Western Isles (Holloway 1996). By the end of the nineteenth century, it was not uncommon in Argyll, the north-west Highlands, the Moray Basin and Tay. During the early part of this century, goosanders spread slowly south into Aberdeenshire and Dumfriesshire. In 1941, breeding was first confirmed in England in Northumberland and later in 1950 in Cumbria. Further increases in these counties occurred until the mid-1960s, but meanwhile there appeared to be a decrease in the population in north-west Scotland, possibly due to persecution to protect fish stocks. From the mid-1960s onwards, the southern expansion continued into Durham, north-west Yorkshire and north Lancashire. By the time of the first comprehensive mapping of sawbill distribution in the 1968-72 Breeding Atlas (Sharrock 1976), goosanders had been recorded breeding in Cardiganshire in Wales. Since then, major increases have occurred in populations in northern England, the southern Pennines and the south-west peninsula. The biggest increase, however, has occurred in the Welsh population and much of the uplands has now been colonised. Further expansion has since occurred to the east into Shropshire and Herefordshire. There have been few breeding records from Ireland, most of these in Donegal (Hutchinson 1989).

The Scottish breeding population was described in the *New Breeding Atlas* (Gibbons *et al.* 1993) as widely scattered north of the Central Lowlands, with concentrations along the Great Glen, in the north Grampians and along the rivers Dee and Tay. Breeding populations were most concentrated in the Southern Uplands extending into the border counties of Cumbria and Northumberland and continuing south into Lancashire and parts of Yorkshire. Elsewhere in England, breeding birds were restricted to the south Pennines and a few records from the south-west peninsula. In Wales, breeding was widespread and a recent estimate put the population at 150 pairs (Lovegrove *et al.* 1994). Breeding was absent from the Northern and Western Isles. The 1987 Sawbill Survey estimated there to be 2,700 adult male goosanders in Britain, which is thought to give the most satisfactory indication of the number of pairs (Gregory *et al.* 1997, after Haapanen & Nilsson 1979). This estimate, however, does not take into account breeding birds away from rivers, and may therefore be an underestimation.

1.2   The Distribution and Expansion of Red-breasted Mergansers

Unlike the goosander, the red-breasted merganser has been resident in Britain since at least Neolithic times. However, during the first half of last century, they bred only in western Scotland, no further south than Loch Awe in Argyll (Holloway 1996). Its population expansion has been very similar to that of the goosander. By the late nineteenth century they could be found throughout the Scottish mainland north of the Clyde and Forth valleys, and occasionally bred further south. At this time, the larger loughs of the Irish midlands were well populated.

The southern and eastern expansion continued and by the 1930s, they bred commonly in Dumfriesshire and Kirkcudbrightshire. In 1950, breeding was first recorded in England in Cumbria, followed by rapid expansion into Westmorland, north Lancashire and north-west Yorkshire. The first Welsh breeding record came from Anglesey in 1953, and from mainland Wales in 1957. By the time of the 1968-72 Breeding Atlas (Sharrock 1976), mergansers were breeding in the Derbyshire Peak District. Since then the *New Breeding Atlas* has recorded a thinning of the populations in central and south-west Scotland, but a continued increase in Derbyshire and Wales. In Ireland there have also been declines as the population has retreated towards the north and north-west coasts.

The *New Breeding Atlas* describes the 1988-91 distribution as predominantly northern and western maritime. The population was most abundant at sites around the Irish Sea, in western central Ireland and along the north-west coast of Scotland extending up to the Shetlands. The British population was estimated at 4,300 with a further 1,400 in Ireland.

1.3   Current Legislation

Fish-eating birds are in conflict with the interests of anglers and fisheries. They have been accused of causing damage to fish stocks, particularly Atlantic salmon *Salmo salar* and migratory sea trout *Salmo trutta*. Goosanders and red-breasted mergansers are afforded protection under the provisions of the Wildlife and Countryside Act (1981). However, if there is evidence of 'serious damage' to fisheries, licences can be obtained to control numbers where no other satisfactory solution can be found. Each year in Scotland, licences are issued for the culling of hundreds of birds while smaller numbers are culled in England and Wales.

Young salmonids may form a high proportion of the diet of sawbills (Cramp & Simmons 1977; Feltham 1990), but as yet, there is no irrefutable evidence that these birds do cause 'serious damage' to fisheries, other than small enclosed systems such as fish-farms (Marquiss & Carss 1997). The issue of the impact of fish-eating birds on fish stocks is complicated, as a number of factors need to be considered (for example, they also eat salmon and trout predators). It is not known whether the effect that they have on fish is additive (taking fish that would normally survive in the absence of these birds) or compensatory (taking fish that would otherwise die of other causes). As yet this question remains unanswered.

