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24.—Waterfowl at Loch Leven, Kinross. By A. Allison* and I. Newton,†
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SYNOPSIS

A large water surface, suitable islands for nesting, extensive shallows, rich adjoining farmland and comparative peace help to make Loch Leven internationally important for waterfowl. It has long held the largest concentration of breeding ducks in Britain, consisting in 1966–72 mainly of tufted duck (500–600 pairs) and mallard (400–450 pairs), but also of gadwall (20–30 pairs), wigeon (25–30 pairs), shelduck (5–18 pairs), shoveller (up to 10 pairs) and teal (up to 10 pairs). In winter, it was important for mallard, teal, pochard and in some years for shoveler, and held good numbers of wigeon and goldeneye. These various species differed in the proportion of their food which they obtained from the loch itself. The loch also acted as a winter roost for up to 5000 greylag geese, up to 12 500 pinkfeet and up to 430 whooper swans, all of which fed entirely in nearby fields. The numbers of most species underwent regular seasonal fluctuations, with peaks and troughs in the same months each year; but different species reached peak numbers in different months. In general, waterfowl numbers were greatest in autumn, when the loch held up to 20 000 birds.

The status of several species at the loch has changed markedly during the last 100 years. Some such changes were linked with general changes in the ranges and status of the species concerned, but other (more recent) ones with the reduction in macrophytes following eutrophication.

INTRODUCTION

This paper documents the status of waterfowl at Loch Leven from regular counts in 1966–72. Lying in the fertile Kinross plain, Loch Leven is one of the best sites in Europe for waterfowl. A water surface of 13.3 km² offers space and security on a scale matched by few other inland waters, while several large islands provide ideal conditions for nesting. Extensive shallows give good feeding for dabbling ducks, while large areas of slightly deeper water, unclogged by weed, are highly suitable for diving ducks. Finally, the productive farmland nearby offers rich pickings for those species prepared to commute. The loch is now generally recognised as of international importance for waterfowl.

More than 1000 duck pairs nest each year on the islands of Loch Leven, the largest concentration in Britain. For wintering the loch is one of the most important sites for mallard, teal, pochard and in some years for shoveler, and also holds good numbers of wigeon and goldeneye (though these last species are generally more numerous near sea coasts). It is one of only seven sites where large numbers of greylag and pink-footed geese overwinter together; both species roost on the loch and forage in nearby fields. For pinkfeet, it acts as an important arrival centre, and for a few days may hold more than 20 per cent of the European (= world) stock. Greylag reach peak numbers in midwinter, when the loch may hold up to 5 per cent of the north-west European stock. Until recently it supported several hundred mute swans during their annual moult, and up to 430 whooper swans still roost there, foraging, like the geese, in nearby fields. In early October, when populations reach their peak, the loch may hold nearly 20 000 ducks, geese and swans.

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Two major changes occurred in the loch and its wildfowl since 1800. The first, in 1830, was a lowering of the water level, and consequent loss of extensive marshlands. The second was eutrophication and the restriction of the macrophytic vegetation. The last good year for macrophytes was about 1950, most of the emergents had gone by 1955, but *Chara* remained plentiful until 1966 and there is still some *Phragmites* (Jupp, Spence and Britton 1974).

Various studies on wildfowl have been made at Loch Leven in recent years, but this paper is concerned only with numbers. Detailed studies on feeding geese have been published elsewhere (Newton and Campbell 1970, 1973; Newton, Campbell and Allison in press), while studies of breeding ducks are in preparation.

