Breeding waterfowl on British inland waters in 1980

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Introduction

This paper describes a survey of waterfowl numbers and breeding performance on inland waters in Great Britain in 1980. This was part of a three-year study into the effects of recreation on waterfowl numbers and distribution on enclosed inland waters (Tuite 1981; Tuite *et al.* 1983, 1984). While the main aim was to relate the counts to the intensity of recreation at each site, this paper examines the general aspects of breeding of waterfowl in Britain and makes comparisons with previous studies.

Although the British summer populations of most ducks, geese and swans are considerably less than their winter levels, there are substantial breeding populations of Mallard *Anas platyrhynchos*, Tufted Duck *Aythya fuligula*, Mute Swan *Cygnus olor*, Canada Goose *Branta canadensis*, as well as other common waterfowl, most notably Coot *Fulica atra*, Moorhen *Gallinula chloropus*, Little Grebe *Tachybaptus ruficollis* and Great Crested Grebe *Podiceps cristatus* in inland Britain (Table 1).

The only previous national survey of summer wildfowl numbers was carried out during the period 1965–1970 (Yarker & Atkinson-Willes 1970). This overlapped with the BTO Breeding Atlas Survey (Sharrock 1976), which provides the most comprehensive information on breeding waterfowl distribution in Britain in terms of presence or absence in 10 km grid squares but little data on population levels, breeding densities or production. There have also been specific national surveys of Great Crested Grebes (Prestt & Mills 1966; Hughes *et al.* 1979) and Mute Swans (Campbell 1960; Ogilvie 1981). The present survey was organised in co-operation with the BTO, using their network of volunteer amateur observers.

Methods

Observers counted waterfowl on a monthly basis from March to August on enclosed inland waters throughout Great Britain. The aim was to collect data on summer numbers and breeding at a sample of sites having as wide a geographical spread and diversity of waters as possible. Any such survey is carried out opportunistically and the sites included are often selected not because of their characteristics, but because of the availability of observers in the vicinity. Because of this the sample is biased towards the well-populated lowlands, but since the birds are also concentrated there, this is probably not a serious limitation. A set of data recording

Table 1. The summer populations of water birds (number of individuals) breeding in substantial numbers in Britain. Data from Sharrock (1976), updated where possible according to recent data (Owen *et al.*, in press).

Species	Estimated population	% peak winter numbers
Mute Swan	18,000	100
Canada Goose	35,000	100
Gadwall	2,000	100
Wigeon	600–1,000	<1
Mallard	200,000–260,000	50–65
Teal	6,000–9,000	6–9
Shoveler	3,000–5,000	6–10
Pochard	400–800	1–2
Tufted Duck	45,000	70
Coot	200,000	–
Moorhen	300,000	–
Great Crested Grebe	5,000	–
Little Grebe	18,000–36,000	–

sheets (1 sheet for each month) was sent to each volunteer, who was asked to count the number of adults of waterfowl species (ducks, geese, swans, Coot, Moorhen and grebes), where possible males and females separately. Information on breeding consisted of a count of the number of females with broods and the number of young in each brood.

At the end of the summer the completed sheets were returned to Slimbridge, entered on a Research Machines 380Z microcomputer and stored on floppy discs. Data collected in the 1960s survey (Yarker & Atkinson-Willes 1971) from sites and months also covered in 1980 were also entered on computer and the same analyses run on these. A few sites had no ducks recorded in the 1960s (counts largely from 1965 and 1966) and these were matched with June counts from 1980 (usually the peak month for breeding birds) or, if June was not covered, May records. Changes in the numbers of some species were examined by calculating trends in Wildfowl Count data for September. The index was calculated by using the ratio of counts on all sites covered in each pair of years to modify the index (Ogilvie 1967), set at 100 for the 1970 season.

Results

Usable results were received from a total of 448 sites, illustrated in Fig. 1. The sample includes a good geographic spread within Great Britain, with most parts excluding north-west Scotland well represented. There was also a good range of habitat types, with 270 natural (or long-established artificial) lakes (60%), 125 reservoirs (28%) and 53 gravel pits (12%). This compares with 56%, 28% and 17% respectively of 979 waters covered in the winter of 1980–81 falling in these habitat categories. These proportions are remarkably similar, so that the summer sample is reasonably representative of at least those inland wetlands holding flocks of waterfowl. The area of each site was taken from the site inventory (Tuite *et al.* 1984) or estimated from Ordnance Survey maps. The mean area of all sites was 33.3 ha (82.3 ac); reservoirs were, on average, considerably larger (45.6 ha) than gravel pits (31.9 ha) and natural waters (27.7 ha).

The number of each species in each month during the survey are given in Table 2. The March count includes many winter migrants, especially for such late breeders as Wigeon *Anas penelope,* Pochard *Aythya*

Table 2. Total numbers of adult birds counted in the 1980 summer survey. The total number of sites covered is 448.

Species	Mar	Apr	May	Jun	Jul	Aug
Mute Swan	506	700	879	1,031	1,218	628
Greylag	537	2,317	584	979	1,075	268
Canada Goose	2,693	2,772	3,181	5,493	5,451	2,747
Shelduck	185	360	449	301	76	7
Egyptian Goose	20	29	13	8	10	0
Gadwall	139	188	183	231	147	9
Wigeon	1,843	530	121	37	37	65
Mallard	7,965	6,568	10,232	11,153	14,461	10,462
Teal	2,271	922	188	159	308	349
Pintail	62	8	2	0	1	0
Shoveler	554	339	247	171	165	215
Pochard	1,574	538	377	540	747	594
Tufted Duck	7,810	8,022	4,793	4,478	6,256	4,776
Mandarin	0	2	2	9	8	2
Goldeneye	490	227	3	12	9	9
Red-breasted Merganser	25	56	176	30	99	38
Goosander	345	155	66	30	40	20
Ruddy Duck	408	218	143	85	128	184
Coot	8894	6240	7541	8749	12,695	7843
Moorhen	1,588	1,360	1,150	1,047	1,144	384
Great Crested Grebe	1,179	1,429	1,434	1,339	1,469	613
Little Grebe	427	281	287	252	270	172
Total wildfowl	39,579	33,289	32,090	36,155	45,844	29,406
No of sites censused	327	398	408	391	361	143

