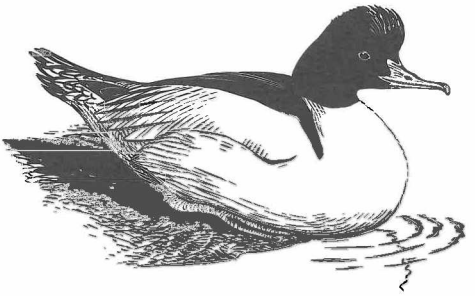
Seasonal switching between habitats and changes in abundance of Goosanders *Mergus merganser* within a Scottish river system.



M. MARQUISS and K. DUNCAN

Systematic weekly counts during 1988, in five wetland habitats within the Dee watershed, showed that Goosanders were most abundant on the upper river in spring and summer, on the lower river in late summer, autumn and winter, and on lochs in late winter and spring. Many birds were in pairs in winter and spring, but adult males were absent from June to October, when the population was successively dominated by females, then females with broods, then juveniles. Most females nested far up tributaries and moved downstream with small ducklings to nursery areas on the main stem Once grown, juveniles possibly moved downstream again before they dispersed from the watershed. Counts on a sample of river sections in mid-April quantified a strong inverse relationship between Goosander density and elevation, and the total population then was estimated to be 173 (including about 61 pairs). A census of the whole river in July estimated a population of 278 birds (including 32 broods) and in December, 66 birds. It is argued that the use of various habitats was associated with food availability, security from predators, pairing and nesting.

Keywords: Rivers, Population Change, Counts, Food Availability, Predation, Goosander

Goosanders *Mergus merganser* are large piscivorous ducks that use a variety of habitats, mainly streams and rivers, but also lakes (lochs) and shallow inshore estuaries (firths) (Cramp & Simmons 1977, Owen et al. 1986). On rivers in Scotland they can consume large numbers of Salmon *Salmo salar parr* (Mills 1962, Marquiss et al. 1991), and are shot under licence to prevent serious damage to fisheries. There is debate as to whether Goosanders damage fisheries, and controversy has surrounded estimates of Goosander abundance. In particular, it is not known whether populations are stable or increasing within the established breeding range.

Estimates of the wintering population have been compromised by the lack of systematic counts on rivers (Owen *et al.* 1986) and estimates of the breeding population, by the precise timing of spring counts. Many counts have taken place in March but these may precede the main arrival of birds in breeding areas (Carter & Evans 1984, 1986, Murray 1988). The objective of the present study was to document variation in the abundance and distribution of Goosanders throughout the year within the watershed of a river which supports a commercially important Salmon fishery. Counts at specific times of year were then used to estimate midwinter population, breeding numbers and success.

Study area

The study area (**Figure 1**) comprised the 2000 km^2 catchment of the river Dee, centred about Lat. 57°N Long. 3°W in Grampian Region, Scotland. The biology, geography and land use of the Dee watershed have been comprehensively reviewed (Jenkins 1985). The river, about 140 km long, drains parts of the East Central Highlands, falling from an elevation of ca 1200 m a.s.l. to the sea. Its tributaries are much divided so that altogether there are about 390 km of waterway of width exceeding five metres from bank to bank, and many narrower streams. The river is steep in profile compared with other large British rivers, much of it runs over gravel or cobbles, and there is virtually no lowland 'depositing' section or estuary. For much of the year the river receives snow melt. It drains predominantly granite hill ground and its waters are nutrient-poor, but pollution is rare so water 'quality' is consistently high. In the river there are only 11 species of freshwater fishes, and

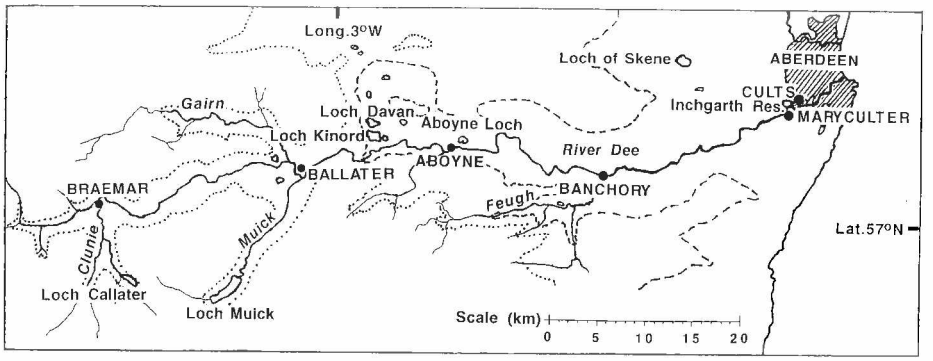


Figure 1. Map of the Dee watershed showing the river, the main tributaries, lochs and places cited in the text. Higher ground is denoted by two contours 183 m (-) and 427 m (...).

