THE BRITISH POPULATION OF THE PINK-FOOTED GOOSE, ITS NUMBERS AND ANNUAL LOSSES

By Hugh Boyd and Peter Scott

THE Trust expedition to the Þjórsárver in 1953 and the rocket-netting operations in Britain in 1953 and 1954 which are described elsewhere in the Report represent the latest and largest contributions to an investigation which was begun in 1950. Earlier Reports have included accounts of the 1951 Þjórsárver expedition and the technique of rocket-netting, and tabular summaries of recoveries and recaptures of marked geese, but hitherto no extensive treatment of the results of this work has been attempted. However, during the last year these results have been examined with some care and the first reports on them have been completed. One of these, dealing with some aspects of the distribution of Pinkfeet in Britain, is included in this report (pp. 107–122). A second, concerned with the method of estimating the numbers of the species and its mortality, will be published elsewhere, because its preoccupation with the technical problems of sampling and estimation might seem tedious to readers unfamiliar with the study of the dynamics of animal populations. But the results of this investigation, tentative though most of them are, should be of interest to everyone concerned with the status of geese in Britain.

The present paper summarises the findings of the technical report and considers their relation to more general problems of conservation, especially the use of censuses, and the relation between total losses and those due to shooting.

The British Population

An essential requirement in any inquiry into the numbers of animals is to define the population with which you are concerned. This is often very difficult, but it happens that the Pinkfoot presents fewer problems in this connection than do most birds. The species breeds in only three places (Greenland, Iceland and Spitsbergen), and winters only in north-west Europe (almost entirely in Britain, Denmark, Germany, and Holland). The breeding-places are all accessible, in the sense that there are no political restrictions on visits by observers, but sufficiently hard to get at to make a complete breeding census in any one season quite impracticable, so that if we are to determine the total number of Pinkfeet we must do so while they are in their winter range. Since in all the countries frequented there is widespread interest in birds it might seem that a winter census should not present very great problems. Before this study was begun it was clear that there were many more Pinkfeet in Britain than on the Continent, so that it seemed reasonable to begin by finding out the number of Pinkfeet in England and Scotland. It is clear now that the Pinkfeet wintering in Britain are almost completely isolated from those on the Continent. The Trust ringing has shown that the British birds go to Iceland and Greenland in the summer, but not, apparently, to Spitsbergen, while only one British-ringed Pinkfoot has been found in Denmark. The ringing in Iceland has shown that the great bulk of the Iceland population must winter only in Britain (there is only one Dutch recovery of an Iceland bird, three from Denmark and none from Germany). Finally the results of ringing 566 Pinkfeet in Spitsbergen in 1952

and 1954 (see pp. 170–176) have shown that these birds visit Denmark, Germany and Holland, but not Britain. Thus it is possible to treat the British Pinkfeet as a distinct population, even though their isolation is insufficient, or has not continued long enough, for them to have become sub-specifically different from the Spitsbergen-Danish group, though it has been shown that the latter are slightly smaller than our birds (Løppenthin, B. (1932) Medd. om Grønland 91, no. 6).

The Numbers of British Pinkfeet

The requirements for a census of the British population may be stated very simply : all the Pinkfeet in Britain on a chosen date have to be counted. Since these birds are not scattered throughout the British Isles but are almost wholly confined to eight English counties and 14 in Scotland and at any one time are based on only about two dozen roosting places it would not be impossible, though it would be difficult, to organise simultaneous observations in all the localities used by the species. This has not been done, nor very seriously attempted, simply because it is too difficult to count geese. The evidence provided by the Wildfowl Count Scheme, by experienced observers, and by the efforts made by members of the Trust staff to count the geese visiting the New Grounds and those flocks encountered during rocket-netting expeditions all combine to produce the impression that *counts* of large numbers of geese are rarely possible and that *estimates* are dangerously unreliable. It is probably easier to count large flocks of geese at Slimbridge than anywhere else in Britain ; yet, when the numbers here are much over 1000 it is unusual to be able both to establish that all the geese in this (unusually limited) area were included and to produce closely consistent totals from the efforts of several counters or repeated counts by one observer. A total *count* of, say, 3200 here probably means *at best* that the number of geese in the area was between 3000 and 3400. An *estimate* of 3200 perhaps implies a range of the order of 2700–3700. In other parts of the country the situation is worse, because the feeding range of the geese is usually much more extensive, the availability of suitable vantage points for counting them while feeding is quite haphazard, counts at the roosts are usually impracticable and estimates of numbers in flight are wildly inaccurate. It would be very surprising if it were to be shown that a national census of Pinkfeet led to a total count of useful accuracy. The results of combining observations from all available sources suggest that during the last five years the Pinkfeet in Britain in early autumn have not exceeded 70,000 or been less than 26,000 : but a ' total count ' of, say, 43,219 obtained by simultaneous observations would not represent any substantial advance on these estimates. The accuracy of a collection of counts cannot be high, and cannot be precisely evaluated.