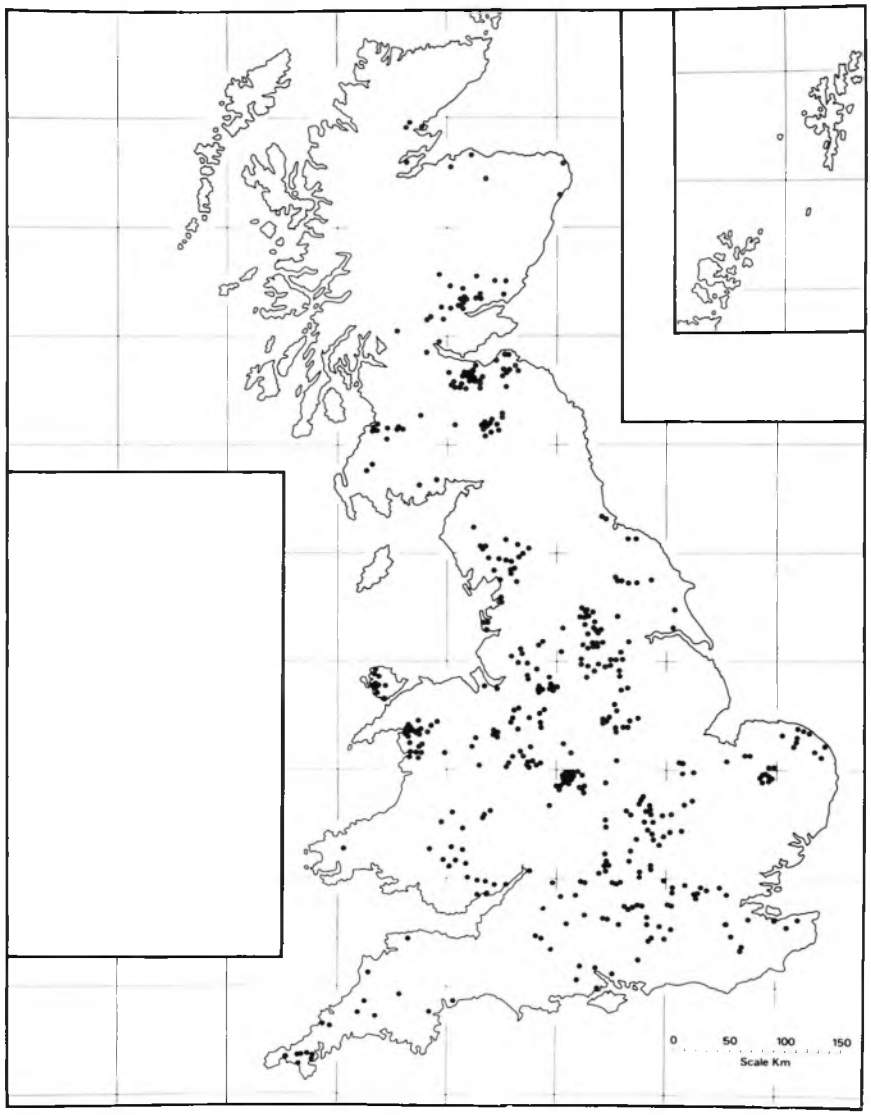

Figure 1. The distribution of the 448 sites from which summer survey data were collected in 1980.

ferina and Goldeneye *Bucephala clangula.* The drop in number of Tufted Ducks in May also indicates that many of these are late migrants.

Table 3 compares the percentage of sites in which each species was recorded with the percentage of 10-km squares in which present and in which breeding was confirmed during the BTO Breeding Atlas survey (Sharrock 1976). This comparison is not entirely valid since the Atlas areas include those without suitable habitat whereas all sites in this survey are potential habitats for water birds, but there is a measure of concordance between the two percentages. As might be expected, shy species such as Teal and Moorhen are recorded less well by this survey than the more intensive Atlas project, whereas the inland water specialists such as Tufted Duck, Canada Goose and Great Crested Grebe are seen in a much higher proportion of our survey sites. Higher proportions for Gadwall *Anas strepera,* Tufted Duck and

Table 3. The percentage of sites where each species was recorded in the summer month when most abundant * and the percentage of sites with broods in comparison with the proportions of squares with birds and where breeding confirmed in the Atlas survey).

Species	% sites	% Atlas squares	% with broods	% Atlas breeding conf.
Mute Swan	40.7	58	22.3	51
Canada Goose	44.5	18	29.2	13
Gadwall	9.8	4	2.9	2
Mallard	92.7	92	74.3	85
Teal	13.5	46	4.7	23
Pochard	17.7	15	5.6	5
Tufted Duck	67.3	42	34.2	26
Coot	78.7	58	57.8	52
Moorhen	58.3	82	40.6	77
Great Crested Grebe	57.0	26	34.6	21
Little Grebe	23.1	49	13.4	36

* months when substantial numbers of wintering or moulting immigrants may have been present do not qualify for inclusion.

Table 4. The proportion of the more important inland species of water birds found on man-made habitats during the 1980 summer breeding survey. Adult numbers are based on pre-breeding populations (in different months for different species) and numbers of young in the peak brood month for each species. Y/Adult is the number of young in the peak brood month per pre-breeding adult.

	Reservoirs			Gravel Pits			Natural
Number (%) of sites	125 (27.9)			53 (11.8)			270 (60.3)
Mean site area (ha)	45.6			31.9			27.7
Percentage water area	38.8			11.3			49.9
	Percentage of total			Percentage of total			
	Adults	Young	Y/Adult	Adults	Young	Y/Adult	Y/Adult
Mallard*	24.6	29.1	0.703	18.7	12.9	0.410	0.608
Teal	19.1	57.0	1.580	2.1	0.0	0.0	0.290
Pochard	6.5	26.8	0.629	10.0	23.2	0.352	0.156
Tufted Duck	20.9	23.8	0.390	29.7	23.4	0.269	0.213
Mute Swan*	22.7	18.1	0.497	16.1	23.4	0.903	0.595
Canada Goose	7.8	15.6	1.005	34.2	33.8	0.494	0.434
Moorhen*	15.6	13.2	0.244	18.0	16.5	0.265	0.305
Coot	25.3	21.5	0.264	20.8	19.7	0.294	0.336
Great Crested Grebe	26.4	24.2	0.304	33.7	25.8	0.254	0.416
Little Grebe	22.9	33.3	0.610	21.2	14.2	0.280	0.391
Total water birds	20.1	22.4	0.327	20.8	18.4	0.260	0.294

* These species have a substantial breeding population outside habitats covered by this survey (rivers and small marshes).