only five (Brook Lamprey *Lampetra planeri*, Salmon, Trout *Salmo trutta*, Minnow *Phoxinus phoxinus* and Eel *Anguilla anguilla*) are widespread and abundant. There are relatively few substantial standing waters in the catchment. Lochs in the hills freeze in most winters; they are deep, cold and oligotrophic, and support populations of small Trout. Lowland lochs (less than 300 m elevation), particularly those draining arable land, are rich with a relatively luxuriant macrophyte flora, and support populations of Perch *Perca fluviatilis*, Pike *Esox lucius* and Eels.

Methods

Seasonal abundance

Throughout 1988 we counted Goosanders in 5 parts of the watershed representing various habitats:

(i) *Mouth* - 5.2 km of the Dee from Cults to Aberdeen, where the river was wide (90-115m), deep and tidal.

(ii) Lower river - 7.4 km of the 19 km stretch between Maryculter and Banchory, about 20 km upstream from the mouth, between 10 and 30 m asl. Here the gradient was steeper (1.5 m km^{-1}), the river bottom cobbled in places, and the width 50-75 m.

(iii) Upper river - 10.6 km of the 21 km stretch between Aboyne and Ballater, about 70 km from the mouth, 120-200 m asl., where the river was still wide (40-50 m) but the gradient steeper (3.5 m km^{-1}) and the cobbled substrate frequently exposed as unvegetated shingle.

(iv) *Tributaries* - 36 km, including part of the Feugh, and most of the Gairn, Muick, Clunie and Callater. These sections varied in elevation from 250-450 m asl., in width from 10-20 m and in gradient from 8-17 m km^{-1}. Their substrates were mainly large cobbles and boulders.

(v) Sixteen *lochs* including all those at lower elevations and the two largest high-elevation lochs, Muick and Callater.

The main stem of the river (habitats i, ii & iii) was counted every week, within two hours after sunrise, when Goosanders had left their roost to forage (Marquiss & Duncan, *Wildfowl* this issue) but had not been disturbed by human activities on the river. The tributaries and lochs were generally less easily accessible and took longer to visit, but nevertheless were counted at least once every two weeks. These counts were usually in the morning but sometimes continued into the afternoon, especially in winter when days were short. The winter months of 1988 were mild and tributaries did not ice over. One of the high-elevation lochs froze briefly in January, but there was still open water in the middle on both count days.

Most counts were conducted from viewpoints, carefully scanning the river or loch without disturbing the birds. Stretches of river/tributary without easily accessible viewpoints were walked, scanning thoroughly at every bend. Though time-consuming, the diligent use of such methods minimised the problem of trying to disentangle repeated counting of disturbed birds. This method also meant that we could take time to age and sex Goosanders as far as was possible. Undisturbed broods were easy to detect and we could count ducklings and judge their stage of development before moving around them to avoid

further problems of skulking, fragmented or 'mixed' broods.

Where possible birds were identified as male or female, and adult or in their first year, using head shape and the colour of plumage and legs and feet (details in Marquiss & Duncan, *Wildfowl* this issue). Paired birds were obvious because the male closely attended the female. Broods were also easy to distinguish because they were in discrete parties of ducklings at a similar stage of development and attended by a single female (we only twice saw unattended broods, and once a brood contain-