1.4   The 1997 Breeding Sawbill Survey

This report presents the results of a national survey of breeding sawbills in 1997, similar to that carried out ten years ago. It addresses the question of change in the population and range of sawbills since the 1987 survey and since the production of the *New Breeding Atlas.*
Of the 615 river stretches surveyed in 1987, 300 were selected for re-survey in spring 1997 in order to evaluate the change in sawbill density in their known range. The spring period is thought to be the optimum time for assessing the size of sawbill breeding populations (Gregory *et al.* 1997). It should be noted that this represents birds found on rivers only. As goosanders breed mainly on rivers, the survey gives a good estimate of change for the British population. Many mergansers, however, also breed in coastal areas, so the survey estimates only the population change on riverine systems.

The question of range expansion was addressed by a questionnaire sent to all BTO Regional Representatives requesting information on sawbills in all areas of Britain.

2.   METHODS

2.1   Fieldwork

The fieldwork for the survey was organized through the national network of BTO Regional Representatives. Organizers were asked to find volunteers to cover the river stretches selected from those surveyed in 1987.

Fieldworkers were requested to survey a river stretch on a single occasion between early March and mid-April in order to record the numbers of potential breeding pairs of goosanders and mergansers. The allocated river stretch was divided into 1 km sections and the divisions were marked on a 1:50,000 scale Ordnance Survey map. The observer walked the river stretch, preferably in an upstream direction, recording adult male, redhead and young goosanders and red-breasted mergansers on each 1 km section. 'Redheads' include all females and immature males in their first summer, as they are difficult to separate in the field. The 'young' category was included to record any unusually early duckling broods.

2.2   The Questionnaire

The river surveys were carried out on stretches that had been surveyed in 1987. In order to address the issue of range expansion or contraction, a questionnaire was distributed to all BTO Regional Representatives.

For goosanders and mergansers, the following information was requested for the years 1995-1997, for each 10 km square in Britain:

1.   Presence or absence during the breeding season
2.   If present   (i)   the number of confirmed breeding pairs
                     (ii)   the number of possible breeding pairs
                     (iii)   the number of male and female sawbills with unknown breeding status

Confirmed breeding was indicated by the presence of young, evidence of nesting or pairs performing courtship displays. Possible breeding was recorded if pairs were seen together in suitable habitat during the breeding season.

The data collected were used to produce current distribution maps and maps of change since the *New Breeding Atlas*. Potential breeding recorded during the river surveys in 1997 was included in the maps. The presence of adult male goosanders was considered to be indicative of the presence of breeding pairs. The presence of redheads only was considered to be indicative of the presence of birds of unknown status. The 10 km square in which these were recorded were taken from the starting grid reference of the river stretch surveyed.

2.3   Selection of River Stretches for Survey in 1997

The 1987 Sawbill Survey sampled approximately 9,000 1 km sections of river, half of these in spring and half in summer, with a mean length of a surveyed stretch of 8.2 km (range 1-50 km, median 7 km). The 1997 survey counts were made only in spring in order to concentrate on quantifying numbers of adult male goosanders and mergansers. A number of river stretches were excluded from the 1987 dataset in order to select stretches for re-survey in 1997. These were all stretches not counted in the spring survey period, stretches which were duplicates of previous

counts, and non-riverine sections of a stretch (*eg* lochs). This left 615 river stretches in the 1987 dataset. Only data for adult male goosanders were used in the simulations.

2.3.1 Comparison of Random Sampling with a Stratification Based on the *New Breeding Atlas*

A well chosen stratification strategy can substantially narrow the confidence intervals attached to a population estimate (increase the precision of the estimate) when there is spatial variation in the density of a species (Cochran 1977, Greenwood 1996). In the present study, abundance and presence data from the *New Breeding Atlas* were used to create a stratification scheme and the resulting population estimates, obtained using bootstrap simulations (see below), were compared with those based on simple random sampling. A potential alternative stratification scheme, based on regional variation in goosander densities measured in the 1987 survey, was not considered further for two reasons:-

1.   Although there was considerable variation in goosander density between the 11 regions of Britain used in the 1987 survey (Gregory *et al.* 1997), the number of stretches within each region was inadequate to use each region as a separate stratum. Stratification using these regions would have necessitated the amalgamation of non-adjacent regions (based on similar goosander densities), resulting in strata not dissimilar to those based on data from the *New Breeding Atlas* (see below).

2.   More importantly, if the data used to test the stratification were the same as those on which the stratification was based, interpretation of a result indicating that the regional stratification was superior would be problematic.