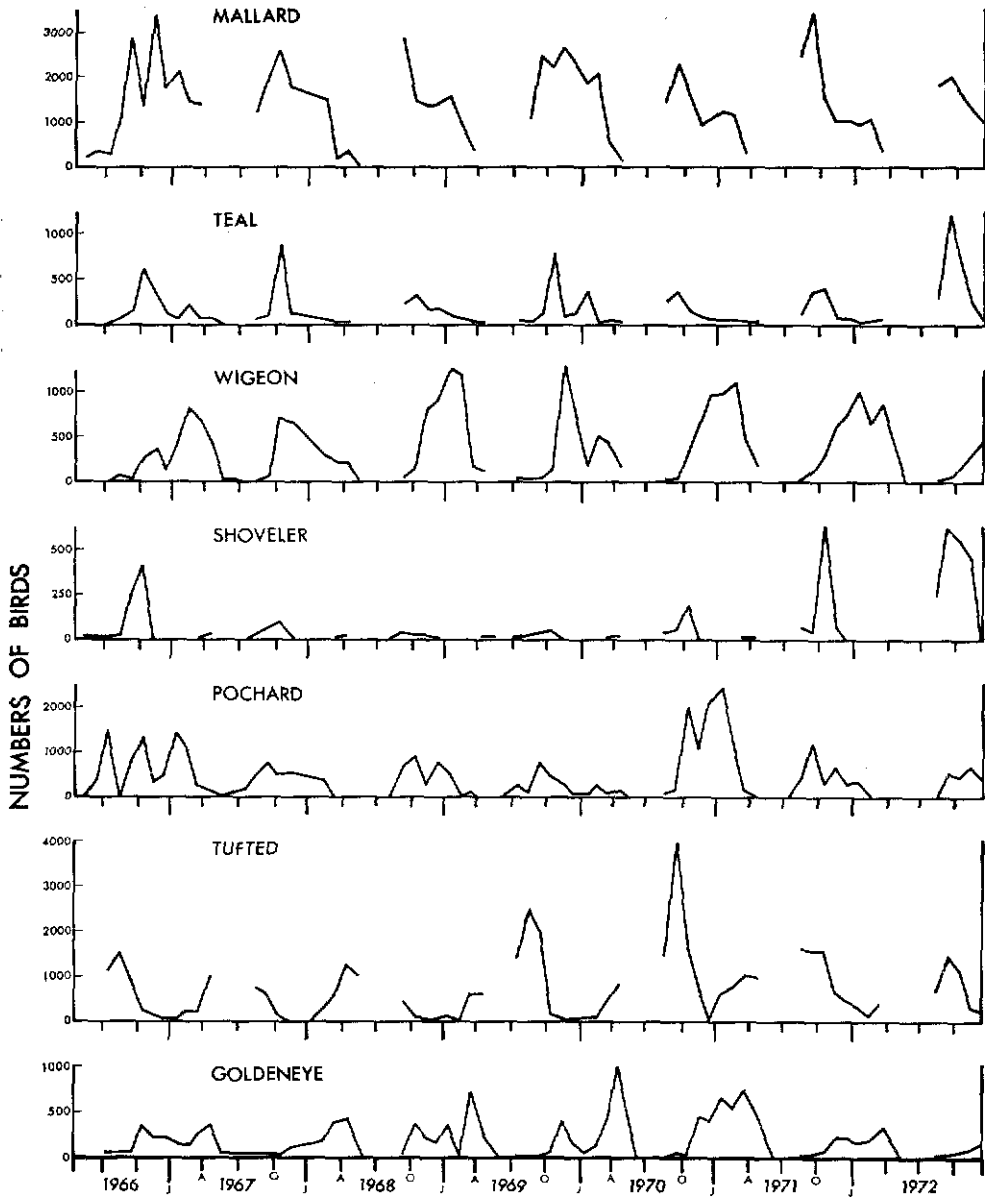
METHODS AND SOURCES OF INFORMATION

The regular counts of waterfowl at Loch Leven, started in 1966, enabled us to assess the status of individual species and to judge the importance of Loch Leven in relation to other waters, which were also counted (less often) as part of a national (Wildfowl Trust) scheme. Geese and whooper swans were counted as they left the loch on their dawn flight to farmland, by three observers posted strategically around the shore. These counts were done weekly for four years and monthly for the last three. Ducks were counted from a boat or raised vantage points on shore at least once each month, except in late spring/early summer when many birds were away at nests. Getting a reliable result for ducks depended largely on having the right conditions. All the birds present could be seen only on clear, calm days, and because many ducks fed on land, or in nearby ponds and ditches, there was some movement of birds on and off the water. Early morning was selected as the best time to count, because most birds were present then and movement was minimal. Also at this time no disturbance was experienced from other boats on the loch. The chief difficulty was then in counting ducks in very large flocks. We had no check on accuracy except for consistency, but each observer kept in practice by checking estimates against counts. The counts provide an order of magnitude to the population, in tens or hundreds, according to species (text-fig. 1).

Another indication of duck numbers came from nests found each year on St Serf's Island, which was searched once each week, taking up to three days (table 1). This index does not reflect the number of pairs accurately, because not all nests were found, and the sample included many repeat nests, started after the loss of an earlier one. It nevertheless indicated the composition of the nesting colony, and provided a baseline against which similar counts might be compared in future.

An idea of the past status of waterfowl at Loch Leven was gained from Sibbald (1710), Old and New Statistical Accounts of Scotland (1793, 1839), Millais (1901, 1902, 1913, based on observations in 1879-89), Baxter and Rintoul, hereafter 'B. & R.' (1922, 1928, 1953), Berry (1939) and others. These earlier accounts depended chiefly on subjective assessments of numbers and the first detailed counts were by Smith (1952-63) and Boase (1964). The estate game books (1904-72) also yielded useful information, but only for 1931-38 and 1947-72 were species listed individually (table 2). While such records reflected long-term changes, probably in no year were the different species shot in proportion to their numbers on the loch. Some wildfowlers were reluctant to shoot diving ducks, which were anyway more wary than

dabblers. Likewise, among geese, pinkfeet formed less than half of the bag in recent years, though for much of the season they greatly outnumbered the less wary greylag. The regular examination of all birds shot during 1966-72 gave some idea of age and sex ratios, food and (from whether the crop was full or empty) of feeding times.



TEXT-FIG.1.—Fluctuations in the numbers of the commonest duck-species on Loch Leven, 1966-72.

TABLE 1

Number of duck nests found on St Serf's Island, 1966-70

	1966	1967	1968	1969	1970
Mallard	272	557	368	415	372
Gadwall	41	47	33	24	34
Teal	8	4	1	2	0
Wigeon	40	36	23	24	30
Shoveller	6	10	6	4	3
Tufted Duck	290	452	250	365	485

TABLE 2

Numbers of ducks and geese shot at Loch Leven in different periods. The composition of the bag in any one period does not reflect the composition of the wintering population because some species are easier to shoot than others. However, changes in the composition of the bag from one period to another are thought to reflect changes in the relative abundance of different species in the wintering population.