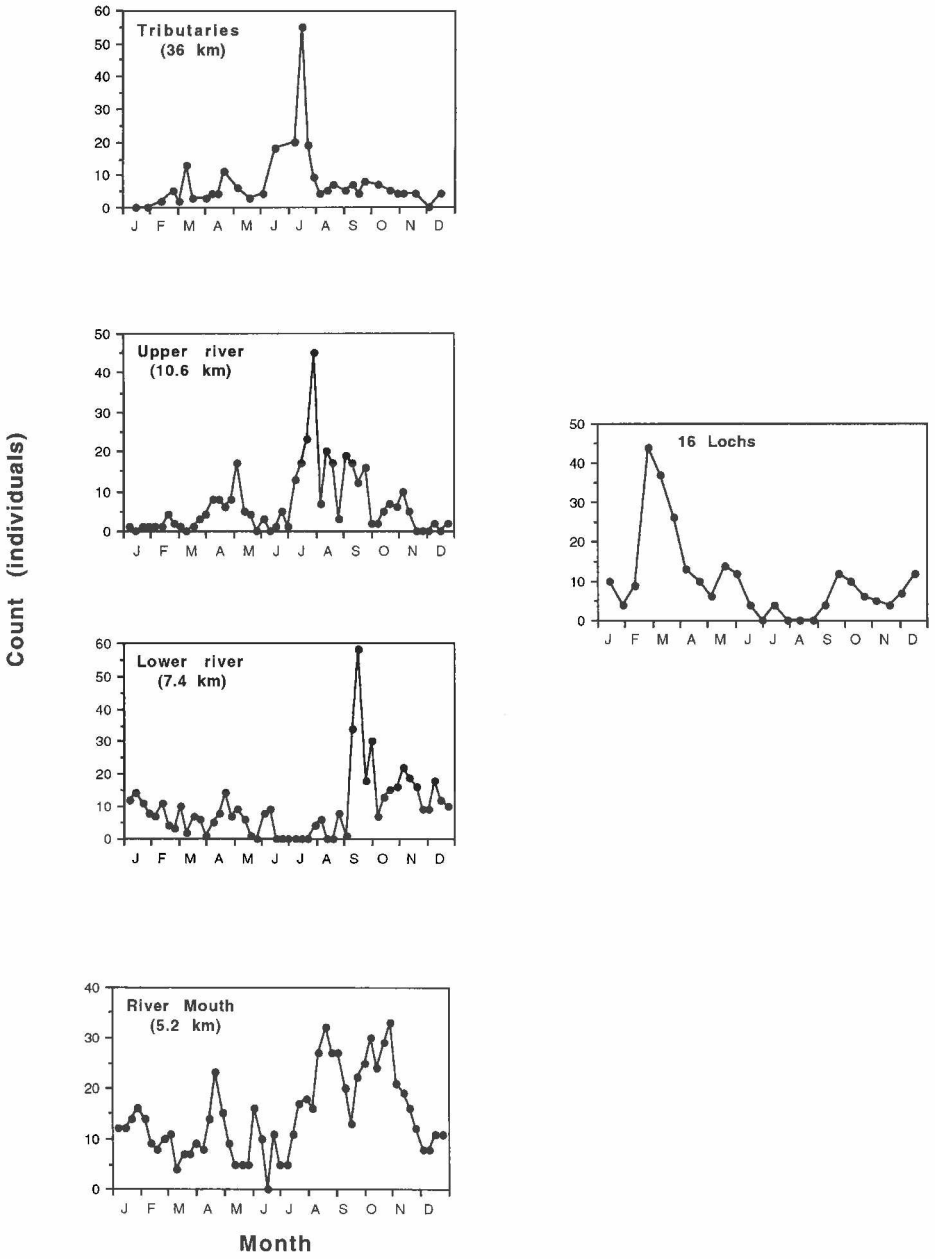


Figure 2. Seasonal trends in regular weekly counts of Goosanders in 1988, on four parts of the river and 16 lochs within the Dee watershed.

ing ducklings of different sizes). We could therefore categorise almost all of the goosanders we saw into one of six cohorts: paired birds, unpaired adult males, yearling males (January-July), unpaired females (January-August), broods (June-August), and 'redheads' (unsexed juveniles and unpaired females, September -December).

Population estimates

To estimate the breeding population of the whole river system, the production of ducklings and the midwinter population, we counted Goosanders over most of the watershed, in three major censuses.

The numbers of pairs we counted on the river increased up to mid-April so we chose to estimate the breeding population from counts then, corrected for the number of females absent from the river because they had already started incubation. From a study of Goosander nesting (Marquiss & Cook *unpublished*) we found that individual females started incubation between 9 April and 26 May, and that by mid-April 15% were sitting on eggs. Breeding production was estimated from a count of well-grown ducklings near fledge in late July. The midwinter population was estimated from a count in December.

To compare Goosander distribution with river hydrographic features, we subdivided the whole river and its tributaries into 10 km sections from the mouth upstream. For each section we estimated mean elevation (m a.s.l.) and gradient (m/km) from maps (Ordnance Survey 1:50,000 second series) and estimated the width (m) at about 1-km intervals in the field.