It is all very well to condemn the direct census method, but can any better alternatives be found ? The massive experience of the Fish and Wildlife Service and the various State agencies in the United States seemed to indicate that, for all its faults, this method was the best available, especially when extensive use can be made of counts from aircraft, a technique we have not yet been able to employ in Britain. However, the capture of comparatively large numbers of geese with rocket-nets opened up the possibility of using methods of estimating population-size from the recaptures of ringed geese in a chain of samples made at regular intervals. Such capture-recapture methods have been used in estimating the numbers of various mammals, fish and insects since the

first attempts of Petersen, a Danish fisheries biologist, in 1894. As long ago as 1930 F. C. Lincoln suggested that the relation

$$\frac{\text{number of waterfowl banded}}{\text{number recovered in their first hunting season}} = \frac{\text{number of waterfowl in N. America}}{\text{number killed by hunters}}$$

could be used to estimate the total number of waterfowl in North America. The failure of this attempt, because of the lack of reliable information about the size of the annual kill and difficulties due to trapping methods, seems to have deterred American waterfowl investigators from serious efforts to employ capture-recapture methods. But the ' Lincoln Index ' is a very crude example of these methods (indeed it is not really one at all, since the kill is not strictly equivalent to a live-recapture sample) and, since the underlying assumptions and the statistical procedures have been the subject of careful investigations in recent years, attempts to use recaptures to estimate the numbers of Pinkfeet seemed well worth while.

The simplest method for estimating total numbers has been found the most suitable. If x is the number of Pinkfeet in Britain in the autumn of the year t_0, if a Pinkfeet were marked and released that year, n caught in the following year t_1, and r of those n found to be carrying rings put on in t_0, then the maximum-likelihood estimate of the population at t_0 is $= \hat{x}\frac{an}{r}$. Where r is small, Bailey (*Journal of Animal Ecology*, **21**: 120–127. 1952) has shown that $\hat{x} = \frac{a(n+1)}{(r+1)}$ is a less biased estimate, and his modified formula has been employed.

The numbers of Pinkfeet in the British population at 1 November are estimated, by the above method, to have been 52,000 in 1951, 37,000 in 1952 and 49,600 in 1953. The standard of accuracy of all these estimates is low.

The theoretical standard errors of the estimates for 1952 and 1953

$$\left[\sqrt{V}, \text{ where } V = \frac{a^2(n+1)(n-r)}{(r+1)^2(r+2)}\right]$$

are 6500 and 8500, i.e., about 17% of the estimated value of x.

These results are more reliable than estimates made from field counts, but may be insufficiently precise for the purpose of determining annual fluctuations in the total numbers of Pinkfeet in Britain in autumn. The 1951 result is unreliable, and an estimate of 18,200 for 1950 must be rejected (see below). It is, however, interesting to note that 1952 was a bad breeding year in Iceland and that the proportion of juveniles in the autumn catches in Britain was only 19·9%, compared with 32·5% in 1953 and the mean for the four years 1951–54 of 29·0%, so that the population in 1952 probably *was* substantially smaller than in 1953.

The estimates of adult and first-year death-rates and the number of adults in 1950 enable the numbers of geese in 1950–53 to be calculated from the theoretical age composition of the population (Table I). These calculations lead to estimates of 51,000 in 1950, 46,000 in 1951, 41,000 in 1952 and 43,000 in 1953. Apart from the 1950 figures, these estimates are in fairly good agreement with those from the recapture method. In particular they confirm that, during the period, the population was greatest in 1951 and least in 1952. The 1950 estimate by this method seems a more likely one than the 18,200 from the recapture data, the latter being impossible to reconcile with the 1951 estimates because of the relatively low productivity of geese, but is itself not very reliable.