(+ = less than 1 per cent)

	1931-38	1948-55	1956-58	1961-73
Mallard	1,585 (48%)	1,175 (45%)	349 (39%)	1,865 (33)%
Teal	866 (26%)	587 (22%)	193 (22%)	1,297 (24%)
Wigeon	589 (17%)	370 (14%)	122 (14%)	1,255 (24%)
Gadwall	94 (3%)	48 (2%)	39 (4%)	96 (2%)
Pintail	28 (1%)	9 (+)	8 (1%)	19 (+)
Shoveller	16 (+)	86 (3%)	22 (3%)	94 (2%)
Tufted	89 (3%)	186 (7%)	69 (8%)	248 (4%)
Pochard	11 (+)	17 (+)	18 (2%)	103 (2%)
Goldeneye	49 (1%)	141 (6%)	56 (7%)	357 (5%)
Scaup	1 (+)	0	0	11 (+)
Long-tail	1 (+)	0	0	2 (+)
	3,329	2,619	876	5,347
Pinkfoot	580	666	178	1,062
Greylag	23	373	137	1,095
Bean	5	0	0	0
Others	8	7	0	3
	616	1,046	315	2,160

Until 1930, the shooting of wildfowl at Loch Leven was light and by the owners. From 1931 to 1938, the shooting was leased and pools near the shore and on St Serf's were baited regularly with grain, a procedure which might have increased the bag of dabbling ducks. During 1939-45, shooting was leased to a new tenant and, from 1947 the present system of leasing to different weekly parties was started, each party consisting of 4 guns (+ 2 with keepers). Up to 1960, 6-7 parties were present each season, and from 1961, 6. Each week included 3 days on St Serf's island, 2 on the smaller islands and 1 on the shore, with separate morning and evening flights as conditions dictated.

Swans

The number of breeding mute swans on Loch Leven fell from a maximum of 25 pairs in the years prior to 1966 to 3-4 pairs in 1966-72. In this last period, few young were raised (1 in 1970, 10 in 1971, 2 in 1972). Also, before 1966 up to 500 non-

breeders accumulated on the loch each June–August to moult. Then total numbers fell steadily, with maxima of 190 in 1966, 95 in 1967, 30 in 1969 and 14 in 1971, then 41 in 1972. This reduction in swans coincided with the reduction in macrophytes, their main food, and the slight increase in 1972 with a temporary resurgence of *Potamogeton*.

Whooper swans, on the other hand, continued to visit the loch in large numbers, but fed entirely in fields. Present from October to April, they reached peak numbers of between 90 and 430 in different autumns. On some nights, many roosted in fields or on a small pond at Balado (and were missed on the counts). Single birds remained through certain summers.

Geese

As recent counts have been discussed in detail elsewhere (Newton and Campbell 1970, 1973), only certain points need to be made here. Each year from 1966 the numbers of pinkfeet roosting on the loch were greatest in early autumn (up to 12 500), then fell to a lower, but greatly fluctuating, level during winter and spring. Greylag were generally fewer than Pinkfeet, and reached peak numbers (up to 5000) in late autumn and winter. Odd greylag pairs, probably pricked birds, bred in some years. Small parties of Canada and barnacle geese were seen in all years, and four other species occasionally (table 3).

TABLE 3

Status of waterfowl at Loch Leven, 1966–72

SWANS	
Whooper swan <i>Cygnus cygnus</i> (L.)	Winter visitor, peak numbers (up to 430) in November.
Bewick swan <i>Cygnus bewickii</i> Yarr.	Rare vagrant. Family party in Jan–Feb 1968.
Mute swan <i>Cygnus olor</i> (Gm.)	Resident, 3–5 pairs bred, up to 30 others Jun–Aug.
GEESE	
Greylag <i>Anser anser</i> (L.)	Mainly winter visitor, peak numbers (4000–5000) in Dec–Feb. Odd pairs (probably ‘pricked’) bred in some years.
Whitefront <i>Anser albifrons</i> (Scop.)	Vagrant, few of Greenland race seen most winters. Odd recent records of European race.
Bean Goose <i>Anser fabalis</i> (Lath.)	Before 1900, regular in small numbers. Few recent records include 4–6 in late Oct 1972.
Pink-foot <i>Anser brachyrhynchus</i> Baillon	Winter visitor, peak numbers 10 000–12 500 Sep/early Oct
Snow-goose <i>Anser hyperboreus</i> Pall.	Rare vagrant, singles most winters.
Ross’s Goose <i>Anser rossii</i> Cassin	1–2 with Pinkfeet each autumn, 1967–71; adult male shot January 1972.
Barnacle <i>Branta leucopsis</i> (Bechst.)	Regular winter visitor in small numbers (usually 2–5 birds), with Pinkfeet.
Dark-breasted brent <i>Branta b. bernicla</i> (L.)	One bird with Greylag, Dec 1970.
Pale-breasted brent <i>Branta b. hroia</i> (Muller)	Rare vagrant, one each autumn, 1967–72, with Pinkfeet.
Canada Goose <i>Branta canadensis</i> (L.)	Small parties occasionally stop during moult migration, Jun/Jul and Sep/Oct.

TABLE 3 (cont.)

Ducks	
Shelduck <i>Tadorna tadorna</i> (L.)	Mainly summer visitor, up to 18 pairs bred; also up to 2 non-breeders present in Jun. Odd birds in winter.
Mallard <i>Anas platyrhynchos</i> L.	Resident, 400-450 pairs bred; peak numbers (up to 3500) in Sep.
Gadwall <i>Anas strepera</i> L.	Mainly summer visitor, 20-30 pairs bred. Odd birds in winter.
Teal <i>Anas crecca</i> L.	Resident, up to 10 pairs bred. Mainly autumn migrant, peak numbers (up to 1200) in Oct, 100 in mid-winter.
Garganey <i>Anas querquedula</i> L.	Recorded once, in Sep 1936. No recent records.
Wigeon <i>Anas penelope</i> L.	Resident, 20-30 pairs bred. Mainly winter visitor, peak numbers (up to 2000) in Jan.
Pintail <i>Anas acuta</i> L.	Former breeder. Small numbers (<50) in Sep/Oct, odd birds later.
Shoveler <i>Anas clypeata</i> (L.)	Resident, up to 10 pairs bred. Mainly autumn visitor, peaks up to 650, but varying greatly from year to year.
Pochard <i>Aythya ferina</i> (L.)	Breeding not proved. Present all year, with influxes varying in time and numbers. Up to 2500 seen at once.
Tufted <i>Aythya fuligula</i> (L.)	Resident, commonest breeding species, with 500-600 pairs. Peak numbers (up to 4000) late Sep, usually < 50 during winter.
Scaup <i>Aythya marila</i> (L.)	Winter vagrant in small numbers. Twice seen in summer.
Goldeneye <i>Bucephala clangula</i> (L.)	Mainly winter visitor. Peak numbers (up to 1000) in Mar/Apr.
Long-tailed duck <i>Clangula hyemalis</i> (L.)	Rare vagrant, several autumn records, immature pair in Jun 1971.
Velvet scoter <i>Melanitta fusca</i> (L.)	One record, Aug 1972. (The only previous record was one in 1959).
Goosander <i>Mergus merganser</i> L.	Winter visitor, peak numbers (up to 150) in Feb/Mar.
Red-breasted merganser <i>Mergus serrator</i> L.	Bred at least once (female and young ringed). Otherwise rare vagrant.
Smew <i>Mergus albellus</i> L.	Rare vagrant, two winter records.