None of the three censuses covered the whole river system (390 km of waterways > 5 m in width), although the December and July counts probably covered all parts of the river used by Goosanders at those times of year. In December, all the main stem (120 km) and 140 km of the tributaries were covered, a total of 260 km. The same stretches were searched in July together with an additional 70 km of tributaries, making 330 km in all. In mid-April there was insufficient time to search all the breeding and foraging habitat, so samples of seven 10-km sections of the main river and twelve 10-km sections of tributaries were counted. These sections were selected to cover a range of elevations (up to 550 m asl), widths (down to 2 m across) and gradients (up to 31 m/km over a 10-km section) because it was anticipated that, like Red-breasted Mergansers (Marquiss & Duncan 1993), Goosander abundance might vary with these parameters, and that estimates of the total population would need to take account of them. The lochs were counted at all three times of year.

Results

Seasonal patterns of abundance and in the age/sex composition of the population

Through the coldest part of the year (January, February, November and December) Goosanders were scarce on the upper river and tributaries, being most abundant on the lower river and at the mouth (**Figure 2**). The decline in numbers on these lower reaches, in February and March, occurred at the same time that numbers on lochs increased dramatically, and the subsequent decline on lochs through March and April was accompanied by increases on all parts of the river. Numbers on the river increased until the first week of May, increasing again in June (tributaries), July (tributaries and upper river), August (mouth) and September (lower river). Thereafter numbers fell to the wintering levels.

These changes in abundance were associated with major changes in sex and age composition (**Figure 3**). Data were grouped into three areas, (i) the upper river and tributaries, which mainly held birds in summer and autumn, (ii) the mouth and lower river, which held the most birds in winter, and (iii) lochs:

(i) On the upper river and tributaries, in June, July and August, most Goosanders were unpaired females, adult females escorting their broods, or full-grown females in small parties. To judge from their behaviour and leg colour, many of the latter were yearling females prospecting nest sites on the tributaries in June, a few moulting near the main stem of the river in August. The birds present in September and October included juveniles. The first adult males did not appear until November, and most not until December. Some were paired then, but the proportion of birds in pairs (and the numbers of pairs) increased to a peak in April and then decreased in May, leaving single males which had gone by June. Yearling males were rarely seen, usually on the