2.3.2 Stratification Based on the *New Breeding Atlas*

Goosander abundance data from the *New Breeding Atlas* refer to the mean number of fully-grown birds per tetrad in each 10 km square resulting from timed counts in each tetrad; at least eight of 25 tetrads in each 10 km square were sampled (Gibbons *et al.* 1993). 10 km squares in which goosander abundance was recorded formed the first two strata in the stratification: 'HIGH ABUNDANCE' (>0.2 birds per tetrad, n=208 10 km squares) and 'LOW ABUNDANCE' (>0 to 0.199 birds per tetrad, n=187 10 km squares). In addition to the former timed counts, the presence of goosanders was recorded in a further 279 10 km squares in 1988-91 by casual observations. In the present study, a lower density of goosanders in the latter squares compared to those for which abundance data was recorded was assumed because birds were not located during timed counts. The 10 km squares with goosanders present but no abundance records formed the third stratum for the simulation study: 'PRESENT'. Each river stretch from the 1987 Sawbill Survey was matched to a 10 km square using the starting grid reference for the river stretch. After this matching, 455 river stretches started in 10 km squares in which goosanders were recorded during the *New Breeding Atlas* survey (171 'HIGH', 119 'LOW' and 165 'PRESENT') but 162 stretches could not be matched to a 10 km square containing goosanders in 1988-91 (of which 52 had goosanders recorded within them in the 1987 survey). The majority of the 162 stretches which could not be matched to a *New Breeding Atlas* 10 km square containing goosanders started in a 10 km square adjacent to square(s) in which goosanders were recorded in 1988-91 (presumably because the 1987 survey asked observers to select river stretches which they thought might hold breeding goosanders). Therefore, all river stretches which started in 10 km squares adjacent to occupied *New Breeding Atlas* squares were included in a fourth stratum ('EDGE', n=139 stretches) for the simulation study. Using the four strata scheme, 594 out of the

615 river stretches surveyed in 1987 could be used in the simulation study (containing a total of 860 adult male goosanders). The allocation of river stretches to strata and mean densities within each stratum are shown in the Table 2.3.1.

2.3.3   Types of Simulation Undertaken

Three types of bootstrap were undertaken for comparison:-

1   Random selection of river stretches from all strata pooled (from the total of 594 stretches).

2   Four strata scheme, with random selection from each stratum of a sample proportional to the total number of river stretches available in the stratum.

3   Four strata scheme, with random selection from each stratum of a sample proportional to the coefficient of variation (mean/variance) of goosander density in the stratum.

As the distribution of the lengths of sampled stretches did not display a high degree of skew, the simulations selected river stretches up to a total number of stretches, rather than up to a total required river length. For each bootstrap, the required sample(s) were taken without replacement and then resampled with replacement 999 times, and the 25th and 974th estimates were taken as the 95% confidence limits for the mean (Greenwood in Shrubb & Lack 1991). Each simulation of this type was carried out five times (due to time constraints, ideally it would be 999 times). For bootstrap type (1), the density of birds in all sampled stretches (birds per km) was multiplied by the total river length in all 594 stretches to obtain the 'population estimate'. For (2) and (3), the density in each stratum was multiplied by total river length in each stratum, and the populations in the four strata were pooled to give the final population estimate. Each of the bootstrap types (1) to (3) was run with sample sizes of 500, 400, 300 and 200 river stretches. For each run of a bootstrap, the percentage relative precision (PRP) was calculated as:-

$$\text{PRP (\%)} = \frac{\text{974th estimate - 25th estimate}}{\text{Mean estimate}} \times 50$$

The PRP gave a measure of the precision of the population estimate obtained by each run of the simulation. For each combination of sample size and sampling strategy, five PRP values were obtained, and the mean of these was used to compare the three sampling types across the range of sample sizes considered.

2.3.4   Simulation Results and Choice of Sampling Strategy

The results of the simulation are shown in Table 2.3.2 and in Figures 2.3.1 and 2.3.2. As expected, the precision of the 'population estimate' decreased as the number of river stretches sampled was reduced but the stratification scheme had little influence in increasing precision, even when stretches were sampled in proportion to the variation in goosander density within each stratum. It was decided that we would use the stratification proportional to the number of river stretches in each stratum, and attempt to re-survey 500 river stretches. These were 144 stretches from the 'HIGH ABUNDANCE' stratum, 100 from the 'LOW ABUNDANCE' stratum, 139 from the 'PRESENT' stratum and 117 from the 'EDGE' stratum. All 10 km squares which did not have goosander present either during the Atlas survey or during the 1987 Sawbill Survey were addressed using the 'questionnaire survey', as were the 23 squares

containing river stretches which were surveyed in 1987 but did not fall into the 'EDGE' stratum for the purposes of the simulation study.