Canada Goose also reflect the increase in numbers of these as breeding species in the last decade (Owen *et al.*, in press).

In addition to those listed, a number of uncommon summering and breeding species were reported from between 1 and 10 sites. These included escapes from captivity, feral exotics as well as scarce breeding birds.

A summary of the results broken down by habitat type is given in Table 4. Of the three habitats, natural lakes, representing some 50% of the water area, hold about 60% of the birds. Gravel pits and reservoirs have some 20% each, though 39% of the water area is in reservoirs and only 11% in gravel pits. The lower carrying capacity of reservoirs is not unexpected since many are large

waters with rather simple perimeters, providing less food and nesting cover than smaller sites with more complex margins. Reservoirs are more suitable for diving species, holding 33% of Tufted Ducks at peak, 23% of Coot and 32% of Great-crested Grebes.

Production (young/adult) is higher in 7 out of 10 species on reservoirs than gravel pits and in 6 cases higher than on natural habitats. Perhaps reservoirs provide good brood rearing areas with little competition because of the low density of nesting birds in the largely unsuitable marginal areas. It may be no accident that three of the exceptions – Mute Swan, Coot and Moorhen – are largely vegetarian. Reservoirs are generally poorer in submerged and emergent macrophytes than other inland waters. Gravel pits tend to be less productive than natural habitats, often because they are newly-formed.

Mean densities were calculated in two ways: (a) overall density – calculated by dividing the total area of all sites combined into the total number of birds counted; (b) mean site density – the average of all the individual site densities on areas where the species was recorded.

Both these density measures can be useful for different purposes and are presented in Table 5. Overall density is not a realistic measure to indicate population levels for those species with restricted ranges; site values show Mallard and Coot to be the species occurring at highest densities. Species such as Mute Swan and Great Crested Grebe, though very widespread, occur at very low densities.

The adult sex ratios for species which are sexually dimorphic are shown in Table 6. Even before the breeding season is under way there is a preponderance of males in most species, as there is in the wintering populations of the majority of ducks. The preponderance of females in the Goosander *Mergus merganser* is probably due to the inclusion of some immature males with the females. The sex ratios of Ruddy Ducks *Oxyura jamaicensis* are near 1:1 both in southern England and in North America (Cramp & Simmons 1977), as they are in our sample. The sex ratio during the summer gives an indication of the timing of laying since a rise in the percentage of males follows the disappearance of females to incubate. This rise begins in April in Mallard as opposed to June in Tufted

Table 5. Site and overall density of adults recorded during the survey. Density is recorded as no. of individuals/sq km.

Species	Apr	May	Jun	Jul	Aug
a) Site density					
Mute Swan	16	14	14	16	20
Canada Goose	73	74	101	116	123
Mallard	179	243	235	329	489
Teal	16	4	4	5	88
Pochard	18	9	9	12	25
Tufted Duck	181	104	105	116	238
Coot	168	167	202	278	482
Moorhen	47	41	41	50	60
Great Crested Grebe	24	25	24	25	22
Little Grebe	11	9	10	11	26
b) Overall density					
Mute Swan	6	7	9	10	11
Canada Goose	24	23	47	44	46
Mallard	56	74	94	115	177
Teal	8	1	1	2	6
Pochard	5	3	5	6	10
Tufted Duck	69	35	38	50	81
Coot	53	55	75	102	133
Moorhen	12	8	9	9	7
Great Crested Grebe	12	11	12	12	11
Little Grebe	2	2	2	2	3

Table 6. The number of sexed adults and percentage of males in dimorphic species counted during the summer survey.

Species	Mar		Apr		May	
	Total	% Male	Total	% Male	Total	% Male
Gadwall	139	52.5	188	52.1	160	61.3
Wigeon	1,031	52.0	166	53.6	121	82.6
Mallard	6,854	54.4	6.310	68.7	9,620	72.1
Teal	1,430	54.2	810	53.1	188	65.4
Shoveler	553	67.8	319	75.5	247	77.7
Pochard	1,499	59.2	534	69.5	366	71.6
Tufted Duck	6,932	57.9	7,708	57.8	4,660	59.6
Red-breasted Merganser	25	56.0	56	57.1	175	66.3
Goosander	304	40.8	111	39.6	53	52.8
Ruddy Duck	241	45.2	168	55.4	143	60.8

Species	Jun		Jul		Aug	
	Total	% Male	Total	% Male	Total	% Male
Gadwall	129	51.9	32	46.9	7	28.6
Wigeon	23	39.1	11	54.5	13	53.8
Mallard	8,101	60.5	3,942	49.2	1,690	43.9
Teal	142	54.9	138	34.1	17	41.2
Shoveler	171	64.3	177	46.2	13	23.1
Pochard	540	76.7	698	75.1	422	73.7
Tufted Duck	4,370	68.6	4,468	61.2	2,348	62.4
Red-breasted Merganser	30	43.3	26	23.1	10	0.0
Goosander	22	4.5	20	20.0	0	0.0
Ruddy Duck	85	62.4	129	64.3	184	65.2

Ducks. A drop in the percent males for dabbling ducks later in the season reflects the fact that males move to other waters to moult.

A monthly breakdown of the number and percentage of sites at which broods of each species were observed is presented in Table 7. As might be expected, where the sample is large enough, brood size declines through the summer. The decline is marked in some of the ducks, but much less pronounced in the Mute Swan, geese and grebes, Fig. 2 shows the number of females with broods in each month, expressed as the percentage of the species monthly maximum, in eight of the more common species. These histograms illustrate the pattern of brood abundance rather than their appearance, so that the peak value does not necessarily represent the time of peak hatching. This analysis does, however, provide valuable comparative data. Whereas broods of most species are abundant in May and June, the Tufted Duck is a notably late breeder, with few young appearing before July. Breeding seasons for the Mallard and Canada Goose are earlier than for other species and that of the Mallard more extended.

Where amalgamations of broods occurred, these were excluded from the analysis. A likely maximum brood size was allocated to each species, based on figures in Cramp and Simmons (1977) and any recorded brood size greater than this discarded (though included in analyses of total young).

Individual species accounts are given for the commoner and most widespread species. Where relevant, data are presented for other species in the tables.