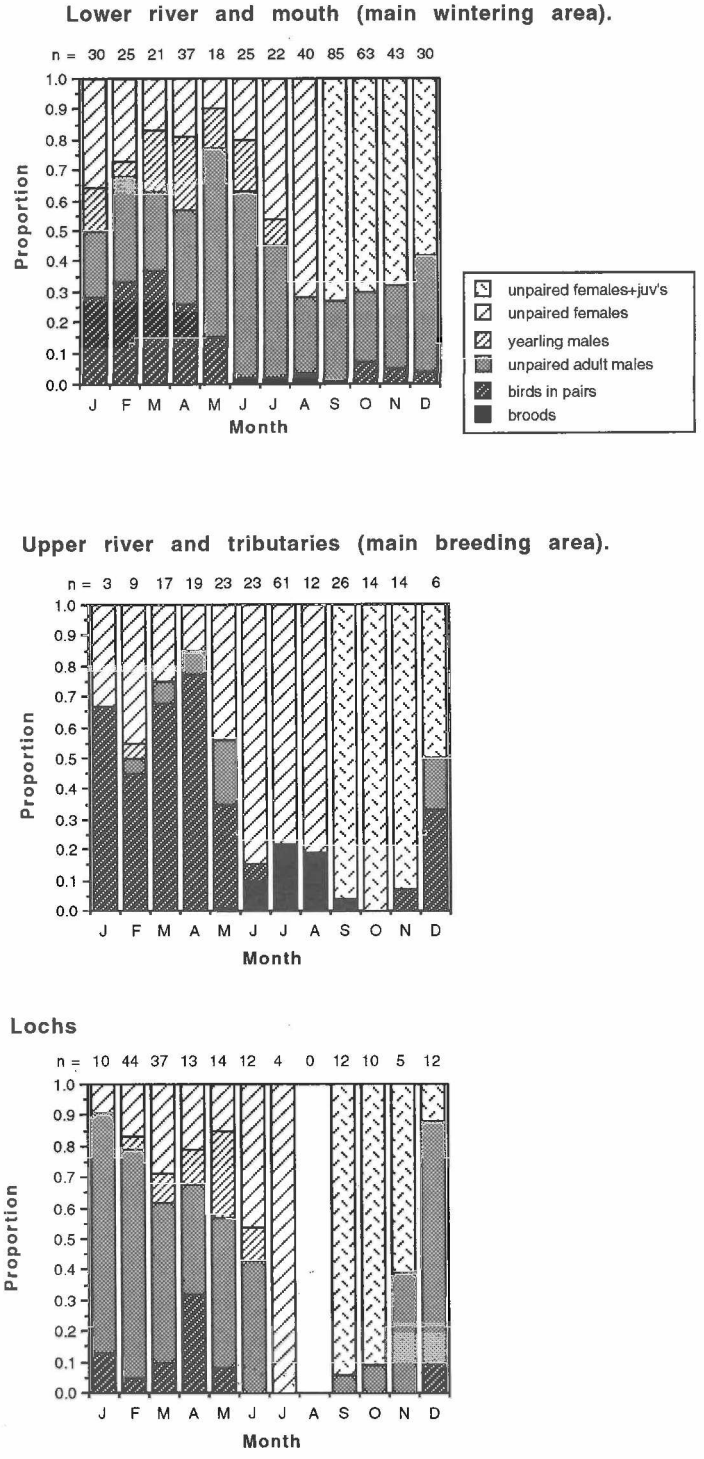


Figure 3. The proportions of six categories of Goosanders seen in different months, in the main wintering area, in the main breeding area and on lochs (*n* = the number of birds from which the proportions were derived).

main stem of the river in May.

(ii) On the lower reaches of the river, broods were scarce and adult and yearling males were always present, a small group moulting near the river mouth in July and August. The proportion of birds in pairs was lower than upstream and peaked earlier, in March. Unpaired females were least abundant, decreasing through spring but increasing again in July and August as non-breeding yearlings, or failed breeding adults, arrived to moult.

(iii) Goosanders on lochs were mostly adult males, though some yearling males were present from December to June. As numbers decreased in midsummer, only a few unpaired females remained. Juveniles predominated in September and October, prior to some adult males arriving in November and December.

Population estimates

The winter population was estimated from counts in December when most Goosanders were on the lower reaches of the river. Only four Goosanders were seen on the main stem of the Dee upstream of Banchory. On tributaries (120 km covered) the only Goosanders located were five on the Feugh (not far from its confluence with the Dee near Banchory), and a pair on the Clunie. The highest counts came from the lowest elevation sections of the river (**Figure 4**) which was also where the river was widest. No ducks were found on the 80 km of river we checked that was less than 15 m wide, or above 400 m a.s.l. We covered all parts of the watershed below this elevation so we probably censused all of the river used by Goosanders in December. The total count was 62 Goosanders on the river; 20 adult males, at least eight young males, and the rest females and unsexed young birds. An additional four adult males were found on lochs bringing the total December population to 66 birds.

In July no Goosanders were found in the sample of 90 km of streams that were 2-13 m wide. The narrowest 10-km stretches where we found broods were 14 m. We searched all parts of the river system where waterways averaged 10 m wide or more, and so probably covered all the habitat used by Goosanders in July. A single brood, eight additional adult females and nine males were counted near the mouth of the river. Upstream the number of broods increased, with a maximum brood density at about 80 m a.s.l. (**Figure 4**) where the river averaged 63 m wide. Further upriver brood density declined. The population counted on the whole river included 32 broods and totalled 218 ducklings, 51 females and nine males, (278 birds in all). No Goosanders were found on the lochs at this time of year.

The mid-April census of 19 sections gave counts (**Figure 4**) that were negatively correlated with elevation (log count+1=1.096 - 0.00183 x elevation; t=-5.6, p=0.001, r^2=0.646). The relationships with width and gradient were much poorer (r^2= 0.499 & 0.294 respectively) and incorporating them in multiple regression did not improve on the relationship with elevation alone, so we used this equation to estimate the numbers of Goosanders on uncounted sections.

A total of 87 Goosanders was actually counted on 190 km of river. Thirty were adult males, of which 22 were paired with females. The calculated total of Goosanders in the 20 uncounted sections was 67.4. The 95% confidence limits about this figure (64.1, 70.7) were calculated from the overall variance i.e. the sum of variances for all 20 individual section estimates. All the uncounted sections were in breeding areas, where to judge from other sections (110 km), 83% of Goosanders were in pairs and 44% were adult males. Thus, of the 67 Goosanders calculated to have been on uncounted sections, about 30 would have been adult males, 28 paired with females. On the lochs we counted ten Goosanders including six adult males, two of them paired to females.