After sending details of the stretches to be re-surveyed to the BTO's Regional Representatives, it was decided that the total length of river to be re-surveyed was far in excess of what was practically possible. Removing the longest stretches from the analysis (*eg* all those >20 km, 2% of the stretches) was shown to have little effect on PRP when the simulation was repeated with samples of 100 and 500 stretches (Stratification 1). A pragmatic approach was taken to reach a compromise between statistical precision and feasibility of coverage. Of the random sample of 500 stretches which had already been sent out to Regional Representatives, all stretches greater than 20 km in length were removed. Three stretches were identified as not following the course of a river and were therefore also removed. A sub-sample of 300 stretches was then extracted randomly from the remaining sample, using the *New Breeding Atlas* stratification and allocation proportional to the number available in each stratum. When assuming that 250 of these stretches would actually be re-surveyed, the simulations suggested that estimates were ± *ca* 22% of the mean (Figure 2.3.2).

3.   RESULTS

3.1   Survey Coverage

The distributions of river stretches surveyed in spring 1987 and spring 1997 are shown in Figures 3.1.1 and 3.1.2. In the 1997 survey, 222 of the 300 selected stretches were actually re-surveyed, comprising *ca* 1750 1 km sections. This gives a PRP of 22.5% (Figure 3.1.1). In order to pair river stretches surveyed in 1997 with those surveyed in 1987, some stretches were amalgamated, leaving a total of 218 river stretches for analysis. Mean stretch length was 8.1 km, range 1-30 km and median 7 km. In order to refine the analysis, Britain was split into England, Scotland and Wales and then further into 11 regions based on hydrometric areas (Figure 3.1.3, following Gregory *et al.* 1997). Mean, range and median stretch lengths in the 11 regions and in England, Scotland and Wales are shown in Tables 3.1.1 and 3.1.2.

The questionnaire survey covered most regions outside the river survey. It was not possible to collect enough data for 1997 from the questionnaires, as it often takes a considerable amount of time to collate all of the information, hence questionnaire data from only 1995 and 1996 have been used. Potential breeding birds recorded during the river surveys in 1997 have been included.

3.2   Sawbill Densities

In Britain, mean goosander (adult males and redheads) density was 0.706 ± 0.038 S.E. birds per 1 km section of surveyed river. Mean red-breasted merganser density was 0.059 ± 0.013 S.E. Only two broods of young were recorded, both of goosander, one in north-east England, the other in Wales.

The 1987 and 1997 densities of goosanders and red-breasted mergansers (number of birds per 1 km surveyed river section) in the 11 regions are shown in Tables 3.2.1 and 3.2.2. One-way analysis of variance (Table 3.2.3) showed that there was significant variation among regions for each species (goosanders: $F_{10,6254}=15.21$, $P<0.001$; mergansers: $F_{10,6254}=9.82$, $P<0.001$). Goosanders showed a significant increase in density between the 1987 and 1997 surveys (total goosanders: 1987 mean=0.430 ± 0.023, 1997 mean=0.706 ± 0.038; $F_{1,6263}=32.12$, $P<0.001$; male goosanders: 1987 mean=0.178 ± 0.010, 1997 mean=0.295 ± 0.017; $F_{1,6263}=30.69$, $P<0.001$). There was no significant difference between the number of red-breasted mergansers in the 1987 and 1997 surveys (Table 3.2.3). However, there were regional differences between the two surveys ($F_{10,6254}=5.10$, $P<0.001$).

Due to the small size of the dataset for some regions, further exploratory analysis was carried out only by country. Densities in Britain, and in England, Scotland and Wales are shown in Tables 3.2.4 and 3.2.5. Goosander density per 1 km section of surveyed river was highest in England and lowest in Wales. Merganser density was highest in Scotland and lowest in England. Paired t-tests on the density of birds in each country (Tables 3.2.6 and 3.2.7) between surveys revealed that there was a highly significant increase in the density of goosanders in Wales (total: $T_{42}=3.891$, $P<0.001$; adult males: $T_{42}=4.345$, $P<0.001$), but not in England or Scotland (total: $T_{61}=1.869$ and $T_{112}=0.518$ respectively, N.S.; males: $T_{61}=1.778$ and $T_{112}=0.757$ respectively, N.S.). There was no significant change in the number of red-breasted mergansers between surveys.

3.3   The Questionnaire Survey

The distribution of sawbills recorded in the 1987 survey and in the *New Breeding Atlas* (1988-91) and by the questionnaire survey (1995-96) and 1997 river survey are shown in Figures 3.3.1 and 3.3.2 (goosanders) and Figures 3.3.5 and 3.3.6 (mergansers). Changes in sawbill breeding status that have occurred between the surveys are shown in Figures 3.3.3 and 3.3.4 (goosanders) and Figures 3.3.7 and 3.3.8 (mergansers). The proportion of 10 km squares for which data were either not returned or where the breeding status of sawbills was 'unknown' was 45.8%. These are displayed in the distribution maps and change maps as '±' and '?' respectively. The second change maps (Figures 3.3.4 and 3.3.8) show the 1987-91 breeding distribution with 10 km squares now known to be occupied, but previously unoccupied marked by '+' and 10 km squares no longer occupied marked by open circles. Squares that are 'unknown' have been left as they were for the period 1987-91.