Mallard

The Mallard is the most widespread summer waterfowl species in Britain, according to both its presence and breeding frequency in both this and the Atlas survey. The total numbers and overall densities of Mallard were the highest of all species in all months except those where remaining migrant birds increased the early season populations of other ducks.

The site density of Mallard in March was 220 birds per sq km of water and the overall density was 69. It is generally recognised that due to the bias in sex ratio in favour of

Table 7. The number of broods recorded and the mean brood size in each month of summer survey. The total number of sites covered is 448.

Species	Apr		May		Jun		Jul		Aug		Sites	%
Mute Swan	2	3.0	33	4.9	100	4.2	118	3.6	30	4.1	99	22.1
Greylag	1	5.0	53	5.0	25	4.0	10	5.2	0	0.0	30	6.7
Canada Goose	10	1.9	221	4.2	207	4.0	70	3.6	7	4.7	131	29.2
Shelduck	0	0.0	11	6.6	37	6.9	7	6.1	0	0.0	17	3.8
Gadwall	0	0.0	9	5.3	10	6.2	9	6.6	0	0.0	13	2.9
Mallard	95	6.8	696	5.3	803	4.9	582	4.2	73	3.6	333	74.3
Teal	1	6.0	2	6.0	17	5.9	22	4.6	1	4.0	21	4.7
Shoveler	0	0.0	4	5.5	10	4.4	9	4.9	1	6.0	11	2.5
Pochard	0	0.0	9	4.6	40	4.0	30	3.7	4	2.8	25	5.6
Tufted Duck	1	6.0	7	3.9	93	5.3	349	4.7	158	4.1	153	34.2
Coot	11	3.4	238	3.1	682	2.6	817	2.3	178	2.3	259	57.8
Moorhen	3	4.7	55	3.4	147	2.7	192	2.0	65	1.8	182	40.6
Great Crested Grebe	20	2.4	105	2.0	189	1.9	257	1.9	129	1.8	155	34.6
Little Grebe	0	0.0	9	2.6	32	2.3	58	2.1	32	2.2	60	13.4
Sites with broods	77		283		328		304		101			
No. censused	398		408		391		361		143			
% with broods	19.3		69.4		83.9		84.2		70.6			

males, which is characteristic of most populations, the number of females provides the best estimate of potential breeding pairs (Dzubin 1969). The factor of 0.456 (proportion of females – see Table 6) can therefore be used to convert the site adult density to pair density and gives a value of 100 pairs per sq km. The overall pre-breeding density of females (March) is 27.3. Perhaps because this figure is elevated as a result of the sample bias towards the more productive and lowland regions, it is substantially higher than the comparable figure from northern Fennoscandia, where the maximum Mallard pair density for inland regions was 1.98 pairs per sq km of water (Haapanen & Nilsson 1979). In southern Sweden, values in the range 1.7–58.0 pairs per sq km were recorded by Nilsson (1978) on lakes which had become partially or wholly eutrophic as a result of pollution, and on naturally eutrophic lakes. Figures derived from ground censuses in two of the best parts of the important North American Mallard production area, the Prairie Parklands region, produced average estimates of 0.89 and 1.58 pairs per ha of water (Dzubin 1969).

The Mallard is an early breeder; the first broods in this survey were recorded in March, with peak numbers in May and June (see Fig. 2). This gives a peak laying period of April–May, rather later than the birds studied by Ogilvie (1964) in the Slimbridge decoy, Gloucestershire. However, the artificial feeding regime at Slimbridge almost certainly accounts for the very much earlier laying date there. Additionally, the 1980 spring was rather colder and wetter than average. Mean brood size decreased from 6.84 in April to 3.63 by August. This value cannot be used to estimate total duckling mortality since some broods may be lost altogether and some of the later broods will decrease further. On a Buckinghamshire gravel pit, Hill (1982) found that Mallard broods from clutches averaging just under 9, declined from 6.5 at 3 days to just over 2 at fledging. This represents a survival rate of 34% in broods where some young fledged. When total brood losses were taken into account the survival rate was 27%. Though gravel pits are not as productive as many other habitats, at least in the early years of establishment, our figures show that losses are of the same order, considering that the size of late broods in our survey do not take their losses fully into account..

Teal

Teal are fairly uncommon breeding ducks in Britain with a total estimated breeding population of 3,500–6,000 pairs (Sharrock 1976). Their main strongholds are the uplands of northern England and southern and eastern Scotland, in areas and habitats not well represented in our survey. Broods were observed at only 21 sites (5%) with the maximum number being in June and July,

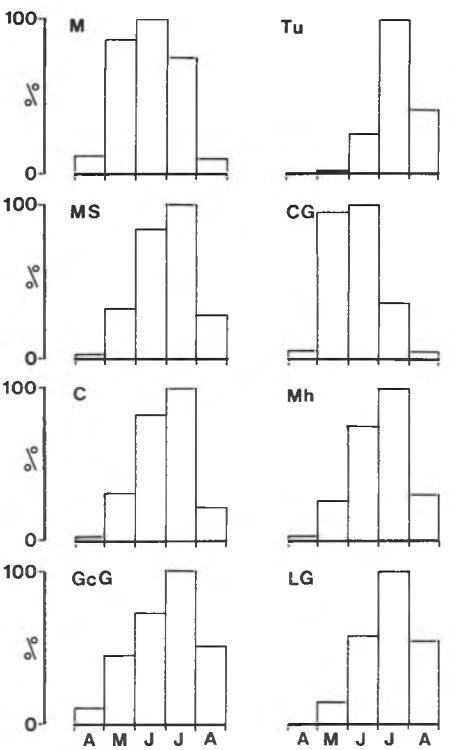

Figure 2. The number of females with broods in spring and summer months, expressed as a percentage of the number in the month where brood numbers were highest:

M – Mallard
MS – Mute Swan
C – Coot
GcG – Great Crested Grebe
Tu – Tufted Duck
CG – Canada Goose
Mh – Moorhen
LG – Little Grebe

giving a peak laying period of May/June.

As has been found in other comparable studies, Teal breeding densities were comparatively low, even in their favoured habitat. The mean number per site and adult density decreased sharply following the March count, which must contain some migrants. On the basis of this and the suggested April/May laying peak, it is probably most realistic to assume that the April count represents the pre-breeding Teal population. The overall April total adult density of Teal was 7.9 adults per ha of water, with a sex ratio corrected pair density of 3.7 pairs per sq km. Overall densities in northern Fennoscandia ranged from 0.07–5.27 pairs per sq km of water.