The total number of Goosanders in pairs in the Dee watershed in mid-April was about 104 (95% c.l., 101, 107) but this figure excluded the 15% of breeding pairs whose females had commenced incubation. Our estimate (52 pairs) represented only 85% of the breeding population which was therefore calculated to be about 61 pairs. At least three of the adult males at the river mouth were injured, were never seen paired and probably did not breed, so the overall estimate of 66 adult males (95% c.l., 64, 67) was consistent with the estimate of 61 breeding pairs (95% c.l., 59, 63). The total population of Goosanders in the Dee watershed in spring 1988 was thus about 173 (95% c.l., 169, 178).

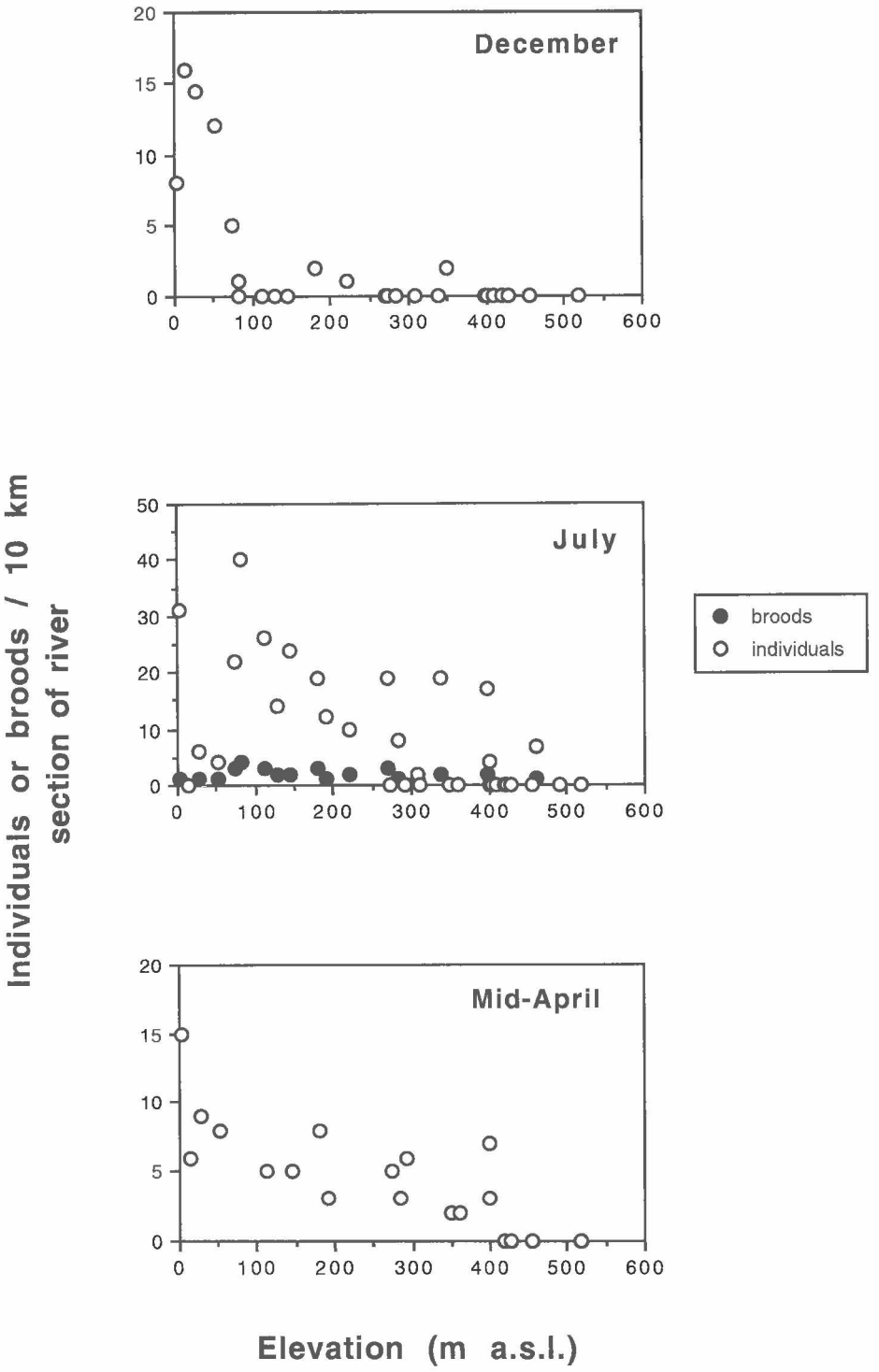


Figure 4. Goosander densities in relation to elevation on the River Dee, on three occasions in 1988. Points represent the number of birds (or broods in July) counted in a 10 km stretch of river.