Goosanders were absent from 23 10 km squares where they may have bred in 1987-91. New breeding records were recorded in 67 10 km squares adjacent to previously occupied squares and in ten squares not adjacent to previously occupied squares.

In total, 'known' data were available for 207 squares adjacent to those previously occupied (440 'unknown'). Therefore, potentially, 32% of squares adjacent to those occupied in 1987-91 have been colonised by goosanders.

Mergansers were absent from 36 10 km squares where they may have bred in 1987-91. New breeding records were recorded in 44 10 km squares adjacent to previously occupied squares and in five squares not adjacent to previously occupied squares. 'Known' data were available for 231 squares adjacent to those previously occupied (389 'unknown'). Therefore 19% of squares adjacent to those previously occupied by mergansers may have been colonised.

3.4   Cormorants, Herons and Kingfishers

The densities of cormorants, herons and kingfishers on surveyed river sections in Britain, and in England, Scotland and Wales in 1997 are shown in Table 3.4.1. One-way analysis of variance (Table 3.4.2) showed that cormorants increased significantly between surveys (1987 mean=0.053 ± 0.009, 1997 mean=0.104 ± 0.034; $F_{1,6263}$=4.12, P<0.05). Herons showed a significant increase in density between surveys (1987 mean=0.081 ± 0.007, 1997 mean=0.121 ± 0.011; $F_{1,6263}$=11.56, P<0.001) and significant variation among regions ($F_{10,6254}$=4.23, P<0.001). The interaction between survey and regions was also significant ($F_{10,6254}$=2.25, P<0.05). There was significant variation in kingfisher density among regions ($F_{10,6254}$=5.04, P<0.001), but no change in density between surveys.

Further exploratory analysis (paired t-tests) on densities of birds on surveyed river stretches in each country (Table 3.4.3) revealed that heron density had increased significantly in Scotland (but not England or Wales) between surveys (T_{112}=2.801, P<0.01).

4. DISCUSSION

4.1 Sawbill Density and Range

Goosanders have continued to increase both in range and density (by 64% overall), particularly in Wales, where the density on surveyed rivers has increased 150%. However, the number of birds per surveyed river section remains lower than in Scotland and the north of England. If the habitat is equally suitable here, this may explain why goosander numbers continue to increase so rapidly in Wales. In Scotland and northern England, goosander density did not change significantly

Figure 3.3.4 shows some evidence of a continuing eastward expansion of goosanders from the Welsh population into areas of Shropshire, Herefordshire and Gloucestershire. On the south-west peninsula, there were no confirmed breeding records in Cornwall, but there was a new breeding record from Exmoor. Newly occupied squares were adjacent to previously occupied squares in 87% of cases, although there was a concentration of new records from parts of the southern uplands (which also recorded one of the highest goosander densities in the river survey).

The mean density of red-breasted mergansers on surveyed river sections was lower in 1997 than in 1987, but not significantly so. There was, however, a significant interaction between surveys and regions. This might suggest a distributional change since 1987. Mergansers are predominantly a coastal species, however, and our results only refer to the population found on riverine systems.

There was a concentration of newly occupied squares around Cumbria. However, many of these refer to the presence of mergansers of unknown breeding status only, which may not be breeding birds. This may also be the case for the two newly occupied squares in Gloucestershire and Radnorshire. There are a number of newly occupied squares on the southern edge of the population found north of the central lowlands which could represent a degree of southward expansion from that population.

4.2 Densities of Cormorants, Herons and Kingfishers

The survey was not designed specifically for these species. However, it does give an indication as to the change in densities on rivers since the 1987 survey. An increase in cormorant numbers is fuelling the debate over their effect on fish stocks. Fisheries and fishermen argue that they are affecting the yield of fish. It appears that their numbers, at least on rivers, may have increased, thus demonstrating the urgent need for a cormorant survey on this habitat. Increases in heron numbers were most evident in Scotland. The number of herons breeding at colonies counted by the BTO's Heronries Census in 1995-96 reflects this change (Marchant 1997).

Kingfishers may be declining in northern England (results were significant at 10% level). The Kingfisher is on the Amber list of Species of Conservation Concern in the U.K. (Gibbons *et al.* 1996) and in Table 4 of Species of Conservation Importance (JNCC 1996). Tucker and Heath (1994) reported that populations have fallen in a number of European countries, due to industrial and agricultural pollution. As a result, it has been declared a Species of European Conservation Concern (Category 3). Kingfishers can be easily and successfully monitored and give an indication as to the health of river ecosystems, therefore it would be worthwhile investigating the status of the British population more thoroughly.