In Millais' (1906) time, bean geese were regular in small numbers at Loch Leven, pinkfeet were many fewer (autumn peak 2000-3000) than today, and greylag were scarce. Bean geese largely disappeared around 1900 as in most of their British haunts (Berry 1939), pinkfeet increased mainly after 1920, and greylag colonised in numbers only after 1940, and increasingly so from 1950 (see Shooting Records, table 2).

Ducks

Much the same species were present through the year. Of seven regular breeders, tufted duck (500-600 pairs) and mallard (400-450 pairs) were most numerous, followed by wigeon (25-30 pairs), gadwall (20-30 pairs), shelduck (15-18 pairs), shoveler (up to 10 pairs) and teal (up to 10 pairs). Each year, after breeding, some of these seven species declined in numbers, through emigration, while others increased. In addition, three species, of which only odd birds were present in summer, came in for the winter. One species visited the loch in smaller numbers or for short periods, another bred at least once, while several other species were seen rarely (table 3). In general, the duck population as a whole reached its peak in September.

Species are discussed individually below, and the fluctuations of the seven most numerous ones during 1966–72 are shown in text-fig. 1. During the years considered, periods of hard weather were few, except in 1969, when ice cover was complete, or almost complete, from 9 February to 7 March. But at no time did the loch's freezing coincide with deep snow on surrounding fields, so for certain species food was always available.

Mallard

In 1966–72 some 400–450 pairs nested each year, most at high density on St Serf's Island, with small numbers on other islands and around the shore, especially near Kinross House. Each year an increase occurred from August, through immigration, and peak numbers were reached in late September of 2200–3500 in different years. Numbers then declined until the next March, but earlier in some years than in others, so that the use of the loch by mallard varied greatly from winter to winter. The autumn level depended partly on the condition of other local waters (more birds on Loch Leven in 'drought' years) and partly on the proportion of young in the population (judged from the ages of shot birds).

In autumn and winter, mallard fed mainly from farmland (at night) and in spring and summer from the loch shallows, especially along the north side of St Serf's, the east loch shore, and around the sewage outfall near Kinross House. During short periods when the loch surface froze, numbers were generally maintained, as the birds roosted on ice and fed on land. Mallard formed around 33 per cent of all ducks shot in recent years (table 2).

Neither literature nor game books suggest any marked long-term change this century in the status of mallard at Loch Leven. The species was mentioned in Sibbald (1710), in both Statistical Accounts (1793, 1839) and every relevant publication until the present, while Smith gave midwinter levels in 1955–63 of *ca* 1000, about the same as in 1966–72.

Gadwall

In 1966–72 gadwall were mainly summer visitors. About 20–30 pairs bred each year, mainly on St Serf's. Most returned in April and left in September/October, the females and young last. Drakes formed groups on their own from mid June, but following poor breeding in 1972, 54 adults of both sexes were seen in one place on 3 July. Levenmouth Pool was a favoured feeding area. Odd birds were seen in winter usually with wigeon. Gadwall formed about 2 per cent of the bag, mainly females and young.

This species did not breed at Loch Leven in Millais' (1902) time, but two nests were found in 1909 and one in 1910 (B. & R. 1922, 1928), while subsequent accounts imply continuity in nesting since. In the past gadwall evidently wintered in larger numbers than at present (B. & R. 1935). Fitting this view, the mean annual kill was about the same in 1931–38 as in 1945–60, but the proportion killed after November was significantly higher in the first period than in the second. Counts by Smith imply that the reduced wintering had set in by 1952–63.

Teal

In 1966–72, the number of nests found on St Serf's fell steadily from 10 to none (table 3). Each year, an influx of birds occurred from August, and peak numbers

of 300–1200 birds were reached in different Septembers. Numbers were lower (often less than 100) from November to March, depending partly on water level, though in some years a temporary increase occurred in spring, after which almost all birds left in March/April. Birds fed almost entirely on the loch, favouring persicaria (*Polygonum amphibium* L.) beds, but in autumn they also visited stubble. They left temporarily when the loch surface froze. Teal formed 24 per cent of the total birds shot.

Always a scarce breeder, no obvious long-term change in status has occurred. Teal were listed in Sibbald (1710), and in both Statistical Accounts (1793, 1839), while Millais (1902), B. & R. (1935, 1952) and Berry (1939) confirmed that it bred, and was most numerous in autumn. During the breeding seasons of 1952–63, Smith saw few birds and found only one nest (May 1961), but in different Septembers recorded up to 1000 with an exceptional 2000–3000 in 1959, a year which was generally good for immigrants. Perhaps fewer teal stayed into winter recently than formerly, however, because in 1931–38 about 50 per cent of teal were killed in December/February, compared to 35 per cent in 1966–72. The difference is not significant statistically, but would be expected, because the baiting of small ponds which occurred in the first period had stopped by the latter.