Discussion

Counting Goosanders

The main problems in counting Goosanders arise from their mobility and varying dispersion pattern. Ideally they should be easiest to count when they are most sedentary, because this gives sufficient time for adequate sampling or a complete count, so we probably achieved complete counts for the midsummer and midwinter populations.

In July most Goosanders were flightless (moulting adults and growing ducklings) or at least for the duration of the census, confined to a few kilometres of river (females tending broods) so counts then could be very accurate. Carter & Evans (1984) relocated only 58% of broods from successive counts of the same 16 km of the river Tyne in Northern England, but this figure probably represented turnover rather than the detectability of broods within this stretch. Single counts on the 60 km mainstem of the Afon Tywi, Wales (Tyler 1986) also only recorded 50-70% of the broods thought to have been present, but there the shortfall was attributed to the skulking behaviour of broods. The well vegetated, heavily wooded terrain meant counters had to disturb broods to count them.

In our weekly counts we identified nine broods by the number of ducklings and their stage of development. In the July census we found eight of these broods in the vicinity of previous observations. The ninth brood was probably also counted but we could not be certain because if so, it had moved 13 km downstream. This was quite possible as studies of the movements of individually colour-marked broods have shown some to be relatively sedentary, but others moving up to 21 km (Erskine 1972, *pers comm*, Alexander & Marquiss unpublished). We therefore think our census probably located most if not all well-grown broods.

In December the population was largely confined to the lower river and lochs; areas which were readily accessible and where the birds could be counted rapidly, so the effects of movements of birds between areas and between days were minimal. In theory the birds could have been counted as they gathered to roost (Marquiss & Duncan, *Wildfowl* this issue) but, to judge from the directions of arrivals and departures, at least two of the Dee communal roost sites were used also by Goosanders which fed in an adjacent watershed.

Counting breeding Goosanders was most difficult because at that time of year they did not aggregate, but were well dispersed at low density over much of the watershed. Also the population was in flux; the number of pairs on the river continued to increase up to mid-April even though some females had by then started incubation. Our counts covered about half the watershed and our estimate of the number of breeding pairs was similar to the estimate of the number of adult males. This was consistent with our observations that, at least for early nests, the males did not desert the incubating female to seek fertile females elswhere, but idled nearby, escorting her when she came off the nest to feed.

If our results were applicable to other rivers, counts of adult males could provide a good index of the number of breeding pairs from mid-April until mid-May, when the first nests are near hatch, and the earliest males would be free to leave. River counts earlier in the spring, e.g. in March, would miss the substantial numbers of Goosanders still on lochs and on wintering grounds outside the breeding areas.

Population shifts with season

We found Goosanders wary and difficult to catch so few birds were individually marked, and the main evidence for movements came from changes in population distribution and abundance. For example, the reduction in numbers of Goosanders on the lower river in spring may have been because the birds moved upstream to breed. If so, this population shift was also accompanied by immigration to the watershed because the numbers in winter could, at most, only have provided about one-third of the breeding population. At least two-thirds of breeding adults and many juveniles must have wintered elsewhere, perhaps on the Beauly Firth where there was at that time a large winter concentration (Aspinall & Dennis 1988, Marquiss & Duncan unpublished). Alternatively they could have been dispersed widely on lochs and reservoirs to the south, or perhaps in continental Europe. Many Goosanders breeding in Scandinavia winter further south in Europe (Hofer & Marti 1988), and Goosanders ringed as ducklings in north-

ern England and recovered in winter had dispersed widely within Britain (Meek & Little 1980).