Acknowledgements

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Stratum name	n stretches	Mean density *males km⁻¹*	Variance	Coefficient of variation
HIGH ABUNDANCE	171	0.25297	0.14603	0.577
LOW ABUNDANCE	119	0.15539	0.07485	0.482
PRESENT	165	0.14086	0.07291	0.518
EDGE	139	0.10268	0.05721	0.557

Table 2.3.1   The allocation of river stretches to strata and mean male goosander densities within each stratum.

Sample size	Random Mean PRP (range)	Stratified 1 Mean PRP (range)	Stratified 2 Mean PRP (range)
500	16.5 (16.3-16.9)	16.1 (14.9-17.9)	16.1 (15.4-16.9)
400	18.4 (17.7-18.9)	17.2 (15.2-18.8)	17.1 (16.4-18.0)
300	20.3 (19.1-21.7)	21.1 (19.5-21.8)	19.5 (19.0-21.5)
200	25.4 (22.7-29.2)	24.1 (22.6-25.5)	23.6 (20.3-26.2)

Table 2.3.2   Results of the simulations based on (1) random selection of river stretches (2) four strata scheme with random selection from each stratum of a sample proportional to the total number of river stretches available in each stratum (stratified 1) (3) four strata scheme with random selection from each stratum of a sample proportional to the coefficient of variation (mean/variance) of male goosander density in the stratum (stratified 2).

Region	n	Sum km	Mean km	Minimum km	Maximum km	Median km
NEE	35	321	9.2	3	21	9
NWE	27	230	8.5	2	30	7
BSU	44	390	8.9	1	18	8
CEL	3	17	5.7	5	6	6
NOS	1	12	12.0	12	12	12
NWH	10	89	8.9	2	22	7
TNE	38	293	7.7	2	17	6
WES	17	154	9.1	2	20	8
NWA	10	49	4.9	3	8	4.5
SWA	24	129	5.4	3	11	5
WWA	9	78	8.7	5	15	8

Table 3.1.1   Mean, minimum and maximum, median and total lengths of river stretches surveyed in the 11 regions of Britain in 1997. See Figure 3.1.3 for the definition of the regions.

Country	n	Sum km	Mean km	Minimum km	Maximum km	Median km
England	62	551	8.9	2	30	8
Scotland	113	955	8.5	1	22	7
Wales	43	256	6.0	3	15	5

Table 3.1.2   Mean, minimum and maximum, median and total lengths of river stretches surveyed in England, Scotland and Wales in 1997.

Region	n	Male	Redhead	Total
NEE	321	0.334±0.041	0.426±0.048	0.760±0.083
NWE	230	0.399±0.054	0.596±0.086	0.995±0.126
BSU	390	0.382±0.043	0.589±0.066	0.971±0.101
CEL	17	0.353±0.170	0.412±0.173	0.765±0.327
NOS	12	0	0	0
NWH	89	0.180±0.054	0.135±0.043	0.315±0.094
TNE	293	0.253±0.044	0.335±0.058	0.587±0.091
WES	154	0.097±0.026	0.143±0.035	0.240±0.058
NWA	49	0.152±0.062	0.196±0.086	0.348±0.129
SWA	129	0.349±0.054	0.457±0.065	0.806±0.111
WWA	78	0.118±0.056	0.224±0.104	0.342±0.129

Table 3.2.1   Mean number ±S.E. of goosanders per 1 km section of surveyed river in 11 regions of Britain in 1997. See Figure 3.1.3 for the definition of the regions.

Region	n	Male	Redhead	Total
NEE	321	0	0	0
NWE	230	0.032±0.012	0.028±0.011	0.060±0.023
BSU	390	0.016±0.007	0.024±0.010	0.040±0.016
CEL	17	0	0	0
NOS	12	0	0	0
NWH	89	0.011±0.011	0.011±0.011	0.023±0.023
TNE	293	0.096±0.033	0.099±0.036	0.195±0.066
WES	154	0	0	0
NWA	49	0.065±0.037	0.109±0.071	0.174±0.105
SWA	129	0.008±0.008	0.008±0.008	0.016±0.016
WWA	78	0.053±0.032	0.013±0.013	0.066±0.043

Table 3.2.2 Mean number ±S.E. of red-breasted mergansers per 1 km section of surveyed river in 11 regions of Britain in 1997. See Figure 3.1.3 for the definition of the regions.

		d.f	Sums of squares	Mean square	F-value	Prob>F
Male goosander	Region	10	54.31	5.43	11.81	<0.001
	Survey	1	14.11	14.11	30.69	<0.001
	Region*Survey	10	3.66	0.37	0.80	0.633
	Error	6243	2870.90	0.46		
	Total	6264	2942.99			
Total goosander	Region	10	366.26	36.63	15.21	<0.001
	Survey	1	77.35	77.35	32.12	<0.001
	Region*Survey	10	19.18	1.92	0.80	0.632
	Error	6243	15031.24	2.41		
	Total	6264	15494.03			
Male merganser	Region	10	9.81	0.98	10.09	<0.001
	Survey	1	0.24	0.24	2.47	0.116
	Region*Survey	10	3.59	0.36	3.69	<0.001
	Error	6243	606.70	0.10		
	Total	6264	620.34			
Total merganser	Region	10	29.46	2.95	9.82	<0.001
	Survey	1	0.30	0.30	1.01	0.315
	Region*Survey	10	15.29	1.53	5.10	<0.001
	Error	6243	1873.47	0.30		
	Total	6264	1918.53			

Table 3.2.3   Results of one-way analysis of variance on numbers of male goosanders and mergansers and total numbers (males and redheads) of goosanders and mergansers on surveyed river sections in Britain in 1987 and 1997.