Wigeon

In 1966–72 about 25–30 pairs nested, mainly on St Serf's. Numbers began to increase from late September each year, reached a peak of 1000–2000 birds in different Januaries, then declined to April. The birds fed mainly on grass on St Serf's, but also (by night) in wet pastures near the loch shore and, not surprisingly, numbers were maintained when the loch surface froze. In September 1971, when *Potamogeton* grew well, this proved a favourite food. Wigeon formed 24 per cent of the ducks shot each year, in October mainly females and young, and later drakes as well.

Millais (1902) found the first wigeon nest and stated that by 1902 the species bred regularly. Evans (1910) found six nests, and Smith (1952–63) estimated the breeding population in 1959 at 7–8 pairs. Outside the breeding season, the situation has not changed greatly (Millais 1902; B. & R. 1928, 1935, 1936, 1953) and the game books confirm that numbers increased each year from October to January.

Pintail

One bird was seen in June 1966 but breeding was not proved. Each year small numbers were present from late August to early October, with peaks of 25 in 1970, 31 in 1971 and 73 in 1972. Numbers then declined, and from early November, most sightings were of singles. Pintail fed mainly in the shallows with other dabbling ducks, but occasionally flew to stubbles at night. As most birds left before the shooting season, they formed a negligible fraction of the bag.

Pintail bred at Loch Leven at least between 1898 (Evans 1898) and 1939 (Berry 1939). Four nests were found in 1898 and nine (on Castle Island) in 1899, while the 13 found in 1900 were thought to form no more than half the population (Millais 1902). In Harvie-Brown (1906), Millais gave the breeding population as 20 pairs; while B. & R. (1935) wrote that the colony had 'continued to increase'. However Smith saw no pintail in the summers 1952–60, and only odd ones in 1961–63. The latest breeding record was a female and young seen by R. W. J. Smith and T. Boyd in 1962. Millais (1901) did not mention the pintail among the ducks wintering at Loch

Leven, but later accounts (e.g. Berry 1939; B. & R. 1953) and the game books indicate an autumn and winter population much as in 1966–72.

Shoveler

Up to 10 pairs nested each year, mainly on St Serf's. Breeders returned in early April, but more birds moved in from mid-August, and reached peak numbers in late September. These varied greatly from year to year, partly according to water level. The largest number seen was 650 in 1971, though numbers were also high in 1966 and 1972. In most years the birds had gone by late November, but in one year many stayed into December. Shovellers formed only 2 per cent of the 'bag'.

Comparing early with recent records suggests no marked change in breeding numbers. Millais (1902) estimated 8–10 pairs in the late 1880s, Evans in B. & R. (1922) 10–12 pairs in 1898 and 1908, B. & R. 'several pairs' in 1910, and Smith 14–18 pairs in 1957. Counts of 20–500 were obtained in September/October in different years, so previously, as in 1966–72, autumn numbers varied greatly. Millais (1902), however, commented on a marked spring passage which was not apparent in 1966–72.

Tufted

In 1966–72 the tufted was the commonest breeding duck, with 500–600 pairs nesting annually, mainly at high density on St Serf's. The main influx of breeding birds occurred each year between early March and mid-April, when surveys revealed 7 drakes to every 5 hens. By late June, when drakes began to moult, they were found in large flocks far off shore. In most years, in August/September, the population was only slightly higher than in March/April, implying poor breeding, and presumably the larger autumn peaks of 1969 (2500) and 1970 (4000) resulted at least partly from immigration. In all years numbers dropped suddenly in late September. On most dates in winters up to 1969–70 less than 50 birds were present and in later winters rather more (text-fig. 1). The relative scarcity of tufted at Loch Leven in winter was puzzling, for they were plentiful on nearby waters. All birds left completely when the loch froze, though odd ones stayed on the River Leven. From observations and gut analyses, most feeding occurred at night. Areas less than 4 m deep were preferred, and Chironomids formed the main food (Laughlin 1974). Tufted formed only 4 per cent of the shooting bag.

Although present earlier (Jardine 1843), tufted ducks began breeding in large numbers at Loch Leven only after 1850 (Harvie-Brown and Evans 1896). Millais (in Harvie-Brown) estimated 100 broods in 1880, 300–1000 birds in late summer and (1913), 400–500 birds in October. Later counts by B. & R. (1953), Smith (1952–63) and Boase (1964) recorded much the same numbers, season for season, as in 1966–72. Likewise, although the game books revealed wide variations in numbers shot from year to year, they suggested no long-term trend, at least since 1931.

Pochard

No nest was found in 1966–72, though odd birds were seen in May/June in some years and a female accidentally killed on 2 June 1969 had recently laid. Pochard occurred at Loch Leven erratically at other seasons and in numbers which varied greatly from year to year. An influx occurred for 2–3 weeks in July, consisting of 1500 birds in 1966, less than 200 in 1967 and less than 40 in later years. A second,

more regular, influx began each August and reached 500–2200 in different Octobers. Numbers then dropped during winter and few birds remained after mid-March. The July and autumn influxes consisted almost entirely of drakes. When ice began to form, pochard were the first diving ducks to leave.

During the first few years, pochard were not seen to feed by day on Loch Leven, but some flew south-east at dusk and returned at dawn, presumably from the Forth. In 1970–72, however, when *Potamogeton* grew well, the autumn flocks grazed it extensively, sometimes in water only a few inches deep. Even after free parts of the plants had been washed ashore, birds fed on the freshly sprouting winter buds (found in shot birds) present in the sand. Pochard were hard to shoot, and formed only 2 per cent of the 'bag'.