The disappearance of males from the Dee was obvious, particularly of adults - starting in May and complete by June. A few adult males remained in Scotland, moulting at the mouths of rivers (small numbers of males moult at the mouth of the North Esk, the Dee and the Spey *pers obs*), in the Beauly Firth (about 45 *pers obs*) and in the Firth of Tay (N. Elkins *pers comm*), but the majority probably migrated to north Norway (Little & Furness 1985). The migration of females from the Dee to moult was less complete; we recorded a few moulting on the mainstem of the river but most left. One colour-marked female was seen moulting on the Beauly Firth, 90 km NW of her Deeside breeding site, and another at the mouth of the river Don, 34 km NE. This latter female was found again two years later, moulting at the mouth of the Dee.

From midsummer onwards Goosander counts peaked sequentially on tributaries (June and early July), on the mainstem of the upper river (July and early August) and then on the lower river (September). This corresponded with the use of these areas by nesting birds, broods of ducklings and flocks of fledged juveniles, respectively. Most females nested high up tributaries (mean elevation 328 m a.s.l.; n=25 nest sites; Marquiss & Cook *unpublished*), but young ducklings arrived on the nursery areas of the lower tributaries and mainstem within a few days of hatching, and most spent their growing period within a few kilometres of river. The flocks of juveniles seen later on the lower river may have been locally reared birds, but on occasions their numbers apparently exceeded Deeside production, so many could have come from other watersheds. By October these flocks had dispersed leaving a wintering population most of which (*c.* 68%) were adults.

Erskine (1971, 1972) recorded spring and autumn migrants using the lower tidal stretches of his study rivers in eastern Canada. The only evidence of migrant Goosanders using the Dee was in the temporary presence of groups of yearling males on the lower river in April and May, and juveniles in September.

Goosanders used most of the Dee watershed, but in a seasonally varying pattern that reflected their needs for food, security from predators, pairing, and nesting. In winter the water of the upper river is very cold and the smaller fish living there (trout, salmon, eel, minnow, and lamprey) are largely unavailable to Goosanders because, at least during the daytime, they are buried in the substrate (Cunjak 1988, Heggenes & Saltveit 1990, Maitland & Campbell 1992, Fraser, Metcalfe & Thorpe 1993, Heggenes *et al.* 1993). At that time of year Goosanders foraged in places where the water was deeper (lochs, the lower river and mouth) where such fish as perch, larger trout and salmon parr, and some brackish water winter-active fishes such as Three-spined Stickleback *Gasterosteus aculeatus* and Flounder *Platichthys flesus*, are still available. They commuted to overnight communal roosting sites (Marquiss & Duncan, *Wildfowl* this issue) where they were relatively secure from predators and where, to judge from the amount of social interaction, most birds paired. In February and March the use of lochs increased as other foods such as Frogs *Rana temporaria* became important (Marquiss & Carss unpublished).

By April, salmon and trout parr have become active, and Goosanders used the mainstem of the river and lower, wider sections of tributaries, which were their main foraging areas until autumn. Females commuted to nests high in the watershed presumably because these areas offered an abundance of nest sites (in tree hollows, cliffs and rocky screes), seclusion from predators, and rapid access downstream to duckling nursery areas. Goosanders nested relatively early, their ducklings hatching at a time when their main food, salmonid fry, was abundant. Juvenile salmonids remained their chief food until fledge (Carss & Marquiss 1992).

Goosanders switched easily between habitats for foraging and roosting (in autumn and winter) or for foraging and nesting (spring). Conversely, when they are less mobile, e.g. when flightless in the nursery or moulting areas, they require a predictable and sufficient food supply. Although juvenile salmonid populations of fast-flowing rivers can provide such a predictable food, most Goosanders left this habitat to moult elsewhere. Security from both ground and aerial predators must be of importance (Lima 1993) because moulting concentrations were in expansive areas

of water with little vegetation. This generalisation did not apply to all birds because some remained to moult on the river. Similarly some birds wintered on the river even though most left to winter elsewhere.

Such varying patterns of movements are exhibited by other wildfowl species, and have been associated with age, sex and the timing of breeding or moult, facilitated by year-to-year site fidelity (reviewed in Owen & Black 1990). However, for Goosanders on Deeside the question remains as to what specific advantage might be gained by some birds moving further than others to moult or overwinter. For example, it could be that the river provides the best wintering habitat but can only support a few birds. Alternatively, rivers may be one of several equally good wintering habitats, and that the advantages in wintering on rivers can be matched by those associated with moving elsewhere.

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M Marquiss, Institute of Terrestrial Ecology, Hill of Brathens, Banchory AB3 4BY.
K Duncan, Scottish Natural Heritage, Achantoul, Aviemore, Inverness-shire