		1987			1997			
		sum	mean±S.E.	n	sum	mean±S.E.	n	nmiss
Britain	Male	806	0.178±0.010	4537	509	0.295±0.017	1728	22
	Redhead	1144	0.252±0.015		711	0.412±0.024		
	Total	1950	0.430±0.023		1220	0.706±0.038		
	Young	10	0.002±0.002		8	0.005±0.004		
England	Male	300	0.221±0.020	1357	193	0.361±0.033	535	4
	Redhead	406	0.299±0.030		265	0.495±0.045		
	Total	706	0.520±0.048		458	0		
	Young	10	0.007±0.007		0	0.856±0.071		
Scotland	Male	427	0.184±0.015	2316	255	0.271±0.024	942	13
	Redhead	617	0.266±0.021		361	0.383±0.034		
	Total	1044	0.451±0.034		616	0.654±0.052		
	Young	0	0		1	0.001±0.001		
Wales	Male	79	0.091±0.013	864	61	0.243±0.035	251	5
	Redhead	121	0.140±0.020		85	0.339±0.049		
	Total	200	0.232±0.029		146	0.582±0.074		
	Young	0	0		7	0.028±0.028		

Table 3.2.4 Mean number ±S.E. of goosanders per 1 km section of surveyed river in Britain, England, Scotland and Wales in 1987 and 1997. 'nmiss' is the number of missing values *ie* the number of sections for which data were not collected.

		1987			1997			
		sum	mean±S.E.	n	sum	mean±S.E.	n	nmiss
Britain	Male	196	0.043±0.005	4537	50	0.029±0.006	1728	22
	Redhead	146	0.032±0.004		52	0.030±0.007		
	Total	342	0.075±0.008		102	0.059±0.013		
	Young	6	0.001±0.001		0	0		
England	Male	29	0.021±0.006	1357	7	0.013±0.005	535	4
	Redhead	15	0.011±0.005		6	0.011±0.005		
	Total	44	0.032±0.010		13	0.024±0.009		
	Young	0	0		0	0		
Scotland	Male	110	0.048±0.007	2316	35	0.037±0.011	942	13
	Redhead	93	0.040±0.006		39	0.041±0.012		
	Total	203	0.088±0.012		74	0.079±0.022		
	Young	6	0.003±0.003		0	0		
Wales	Male	57	0.066±0.016	864	8	0.032±0.013	251	5
	Redhead	38	0.044±0.012		7	0.028±0.014		
	Total	95	0.110±0.027		15	0.060±0.025		
	Young	0	0		0	0		

Table 3.2.5   Mean±S.E. number of red-breasted mergansers per 1 km section of surveyed river in Britain, England, Scotland and Wales in 1987 and 1997. 'nmiss' is the number of missing values *ie* the number of sections for which data were not collected.

		Mean difference±S.E. (1997-1987)	t	P>t	Significance	d.f.
Britain	Males	0.514±0.209	2.463	<0.05	*	217
	Redheads	0.555±0.299	1.854	0.065	(*)	
	Total	1.069±0.468	2.282	<0.05	*	
England	Males	0.710±0.399	1.778	0.080	(*)	61
	Redheads	1.129±0.681	1.657	0.103	N.S.	
	Total	1.839±0.984	1.869	0.067	(*)	
Scotland	Males	0.246±0.327	0.757	0.451	N.S.	112
	Redheads	0.115±0.420	0.274	0.785	N.S.	
	Total	0.363±0.700	0.518	0.605	N.S.	
Wales	Males	0.930±0.214	4.345	<0.001	***	42
	Redheads	0.884±0.340	2.601	<0.05	*	
	Total	1.814±0.466	3.891	<0.001	***	

Table 3.2.6 Results of paired t-tests on the difference in the number of goosanders on river stretches in 1987 and 1997 in Britain, England, Scotland and Wales.