TABLE I

Theoretical Age-composition of the British Autumn Population of the Pinkfoot, 1950–53

d=adult death-rate=26% ; e=survival-rate (=1-d)=74% ; e_1=first-year survival rate =58% ; N=number of adults in 1950=28,000 ; N_0, N_2, N_3=number of juveniles in 1950, 1952, and 1953 as percentage of N.

Number of Pinkfeet in October each year

	Juveniles	16 months	28 months	40 months	Total Adults
1950	N_0	Nd	Nde	Nde^2	N
1951	Nd/e_1	N_0e_1	Nde	Nde^2	N_0e_1+Ne
1952	N_2	Nd	N_0e_1e	Nde^2	$Nd+N_0e_1e+Ne^2$
1953	N_3	N_2e_1	Nde	$N_0e_1e^2$	$N_2e_1+Nde+N_0e_1e^2+Ne_3$

It seems unlikely that very great increases in the annual catch of Pinkfeet can be made without disproportionate expenditure of money and effort. In 1953 and 1954 the catch was about 1550 : it might be increased to 2500. So long as the simple estimate $x = \frac{an}{r}$ is employed such an increase will not greatly improve the accuracy of successive estimates. But it should be possible to devise methods using longer sampling chains (of catches over several years) more suited to the problem than those at present available, and estimates by such means would be improved by larger catches. The principal problems in the development of better methods of estimation are the seasonal variations in the proportion of young birds, the different death-rates of first-year and older birds and the extent of correlation between successive estimates. Though an increase in the annual catch remains desirable, the outstanding difficulty in the catching programme is to relate the size of the catches in different regions to the size of the more or less distinct regional groups which appear to exist within the British population (see pp. 107–122).

Annual Losses

Estimates of total numbers are the most striking indicators of changes in the dynamics of a population, but it is necessary to investigate both productivity and mortality to discover how the changes have been produced. This section is concerned with the annual losses suffered by Pinkfeet after they have entered the British population (in their first October). Losses in the first year have earlier been shown to be proportionately greater than in subsequent years (5th Annual Report, p. 28). It is therefore necessary to estimate the death-rates of juvenile (first-year) and older birds separately.

There are two distinct sources of information on losses, though they are alike in referring to marked birds. (The assumption that losses of marked geese are representative of those amongst unmarked ones also, cannot, perhaps, be fulfilled precisely, but it seems likely that any differences are negligibly

small.) The recapture data provide the first source. This has the important merit that *all* marked geese seen again are recorded, but the disadvantage that the numbers of recaptures are comparatively small (85 adults recaptured in 1951–54, from 2589 marked in 1950–53, and 40 juveniles from 1124 in the same interval). A maximum likelihood method of estimation is used (method 'A' of Leslie and Chitty, *Biometrika*, **38** : 269–292, 1951). By this method the annual death-rate for adults is found to be 21 $\pm$ 12% and the juvenile death-rate in the first year after marking 44 $\pm$ 20%.

It is also possible to calculate the death-rate from the recoveries of marked birds. These are more numerous than recaptures, though more difficult to use, because recoveries do not constitute a complete record of all marked birds killed, but only that proportion of them found and reported. The proportion of October-ringed birds recovered in the same season declined from 12·4% in 1950–51 to 5·6% in 1953–54. This might have been due to a decreasing death-rate, but the evidence suggests that the difference is more probably due to a falling reporting-rate (due to finders of rings failing to report them to the British Museum). Accordingly, two models have been used in estimating the death-rate. In the first the annual death-rate is assumed constant, while the reporting-rate is allowed to vary. The observed juvenile-adult ratios in the British autumn catches are used to determine the initial relation between recovery and reporting. In the second model the reporting-rate is assumed constant, at various arbitrary values, and the death-rate is allowed to vary. The method of estimation again consists in the solution of the maximum-likelihood equation. The first model leads to an estimated death-rate of 26 $\pm$ 1·6% for adults and 42 $\pm$ 2·8% for juveniles in the first year after marking. These results are consistent with (and much more precise than) those obtained from recaptures. From the second model, if the reporting-rate is assumed to be 30%, the adult death-rate was 31% in 1950–51, 31% in 1951–52, 26% in 1952–53 and only 12% in 1953–54. If the reporting-rate was as high as 50% these rates would have been 21%, 18%, 13% and 5·4% respectively. But, as is discussed below, most reported casualties are due to shooting and the evidence of wildfowlers makes it clear that 1953–54 was not a bad year for shooting. It was, indeed, more probably rather a good one. Thus for the purpose of establishing a general picture of the dynamics of the Pinkfoot population the model assuming a constant annual death-rate is to be preferred. However, since the determination of *changes* in the characteristics of the population is a major concern of this investigation, it is clearly desirable to elaborate a model in which both death-rates and reporting-rates are treated as variables. This apparently presents no great statistical difficulties, but at present the recovery data are insufficient to enable such a model to lead to better estimates than are provided by the simpler methods used so far.