The number of broods sampled is small, but early brood sizes are around 6 young, with a decline similar to that in Mallard.

Pochard

The Pochard is described in the Atlas as a "scarce and local" breeding bird with an estimated total British breeding population of only 200–400 pairs (Sharrock 1976). The breeding distribution is restricted to lowland areas with strongholds in East Anglia and South-East England (Hori 1966; Yarker & Atkinson-Willes 1971). In this survey, broods were at only 25 sites with peak numbers in June and July, indicating a main laying period of May/June. Both the March and April figures show a very high proportion of males – 59% and 70% respectively. This is lower than in midwinter, however, when about three-quarters of Pochard caught in traps are males (Owen *et al.* in press). Another notable feature of Pochard is the high number of summering ducks in relation to those that breed, and the high proportion of these which are males. The numbers are swelled by the large number of males of continental origin that moult on such sites as Abberton Reservoir, Essex, and the London reservoirs.

Pochard breeding density is low. Mean brood size varied from 4.6 in June to around 3 in July and August. This may be compared with a mean clutch size of 7 reported by Hori (1966)

Tufted Duck

The Tufted Duck is the second most numerous inland breeding duck in Britain. Like the Pochard it is generally restricted to the lower lying areas of the country, only very few breeding in Devon and Cornwall, Wales, the Pennine region or in north-west Scotland. The total British breeding population, estimated from the September count, is about 45,000 birds.

As has been widely recorded previously, the Tufted Duck is a late breeding species. In 1980 the peak brood month was clearly July, indicating that peak laying took place in June. At Loch Leven, Kinross, laying commenced in the first ten days of May and the peak was in early June. Some clutches were started as late as the first week in July

(Newton & Campbell 1975). Further south in Buckinghamshire the mean date of nest initiation varied between the first and the last week of June in different years (Hill 1982).

The decline in number counted between April and May indicates that some migrants are very late to leave. The May total can be taken as representing the pre-breeding population. Although, as in Pochard, the sex ratio is high early in the season, there is not a substantial increase in the proportion of males until June when laying starts. It is well known that male Tufted Ducks begin their flight feather moult in June or July with breeding females not starting until about 2 months later (Cramp & Simmons 1977). They also undergo moult migrations to congregate at favoured moulting sites, in Britain the same ones as are used by Pochard.

The site weighted breeding pair density in May was 42 pairs per sq km and the overall pair density was 14. On the eutrophic lakes in southern Sweden the range of overall pair density was 2.5–35 pairs per sq km for diving ducks, which were predominantly Tufted Ducks (Nilsson 1978). In northern Fennoscandia pair density was lower, ranging from 0.0013 to 0.047 pairs per ha of water (Haapanen & Nilsson 1979).

Mean brood size declined from 5.3 in June to 4.1 in August. Havlin (1966) recorded a mean clutch size of 8.8 for Tufted Ducks breeding in Czechoslovakia and estimated an average egg loss of 39.8% which would given a mean initial brood size of 5.3. At Loch Leven, clutch size varied from about 11 for early clutches to 6.75 for the latest ones, with an overall mean of 9.2–9.5 in the three seasons 1968–70 (Laughlin 1975) and the average hatching rate was 57% (Newton & Campbell 1975). This would result in an initial mean brood size of 4.0. Hill (1982) found an initial brood size of 6 from a mean clutch of 9.4 on a Buckinghamshire gravel pit. There brood size declined rapidly to 1.4 at fledging, only 15% of the ducklings that hatched reaching that stage. Duckling survival was also very low at Loch Leven but our results indicate that the average survival of British Tufted Duck broods is much higher than at either of these study sites. The gravel pits have low productivity of invertebrate foods, critically important in the early stages of duckling life (Hill 1982) and duckling survival at Loch Leven is low because brood rearing areas are in short supply (Newton & Campbell 1975).

Mute Swan

The most recent data on Mute Swan status and distribution come from the results of the 1978 census (Ogilvie 1981). The total population, which is almost entirely resident, is about 18,400. In this survey samples of 500–1,200 (3–7%) were counted in the well covered months.

The Mute Swan is the most intensively studied wildfowl species in Britain (see Bacon 1980, and references therein). Breeding performance and population status are very variable in different parts of the country, with some local populations in severe decline and others maintaining past levels or increasing. The lumped results of this survey are therefore unlikely to add significantly to current knowledge and are not discussed further.

Coot

The Coot is a widespread breeding species, only generally absent from more oligotrophic upland waters which do not support the growth of significant amounts of macrophytic vegetation (Sharrock 1976).

The peak brood period was June/July, with fairly high numbers in May, suggesting that laying takes place over an extended period. In a study of Coot breeding biology at Hilfield Park Reservoir, Hertfordshire, Sage (1969) found that the peak laying period was from late May to mid-June and that very late July clutches invariably failed to hatch. Although the rather extended breeding season might suggest that some pairs are double-brooded, Sage did not record a single pair laying a second clutch after rearing an earlier one. Many pairs did, however, replace lost clutches or eggs.

Mean brood size decreased steadily through the season from 3.4 in May to 2.3 in August. At Hilfield Park Reservoir the mean clutch size was 5.9, but in three European studies, two in Czechoslovakia and one in Sweden, mean clutch size was 7.9, 7.2 and 7.2 respectively (Lelek 1958; Askaner 1959; Havlin 1970). Hatching success was also higher, 43.6% and 50.7%, compared with 36.6% in Hertfordshire and 34.7% in Somerset (Alley & Boyd 1947). A mean clutch size of 7.2 and a hatching success of 45% would produce an initial

brood size of 3.2, whereas a mean clutch size of 5.9 and hatching success of 35% or 45% would yield post-hatching mean clutches of 2.1 and 2.7 respectively. The survey results do therefore imply that the mean clutch size and/or hatching success in Britain are generally higher than reported in the two British studies quoted. Both clutch size and hatching success may well have been lower than average at Hilfield during the study period because at the time it was a new reservoir which the Coot population was in the process of colonising. At more mature sites, where there is likely to be more food and cover, Coot breeding performance is likely to be improved. The survival of young in our survey was high, excepting a very low September brood size. This is based on a rather small sample and late broods are, in any case, the result of smaller clutches and hatch at a suboptimal time.