N.S.	Not significant
(*)	$P \leq 0.10$
*	$P \leq 0.05$
**	$P \leq 0.01$
***	$P \leq 0.001$

		Mean difference±S.E. (1997-1987)	t	P>t	Significance	d.f.
Britain	Males	-0.060±0.091	-0.655	0.513	N.S.	217
	Redheads	0.041±0.089	0.466	0.641	N.S.	
	Total	-0.018±0.169	-0.108	0.914	N.S.	
England	Males	-0.161±0.231	-0.697	0.488	N.S.	61
	Redheads	-0.097±0.132	-0.736	0.465	N.S.	
	Total	-0.258±0.346	-0.745	0.459	N.S.	
Scotland	Males	-0.071±0.114	-0.623	0.535	N.S.	112
	Redheads	0.080±0.150	0.531	0.596	N.S.	
	Total	0.009±0.255	0.035	0.972	N.S.	
Wales	Males	0.116±0.116	1.000	0.323	N.S.	42
	Redheads	0.140±0.103	1.355	0.183	N.S.	
	Total	0.256±0.200	1.280	0.208	N.S.	

Table 3.2.7   Results of paired t-tests on the difference in the number of red-breasted mergansers on river stretches in 1987 and 1997 in Britain, England, Scotland and Wales.

N.S.   Not significant
(*)   P≤0.10
*   P≤0.05
**   P≤0.01
***   P≤0.001

			1987			1997		
		sum	mean±S.E.	n	sum	mean±S.E.	n	nmiss
Cormorant	Britain	239	0.053±0.009	4537	180	0.104±0.034	1728	22
	England	100	0.074±0.023	1357	56	0.105±0.038	535	4
	Scotland	88	0.038±0.008	2316	111	0.118±0.059	942	13
	Wales	51	0.059±0.016	864	13	0.052±0.025	251	5
Heron	Britain	369	0.081±0.007	4537	209	0.121±0.011	1728	22
	England	121	0.089±0.016	1357	63	0.118±0.018	535	4
	Scotland	130	0.056±0.006	2316	110	0.117±0.016	942	13
	Wales	118	0.137±0.019	864	36	0.143±0.025	251	5
Kingfisher	Britain	59	0.013±0.002	4537	22	0.013±0.003	1728	22
	England	34	0.025±0.005	1357	5	0.009±0.004	535	4
	Scotland	10	0.004±0.002	2316	7	0.007±0.003	942	13
	Wales	15	0.017±0.005	864	10	0.040±0.015	251	5

Table 3.4.1   Mean±S.E. numbers of cormorants, herons and kingfishers per 1 km section of surveyed river in Britain, England, Scotland and Wales in 1987 and 1997. 'nmiss' is the number of missing values *ie* the number of sections for which data were not collected.

		d.f	Sums of squares	Mean square	F-value	Prob>F
Cormorant	Region	10	5.83	0.58	0.72	0.704
	Survey	1	3.33	3.33	4.12	<0.05
	Region*Survey	10	7.44	0.74	0.92	0.511
	Error	6243	5036.38	0.81		
	Total	6264	5052.98			
Heron	Region	10	8.63	0.86	4.23	<0.001
	Survey	1	2.36	2.36	11.56	<0.001
	Region*Survey	10	4.59	0.46	2.25	<0.05
	Error	6243	1273.10	0.20		
	Total	6264	1288.67			
Kingfisher	Region	10	0.85	0.08	5.04	<0.001
	Survey	1	0.00	0.00	0.00	0.982
	Region*Survey	10	0.25	0.03	1.49	0.134
	Error	6243	104.85	0.02		
	Total	6264	105.95			

Table 3.4.2   Results of one-way analysis of variance on numbers of cormorants, herons and kingfishers on surveyed river sections in Britain in 1987 and 1997.

		Mean difference±S.E. (1997-1987)	t	P>t	Significance	d.f.
Britain	Cormorants	0.161±0.368	0.436	0.663	N.S.	217
	Herons	0.151±0.131	1.155	0.249	N.S.	
	Kingfishers	-0.046±0.049	0.945	0.346	N.S.	
England	Cormorants	-0.290±0.491	-0.591	0.557	N.S.	61
	Herons	-0.065±0.255	-0.253	0.801	N.S.	
	Kingfishers	-0.226±0.120	-1.875	0.066	(*)	
Scotland	Cormorants	0.575±0.647	0.889	0.376	N.S.	112
	Herons	0.407±0.145	2.801	0.006	**	
	Kingfishers	0.000±0.036	0.000	1.000	N.S.	
Wales	Cormorants	-0.279±0.295	-0.948	0.349	N.S.	42
	Herons	-0.209±0.396	-0.529	0.600	N.S.	
	Kingfishers	0.093±0.144	0.644	0.523	N.S.	

Table 3.4.3   Results of paired t-tests on the difference in the number of cormorants, herons and kingfishers on river stretches in 1987 and 1997 in Britain, England, Scotland and Wales.

N.S.	Not significant
(*)	P≤0.10
*	P≤0.05
**	P≤0.01
***	P≤0.001

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