Previous records indicate no marked change in status, but confirm that small numbers have bred at Loch Leven from time to time (Millais 1913; B. & R. 1935, 1953; Smith 1952–63). The October population reached 'several thousands' (Millais 1913; B. & R. 1935), though more recently Smith (1952–63) and Boase (1964) recorded up to a thousand in October, and fewer in winter.

Goldeneye

During 1966–72, odd birds seen in summer (mainly immatures) were not proved to breed. The main influx each year occurred from early September to late November. In some years numbers then dropped, while in others they remained more or less stable until late February, when in all years further immigration occurred until late March or April, followed by a sudden drop. Usually 150–200 birds were present in winter, and 400–750 in spring, but in 1970 the corresponding figures were 400–600 and 1000.

For most of winter, the population consisted mainly of females and immatures, but the spring influx contained many adult males. In March and April, scores of males were sometimes seen displaying to only one or two females. Goldeneye fed mainly where the bottom was stony, in water 0.5–3 m deep. When the loch froze, they were the last diving ducks to leave, remaining on any open patches or near the river mouth.

Goldeneye have probably increased at Loch Leven in recent years. They were recorded in autumn and winter by Millais (1901) and B. & R. (1928), while Berry (1939) said they were one of the scarcest of regular winter visitors. They formed more of the bag in 1948–72 (5 per cent) than in 1931–38 (1 per cent). Odd summer records were given by Evans (1909), Smith (1952–63) and Boase (1964).

Goosander

During 1966–72 occasional birds were seen in summer, but not proved to nest. The main influx began in October each year, and numbers built up slowly to a peak in February/March, with up to 150 in different years, mainly adult males. Most birds examined during 1971–73 contained perch (*Perca fluviatilis* L.) fry, one bird sticklebacks (*Gasterosteus aculeatus* L.) and one a trout (*Salmo trutta* L.). As might be expected, all birds left when the loch froze.

Though varying greatly from year to year (B. & R. 1928), numbers were perhaps larger in the past than in 1966–72. Millais (1913) wrote that the goosander was 'no where so abundant as on Loch Leven in early spring, whence I have seen it in

hundreds'. He records once seeing 1000 and shooting six in early spring (birds in Perth Museum killed by him are dated 1883). B. & R. (1935) stated that, while present in some winters in large numbers, in others it was scarce.

Shelduck

During 1966-72 the 5-18 breeding pairs (assuming all birds seen were paired) returned from late February/early March, and most were back by May; 5-9 broods were counted in different years and on some dates in July 1969 and 1971 up to 21 non-breeders or failed breeders were also present (Jenkins 1972). Adults remained into August and young into September or later, though occasional birds were present briefly in winter. Shelduck fed in undisturbed shallows around the loch edge. They nested in old rabbit holes on St Serf's Island and on nearby hillsides and, in at least 3 years, bred much more successfully than other ducks.

It is not certain how long shelducks have bred at Loch Leven, but they probably started this century. Millais (1901) recorded shelducks as present in autumn, and one shot by him in Perth Museum is dated 1885. B. & R. (1922) recorded the species as present in winter and occasionally in summer, but by 1936 had found some nests. Berry (1939) estimated the breeding population at 20 pairs.

Other Species

The status of other water birds at Loch Leven is summarised in Appendix 1. Shortage of space prevents detailed discussion, but the coot deserves special comment because, like other plant feeders, it has declined greatly in recent years. According to B. & R. (1935) this species bred and wintered in large numbers. For 1955-62 Smith and Boase gave monthly peaks of 300 (August), 2000 (September), 1200 (October), 500 (November), 250 (December), 500 (January) and 250 (February). During 1966-72, no more than 25 pairs bred, the autumn peak did not exceed 270, with less than 100 at mid-winter. An exception was in 1971, a good year for weeds, when autumn numbers reached 400.

DISCUSSION

Outside the breeding season, the duck flocks at Loch Leven consisted of both native and foreign-bred birds. From what is known of the size of the British breeding populations, the teal, wigeon, shoveler, pochard and goldeneye, which appeared at Loch Leven, must have come entirely, or almost entirely, from overseas. Ringed birds shot on the loch included mallard and teal from Denmark and Eire. On the other hand, tufted ducks ringed at Loch Leven in summer were recovered mainly in Northern Ireland, mallard in Eire and Holland, gadwall in Eire and Spain, wigeon in Russia, France, Iceland and Finland, teal in Sweden, Denmark and Eire and these and other species on other local waters. Hence, interpretation of both long- and short-term changes in numbers at Loch Leven is often difficult because these changes depended partly on events elsewhere.

Long-term Changes

Although the counts of 1966-72 must usually be compared with no more than subjective impressions from the past, the change in some species was so marked that it must have been genuine. Some such changes were widespread, and clearly unrelated

to change at the loch itself. These included the disappearance of bean geese around 1900, the subsequent increase in pinkfeet, and the colonisation of the area mainly from 1940 by greylag. All these geese used the loch merely for roosting and fed on land near by, where waste from the abundant potato and cereal crops, much increased since 1940, helped to support a large wintering population. The colonisation of the loch by breeding wigeon, gadwall and pintail and the increase in tufted was also linked with a general spread of these species after 1880. On the other hand, certain changes between 1950 and 1972 might reasonably be attributed to the disappearance of the macrophytes following eutrophication. These included the virtual disappearance of the large summer flock of moulting mute swans, the lack of large coot flocks in recent years and the reduced use made of the loch in summer by pochard. All these species at the seasons concerned fed primarily on vegetation. The reduction in macrophytes might also have meant a reduction in food (especially insects and molluscs) and cover for dabbling ducks, as would loss of the large *Phragmites* beds on the east shore. These changes would be expected to have resulted in lowered duckling survival, and might well account for the heavy losses of dabbling ducklings evident in recent years (though good comparative data are lacking for earlier years). They might also explain why the autumn teal and gadwall flocks no longer persist through winter. These two species, with shoveler, were the dabbling ducks which fed mainly from the loch, while the mallard and wigeon whose status has not changed, fed largely from land. Diving ducks other than pochard might be expected to benefit from the disappearance of obstructing weeds. The whole of the eastern third of the loch, nearly all less than 3 m deep, was until about 1950 choked with a dense growth of weed in summer and autumn, rendering the area almost useless to diving duck which could penetrate it with difficulty, if at all. (It is still not a major feeding area for tufted duck however.) Goldeneye are probably present in larger numbers than formerly, while tufted also used the loch more in the autumn and winter from 1970 than before.