The site and overall pre-breeding densities in April were 170 and 53 birds per sq km of water. Without sex ratio data it is dificult to convert these figures to potential breeding pair density, especially as there is evidence that Coot populations contain non-breeders. Whether these are surplus males or young birds is not known. However, if the percentage of breeding females is assumed to be 40% (20% non-breeders and 1:1 sex ratio), site pair density is 68 pairs per sq km of water and overall density 21 pairs per sq km. On eutrophic lakes in southern Sweden breeding pair densities ranged from 4.2 to 45 pairs per sq km (Nilsson 1978).

Moorhen

Moorhens were recorded at 71% of sites and broods were present at 41%. Both these figures and especially the actual counts are likely to be substantial underestimates as Moorhens are very dificult to census. They live in the shoreline areas and in surrounding and emergent vegetation, so making them difficult to see and count.

The brood season was extended with peak brood months of June and July and 11% of waters having broods in May. From analysis of nest record cards Huxley & Wood (1976) found that the onset of laying occurred from March onwards, with a peak at the end of May, which would give maximum numbers of broods in mid- to late June. All studies of Moorhen breeding have emphasised that replacement of lost clutches and second and third clutches are not uncommon (Relton 1972; Wood 1974). Mean brood size was highest in May at 3.4, decreasing to 1.8 in August. Mean clutch size is apparently very variable, probably depending on local habitat quality (Huxley & Wood 1976). The mean clutch size from the nest record card data, which included sites from all over Britain, was 6.6, but figures from individual sites or localities vary from 5.7 in Huntingdon (Relton (1972) to 7.6 at Newburgh, Aberdeen (Anderson 1965). Figures from the continent include values of 7.5 for 32 clutches in Norway and 6.8 for 5 clutches in Germany (Steinbacher 1939). If the mean clutch size in Britain was 6.6 and initial mean brood size 3.4, then the average hatching success, at least for early or peak season broods, would be 52%.

The pre-breeding (March) site adult densities and overall adult densities were 65 and 14 birds per sq km of water. There are no published data on Moorhen sex ratios but it is known that both sexes incubate (Anderson 1965). If a 50:50 sex ratio is assumed, the overall pre-breeding pair density was 7 pairs per ha of water and the site density 33 pairs per ha. Because of the censusing problems already mentioned and the unknown validity of the sex ratio assumption, these figures should be treated with some caution.

Great Crested Grebe

A national survey in 1965 estimated that the May population of Great Crested Grebes in Britain was between 4,000 and 5,000 individuals (Prestt & Mills 1966) and a 1975 census estimated 6,000—7,000 (Hughes *et al.* 1979). Through spring and midsummer, the present survey recorded about 1,400 individuals. Great Crested Grebes have increased in the last 40 years and in the Atlas survey were recorded as breeding in 21% of 10-km squares. In 1980 broods were found on 182 (41%) of the surveyed waters, Great Crested Grebes are very much inhabitants of lowland and eutrophic waters and do not breed in any of the upland regions of the country. They seem to be particularly adept at colonising new habitats such as gravel pits (Sharrock 1976); in this study more than a third of the birds were on gravel pits though they constituted 12% of sites and only 11% of the water area. Grebes also appear to benefit from the eutrophication of waters (Nilsson 1978).

There were a substantial number of broods in May, though July was the peak month. This relatively long breeding season is probably a result of the extended period of parental care, which is normal in this species; also, second broods have been reported in some instances (Cramp & Simmons 1977). Mean brood size varied from 2.4 in April to 1.8 in August. Cramp and Simmons (1977) give a mean clutch size of 3.5, except for very late clutches which are smaller. This suggests a hatching success of 60–70% for early and peak season broods. Pre-breeding (March) densities were 25 birds per sq km of water for site density and 10 birds per sq km overall. These levels remained remarkably constant through the summer.

Comparison with 1960s survey

There was a total of 124 matched sites covered in this and the earlier survey (Yarker & Atkinson-Willes 1971). Some of these may well have changed in character since the original study, in particular the area of many gravel pits has, in most cases, increased. We have no means of correcting for this but the comparison does give an indication of the trends for the commoner species. Only ducks, geese and swans were fully covered in the 1960s so the comparison is restricted to these.

Table 8 gives the total adults and young counted in the matched sites. Of the 11 species listed six have increased both in the number of adults and of young. The Shoveler *Anas clypeata,* never a common breeder, has declined in this sample, whereas Teal and Pochard populations have changed little. The number of adult Tufted Ducks has markedly increased but this is not reflected in the number of young. Since this species has expanded as a breeder (see below), this result may well be because 1980 was a rather poor breeding year for Tufted Ducks. The growth in Shelduck *Tadorna tadorna* numbers reflects its increasing encroachment into inland habitats.

The changes in four measures of abundance and breeding between the two surveys for eight of the common species are shown in Table 9. Most spectacular has been the growth in populations of Greylag Goose

Table 8. Numbers of adults and young wildfowl counted in three summer months on matching sites and months in the summer survey of the 1960s (Yarker & Atkinson-Willes 1971) and 1980.

Species		May		Jun		Jul	
		1960s	1980	1960s	1980	1960s	1980
Mute Swan	Adults	1,688	3,361	1,511	2,611	1,710	2,519
	Young	56	72	69	143	63	111
Greylag	Adults	6	118	16	85	6	40
	Young	12	112	13	95	7	34
Canada Goose	Adults	437	1,118	338	1,931	544	1,341
	Young	133	432	147	345	32	26
Shelduck	Adults	33	159	5	21	38	6
	Young	4	24	0	27	7	0
Gadwall	Adults	40	104	13	137	9	109
	Young	10	33	0	33	0	24
Mallard	Adults	1,688	3,361	1,511	2,611	1,710	2,518
	Young	519	1,192	571	1,008	373	491
Teal	Adults	81	54	74	37	37	37
	Young	0	5	22	40	11	2
Shoveler	Adults	74	83	73	38	90	8
	Young	0	5	9	2	18	0
Pochard	Adults	120	144	109	92	326	49
	Young	22	16	66	54	39	29
Tufted Duck	Adults	916	1,412	715	1,060	584	1,259
	Young	2	5	245	102	141	235
Ruddy Duck	Adults	1	51	0	17	0	15
	Young	0	0	0	0	0	0
Sites counted		100		80		47	

Anser anser, widely introduced in England since the sixties, and the Canada Goose, which continues to expand its range by taking advantage of newly created gravel pit habitat (see Table 5). Gadwall, again largely as a result of introductions, has also increased dramatically, as has the Ruddy Duck *Oxyura jamaicensis,* which first escaped into the wild in 1960 (Hudson 1976). The conflicting data for Teal production seems puzzling, but the sample is rather small. As might be expected, brood size is little different in the two surveys and shows no consistent pattern.