Other long-term status changes at Loch Leven, which we cannot reasonably link with any widespread status change or with changes in conditions at the loch, include the reduction in wintering goosanders and the disappearance (before eutrophication) of the colony of breeding pintail. Breeding by pochard, teal, shoveler and shelduck has probably always been variable and no special significance can be attached to recent changes.

Seasonal Changes

These depended partly on the timing and success of breeding, both on the loch and elsewhere, and partly on arrival and departure dates of migrants. The numbers of most species fluctuated in a consistent manner from year to year, but the numbers reached higher peaks in some years than in others. In certain species, the size of the autumn population was influenced by previous breeding success, at least to judge from the age ratio in the shot sample. This was true, for example, for mallard in 1969 (Harrison 1969-70). In other species, the water level of the loch, and resulting state of the shoreline, influenced the numbers and duration of stay. Thus in autumns when shoveler were recorded in greatest numbers and stayed longest, conditions were better for them than in other years.

Ice affected species differently, depending partly on how much they fed from the loch itself. Numbers of mallard and wigeon were maintained when the loch surface

froze, because these species fed almost entirely from land, while the small numbers of wintering teal moved out, returning after the thaw. Among diving ducks, pochard moved out with the first hint of ice, tufted stayed longer, while goldeneye stayed as long as open pools remained.

To summarise, the only long-term changes in the status of species which, on present knowledge, might reasonably be attributed to changes at the loch itself are the reductions in plant-feeding mute swans and coot which followed the restriction in macrophytes. The only short-term changes were those which resulted from changed water level and its effect on the shoreline, namely the numbers of certain dabbling duck.

SUMMARY

1. A large water surface, suitable islands for nesting, extensive shallows, rich adjoining farmland and comparative peace help to make Loch Leven internationally important for waterfowl.

2. The loch holds the largest concentration of breeding duck in Britain (>1000 pairs), consisting mainly of mallard and tufted, but also of gadwall, wigeon, teal, shoveler and shelduck. For wintering the loch is important for mallard, teal and pochard and in some years for shoveler, and holds good numbers of wigeon and goldeneye. It also acts as a winter roost for up to 5000 greylag, up to 12 500 pinkfeet, and up to 430 whooper swans. Most species underwent regular seasonal fluctuations, with peaks and troughs in the same months each year; different species reached peak numbers in different months.

3. Since 1880 bean geese disappeared from the loch, pinkfeet and greylag increased, tufted duck also greatly increased, while gadwall, pintail, wigeon and shelduck started to breed. All these changes were linked with general changes in the range and status of the species concerned. Since 1950, maximum numbers of mute swans have declined from 500 to less than 50, coot from 2000 to less than 500, while fewer of the teal and gadwall present in autumn remained to winter. These changes more or less coincided with the reduction in macrophytes following eutrophication. The reduced use of the loch by goosanders, and the disappearance of breeding pintail, could not reasonably be attributed to known changes in either general status or in local conditions at the loch.

4. Seasonal changes in waterfowl numbers depended partly on the timing and success of breeding, and partly on arrival and departure dates of migrants. However, water level and the resulting state of the shoreline influenced the autumn numbers and duration of stay of teal and shoveler; these were the only immigrant dabbling ducks which fed extensively from the loch itself.

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APPENDIX I

Status of Other Water Birds at Loch Leven, 1966–72

WADERS

Black-tailed godwit <i>Limosa limosa</i> (L.)	Scarce migrant, usually single 'red' birds late summer. One party of 12 in Sep 1972.
Curlew <i>Numenius arquata</i> (L.)	Resident, 4+ pairs St Serf's and 15–20 in rough fields near loch; peak numbers (2000) in autumn, 200–400 in winter.

Whimbrel <i>Numenius phaeopus</i> (L.)	Scarce autumn migrant, 1-2 most years.
Woodcock <i>Scolopax rusticola</i> L.	Resident, 1 pair St Serf's, at least 5 pairs in east shore woodlands and 1-3 in Home Coverts. Game books suggest influx in Dec/Jan.
Snipe <i>Gallinago gallinago</i> (L.)	Resident, small numbers bred, peak numbers Aug-Oct (up to 60 Levenmouth pool).
Jack snipe <i>Lymnocyptes minimus</i> (Brünn.)	Regular autumn and winter visitor in small numbers
Turnstone <i>Arenaria interpres</i> (L.)	Rare vagrant, two in Jul 1969, one in Jul 1970 and one in Aug 1971
Knot <i>Calidris canutus</i> (L.)	Rare summer and autumn vagrant, 1-2 ('red') birds in Jul/Aug 1969 and 1972, 3 in Nov 1970.
Dunlin <i>Calidris alpina</i> (L.)	Former breeder, now mainly Jul-Nov in small numbers. Up to 136 present Sep-mid-Dec 1972 (6 shot were northern race).
Curlew sandpiper <i>Calidris ferruginea</i> (Pall.)	Rare vagrant. 1-2 in Sep/Oct 1972, with Dunlin.
Little stint <i>Calidris minuta</i> (Leisl.)	Rare vagrant, 1-2 birds in Oct 1972.
Sanderling <i>Calidris alba</i> (Pall.)	Rare vagrant, one in Aug, two in Oct 1971, an exceptional 51 on 25 Oct 1972.
Ruff <i>Philomachus pugnax</i> (L.)	Autumn migrant in small numbers, mainly juvenile males.
Common sandpiper <i>Tringa hypoleucos</i> (L.)	Summer visitor, at least 10 pairs round loch, up to 33 birds seen in Aug.
Green sandpiper <i>Tringa ochropus</i> L.	Rare vagrant, 1-2 in Aug-Oct 1970.
Redshank <i>Tringa totanus</i> Math.	Resident, second commonest breeding wader, 4+ pairs St Serf's, 50-60 pairs in fields round loch, scarce in Oct-Mar. One winter record of 'Icelandic' race.
Spotted redshank <i>Tringa erythropus</i> (Pall.)	Rare autumn migrant, 2 in Sep 1968 and 1 in Aug/Sep 1972.
Greenshank <i>Tringa nebularia</i> (Gunn.)	Autumn migrant in small numbers (parties of up to 6), few in winter. One old spring record.
Ringed plover <i>Charadrius hiaticula</i> L.	Summer visitor, 1-2 pairs bred most years. Autumn 1-4 birds seen with Dunlin, otherwise absent.
Golden plover <i>Pluvialis apricaria</i> (L.)	Passage migrant, few Jul/Aug, mainly late Sep-early Nov (up to 500).
Grey plover <i>Pluvialis squatarola</i> (L.)	Rare vagrant, none during 1966-72, but odd earlier records.
Lapwing <i>Vanellus vanellus</i> (L.)	Resident, commonest breeding wader, 5+ pairs on St Serf's, 50-100 pairs in fields near loch. In autumn up to 2500 birds, in winter several flocks of 50-100.

- Oyster-catcher
Haematopus ostralegus
Neum. Mainly summer resident, 4+ pairs bred on St Serf's Island, 30-50 in fields near loch. In autumn, flocks up to 80 birds, in winter seldom seen.
- Little gull
Larus minutus Pall. Vagrant, seen most years usually in late summer/autumn.
- Black-headed gull
Larus ridibundus L. Very common resident, 5000-7000 pairs bred on St Serf's, several hundreds on other islands. Winter population 2000-5000 birds.
- Common gull
Larus canus L. Mainly winter visitor. Roost on St Serf's of 10 000-15 000 birds.
- Herring gull
Larus argentatus Pont. Resident, few pairs attempted to breed each year (but were prevented), large roost on St Serf's in autumn and winter (up to 20 000 in Sep 1967-68 and lower numbers subsequently).
- Lesser black-back
Larus fuscus Brehm Present all year (usually <20), but did not breed.
- Great black-back
Larus marinus L. Present all year (usually <100), but did not breed.
- Glaucous gull
Larus hyperboreus Gunn. Rare vagrant, 1 first-winter bird seen Oct-Nov 1971.
- Kittiwake
Rissa tridactyla (L.) Rare summer vagrant, mainly singles but 15 in May 1970.
- Black tern
Chlidonias niger (L.) Summer/autumn migrant in small numbers; up to 6 seen together.
- Sandwich tern
Sterna sandwichensis Lath. Rare spring vagrant, and one autumn record of 7 individuals.
- Common tern
Sterna hirundo L. Summer visitor, 10-80 pairs bred St Serf's.

OTHER WATER BIRDS

- Heron
Ardea cinerea L. Resident, up to 23 seen at once. Three nests in 1972, earlier heronries destroyed.
- Bittern
Botaurus stellaris (L.) Rare vagrant. One Jan 1964. References (Sibbald 1710) suggest possible breeding in eighteenth century.
- Cormorant
Phalacrocorax carbo (L.) Resident, but did not breed; up to 60 in Jan-Mar. Shot by estate.
- Gannet
Sula bassana (L.) Rare vagrant, 1 in Sep 1968, 1 in Jul 1971, both immatures.
- Fulmar
Fulmarus glacialis (L.) Summer visitor, up to 8 together. Pair bred on nearby crags in 1972.

Great-crested grebe <i>Podiceps cristatus</i> (L.)	Mainly summer visitor, 3-7 pairs bred, up to 27 birds seen Aug/Sep.
Red-necked grebe <i>Podiceps grisegina</i> (Bodd.)	One record, Sep 1972.
Slavonian grebe <i>Podiceps auritus</i> (L.)	Rare vagrant; four records, 3 in autumn.
Black-necked grebe <i>Podiceps nigricollis</i> Brehm	Rare vagrant; none seen 1966-72, but earlier records.
Little grebe <i>Tachybaptus ruficollis</i> (Pall.)	Former breeder, now seldom seen, though bred on River Leven.
Great northern diver <i>Gavia immer</i> Brünn.	One record, Feb 1972.
Black-throated diver <i>Gavia arctica</i> L.	One record, Feb/Mar 1971.
Red-throated diver <i>Gavia stellata</i> Pontopp.	Rare vagrant. Singles Jan/Feb 1968, 1969, 1970.
Water Rail <i>Rallus aquaticus</i> L.	Status uncertain; a few records for spring and summer, but none of breeding.
Waterhen <i>Gallinula chloropus</i> (L.)	Resident, probably > 500 pairs.
Coot <i>Fulica atra</i> L.	Resident, up to 25 pairs bred, up to 400 birds in autumn, <100 in winter.