The September trend data for six of the commoner species between 1960 and 1982 are shown in Fig. 3. Of the other species listed in Table 9, Greylag Geese are often missed in Wildfowl Counts, Teal breed uncommonly and numbers are likely to be swamped by early migrants, and the Pochard trend is affected by the influx of moulting birds. Shoveler numbers are not large enough to include in Table 9 but since there is a suggestion from Table 8 that their numbers, at least as breeders, have declined; their September trend is also included.

The trends in most cases confirm the indications from the breeding surveys. Mute Swan numbers have changed little countrywide, as confirmed by national censuses (Ogilvie 1981). The Canada Goose has increased in density and has extended its distribution. Numbers of Gadwall have also increased greatly, though indices in the 1960s are not very reliable because of the rather small numbers of birds involved (100–300 compared with 1,500–3,000 in recent Septembers). Despite the higher density of Mallard on the paired sites in 1980, its post-breeding numbers nationally have changed little since 1960. Presumably local increases have been counterbalanced by habitat losses elsewhere. The trend in Shoveler gives a different pattern from that of the breeding surveys. Enclosed waters are not the most important breeding habitats for the species and there have been notable improvements in some of the most important marshland sites (especially the Ouse Washes) in recent years.

Discussion

Waterfowl breeding surveys in Europe and North America

Censusing breeding waterfowl and obtaining estimates of their productivity is notoriously difficult because of a potentially huge number of factors which may lead to bias and error (Dzubin 1969). However, statistics on breeding populations and their productivity are clearly of extreme importance for the development of conservation policies, both with regard to the maintenance of suitable habitat conditions and, in quarry species, the setting of appropriate hunting regulations and limits.

In North America, very considerable effort and financial resources have been expended on the censusing and monitoring of their breeding waterfowl and these data are used in the planning of land acquisition and management as waterfowl habitat and in setting hunting regulations (Anderson & Burnham 1976).

In Europe, the wintering populations and their ecology have received the most attention in terms of censusing and monitoring. Between 1972 and 1976 there was a large-scale survey of breeding waterfowl in northern Fennoscandia (Haapanen & Nilsson 1979), which is an important breeding area for several European waterfowl species. In Britain, the BTO Breeding Atlas survey and the Wildfowl Trust breeding duck survey (1965–70) (Yarker & Atkinson-Willes 1971) are the only studies which have investigated our breeding waterfowl populations on a national scale.

Censusing methods and problems

The type of large-scale transect census techniques which have been applied in North America and Scandinavia are not applicable to conditions in Britain, where the wetland habitats are relatively discrete and very variable in character. However, the small size of the country and high human population density does permit the organisation of a volunteer network which is able effectively to sample or count most areas at a fairly high intensity. Undoubtedly, the overall standard of observers is extremely high, but because of the inevitable variation in their efficiency, experience and commitment to any particular project, it is impossible to obtain estimates of errors and bias. On top of this there are also the intrinsic factors which affect any survey or census, such as species differences in countability, weather and local habitat conditions (Diem & Lu 1960;

Table 9. The 1980 survey figure as a percentage of the 1960s value for various species and measures of abundance, in the peak month for that species and measure.

Species	Measure			
	Total Adults	Total Broods	Total Young	Brood Size
Mute Swan	119	200	207	85
Greylag	738	633	861	-
Canada Goose	355	181	294	94
Gadwall	346	600	330	-
Mallard	197	115	209	90
Teal	67	78	181	104
Pochard	102*	94	82	87
Tufted Duck	154	75	96	110

* July excluded because of probable moulting flocks.

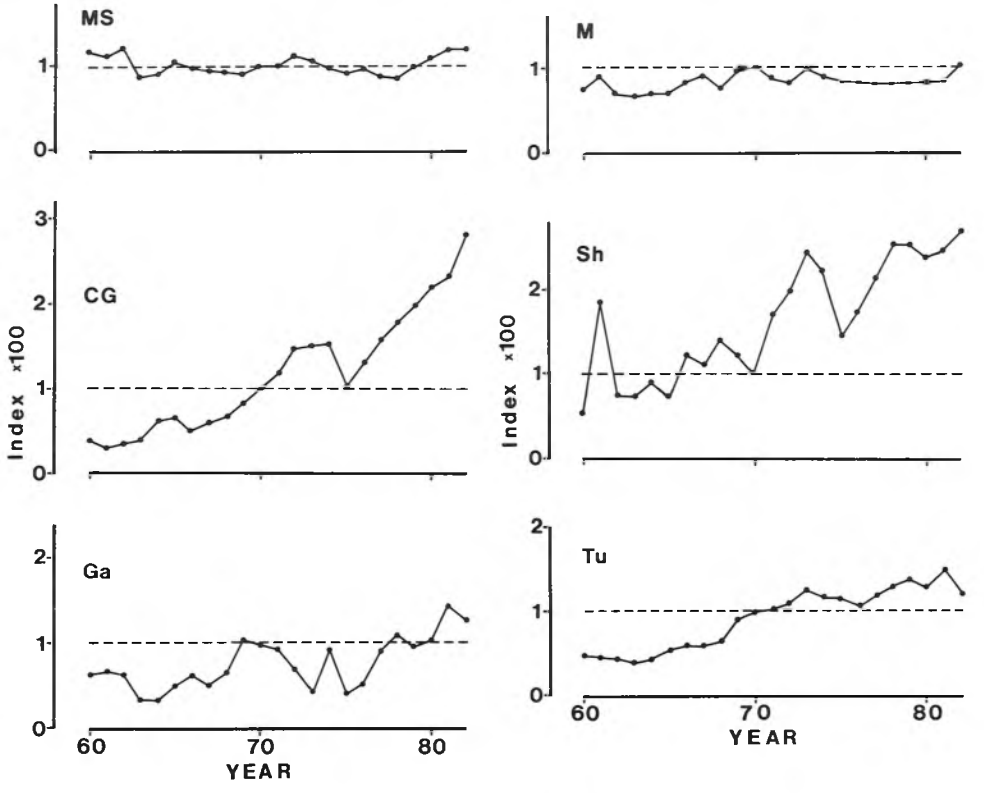

Figure 3. Trends in the numbers of five common species in September, from National Wildfowl Counts. Sh – Shoveler; Ga – Gadwall. Other abbreviations as in Figure 2.

Dzubin 1969; Prater 1979).

In the present survey each observer was aiming to count accurately the numbers of adult and young waterfowl at a particular inland water site. Counts of nests and clutches would not be acceptable because of the difficulties and time needed to locate nests and because of the resulting disturbance.

Most of the errors in this survey are likely to be underestimates because of birds being hidden by vegetation or inhabiting inaccessible parts of a site and the degree of error is likely to show considerable inter-specific variation. Large and obvious species such as Mute Swans can probably be fairly precisely censused and diving ducks and Great Crested Grebes, which spend a large proportion of their time on open water, are likely to be more accurately counted than dabbling ducks. The highest errors will occur for shy, inconspicuous species such as Teal.

In spite of these inherent weaknesses, the results represent the most comprehensive set of data on a national scale for British breeding waterfowl.

Breeding densities

For most migratory waterfowl Britain does not support very significant proportions of their North-West European Flyway populations during the breeding season; the main breeding areas are in Iceland, Greenland, Fennoscandia and eastern Europe.

In all the species for which comparative data are available, the breeding densities in Britain are generally higher than in the extensive boreal and sub-arctic breeding areas of northern Fennoscandia, except for Teal, which seem to breed at low density throughout their range. The British figures were generally comparable with those found on relatively productive eutrophic waters in southern Sweden. In the case of Mallard, breeding pair densities per unit area of water are equivalent to the values reported from some of the prime areas of the Northern Prairie breeding zone in North America. This suggests that the main reason for the relatively small British breeding populations is the limited availability of wetland habitat rather than its quality.

Total breeding populations

If this survey had sampled a representative number of sites, and the area of enclosed inland water throughout the range were known, it should be possible to estimate the total populations of those species largely dependent on that habitat. However, although figures are available for the area of water in England, Wales and Scotland separately, the distribution of the birds was not well enough matched with the national boundaries for reasonable estimates to be made. In particular, the concentration of waters in north-west Scotland and the relatively scarcity of data from there makes any extrapolation for species inhabiting Scotland meaningless. All that can be said is that figures from this survey are not inconsistent with the population estimates given in Table 1.

Productivity

Productivity is one of the key variables in understanding the population dynamics of any species and becomes of especial significance where questions of harvesting are concerned. As there are no national-scale production estimates for most British breeding waterfowl, an attempt at using some of the survey data to make some estimates would seem to be justified. The figures will no doubt be improved in the future in the light of new studies. In Table 10 estimates are produced for four of the commonest species, in which censusing problems should not have produced excessive bias in the variables used.

The analysis is based on the estimates of the pre- and post-breeding densities and the other parameters are calculated as follows:

Let: D1 = Pre-breeding density
D2 = Post-breeding density (August)
S = Proportion of breeding females
PD = Pair density (D1 x S)

Therefore: Production per pair (P1) = (D2–D1)/PD
Production per adult (P2) = (D2–D1)/D1

In each case density is on a site basis (i.e, mean of site densities where the species occurs).

The only species for which a comparative estimate is available is for Mallard in North America, where between 1955 and 1957, the overall continental production ranged from 0.6 to 1.7 young per adult, with a mean of 1.1. The value calculated above is slightly higher than the average of the North

Table 10. Estimates of breeding productivity of three of the most common British waterfowl.

Species	Month	D1	S	PD	D2	P1	P2
Mallard	Mar	2.21	0.45	0.99	4.89	2.7	1.20
Tufted Duck	May	1.04	0.40	0.42	2.38	3.0	1.30
Coot	Mar	2.50	0.40*	1.00	4.82	2.3	0.93

* The proportion of breeding females is based on an estimate of non-breeding rather than a disparity in the sex ratio.

American rates and suggests that Mallard production per unit area of water in Britain is relatively high. On a smaller scale, Hill (1982) found that Mallard production per pair at Sevenoaks Gravel Pit Reserve, Kent, varied between 5.3 and 0.8 young, with a mean of 3.3. The reserve was managed specifically for the ducks, but our figure for Britain as a whole in 1980 was not much below the Sevenoaks average.

Acknowledgements

This study was part of a three-year project investigating the effect of recreation on waterfowl in inland waters in Britain, funded jointly by the Nature Conservancy Council and the Sports Council.

We sincerely thank the volunteers and local organisers of the BTO network for their work in the field and the Populations and Surveys Committee and Dr. R. O'Connor for support and help with the organisation of the survey.

The three project supervisors, Dr. S. Glyptis, Dr. D. R. Langslow and Professor G. V. T. Matthews, are thanked for their guidance, encouragement and constructive suggestions throughout.

Many people at the Wildfowl Trust, especially D. Salmon, at the Sports Council and the N.C.C. gave information and practical help, and N. Mays and M. Tanner are thanked for critically reading drafts of the manuscript.

Summary

This paper describes a survey of breeding waterfowl (ducks, geese, swans, rails and grebes) on enclosed inland waters in Britain in 1980. Data on numbers of adults, broods and young and on brood size, were collected from 448 sites with a wide geographical spread and representative of habitat types available. Information on the recreational activities taking place at each site and their intensity was also collected.

Sixty percent of waters were natural lakes, 28% reservoirs and 12% gravel pits. Reservoirs were the largest sites on average (45 ha) followed by gravel pits (33 ha) and natural waters (28 ha). Overall 40% of birds are on man-made habitats, but these are particularly important for Tufted Duck *Aythya fuligula* (51%), Coot *Fulica atra* (46%) and Great Crested Grebe *Podiceps cristatus* (60%).

Mallard *Anas platyrhynchos* was by far the most widespread and numerous of the species, and occurred at the highest densities, followed by Coot, Tufted Duck and Canada Goose *Branta canadensis*. Density and productivity on British inland waters compared favourably with published figures for Scandinavia and North America. Details are given of density, productivity and breeding seasons of the commoner species.

The number of adults counted was positively correlated with site area but area had no effect on either the number or density of young.

In a comparison of matched sites surveyed in the mid-1960s, and an examination of Wildfowl Count trends for September, most species had increased their numbers since, and some very dramatically. Only one species, the Shoveler *Anas clypeata*, an uncommon breeder, had shown a noticeable decline in the survey comparison, but the reverse was true in all habitats.

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