Losses from Shooting

At least 860 deaths in 982 casualties to ringed Pinkfeet reported between October 1950 and July 1954 were due to shooting. The inference that 88% of all losses to Pinkfeet after their first October are caused by shooting is perhaps unjustified, since presumably geese dying from ' natural causes ' are less likely to be found than those killed by man, but it seems likely that at least four-fifths of losses are due to shooting.[1]

We have seen that the estimated British population in late October 1953 was 49,000 by the capture-recapture method, or 43,000 from the death-rate method. If we take the mean of these values (46,300) and suppose that the juvenile-adult ratio in the catches of 1953 (506 juveniles : 1052 adults) was representative, the approximate numbers of adults and juveniles were 31,200 and 15,100 respectively. If 26% of the adults and 42% of the juveniles died before the next November the total losses would have been 8100 adults and 6300 juveniles, or 14,400 geese, and the losses due to shooting 88% of this total, say 12,700 geese.

Is an annual kill in Britain of 12,700 Pinkfeet improbable ? When, in the course of a protracted correspondence in the *Shooting Times* in 1954, a similar total kill in the season of 1951–52 was suggested, that estimate was assailed as extravagantly large. Can any support be found for the estimate of losses in the period November 1953–October 1954 ?

The problems of estimating the waterfowl kill have engaged the United States Fish and Wildlife Service for over 20 years, without the attainment of techniques of proven validity, although the hunter survey by mail questionnaires introduced on a national scale during the 1952–53 season appears highly promising. (Publication of the results is being delayed until results from other seasons are available.) By comparison the data available on the British kill are incredibly meagre. Comparatively few sportsmen keep careful detailed records of their bags, and few of those who do are willing to disclose them to anybody who might conceivably use them to the shooter's disadvantage. But a small number of bag records are available and can be supplemented by information collected from the letters reporting the shooting of ringed Pinkfeet.

From the recovery letters we know that, during the season 1953–54, 451 persons shot 586 ringed geese and that 113 of these rings were found in bags totalling 583 geese. It appears that the most probable bag of these 451 shooters was $583 \times \frac{586}{113} = 3020$ geese. It is assumed that all these shooters reported *all* the ringed geese they obtained. This is probably not true, because there are indications that people are more likely to report the first rings they obtain than those which they find later. The bag sample is also biased by containing too many October letters. In October 1953 a large proportion of the juveniles entering the British population carried rings (put on in Þjórsárver in July and August). It is a feature of October shooting that the proportion of juveniles bagged is very high and that these include a lot of young birds shot when flying singly and ' lost.' Thus the ratio $\frac{113 \text{ rings}}{583 \text{ geese}} = 0{\cdot}19$ is probably too large (it is appreciably higher than the ratio $\frac{235 \text{ rings}}{1558 \text{ geese}} = 0{\cdot}15$ found in rocket-netting catches in 1953). Corrections for these failings would both increase the estimate

[1] The second most frequent cause of death reported was collision with overhead cables or telegraph wires. Ten cases of this kind occurred up to July, 1954.

of the season's kill. This estimate of 3000 represents the total kill during the season only if all the ringed geese *shot* were reported. No one will maintain that this is so. Indeed, the estimate of the reporting-rate in 1953–54 suggested that only about one-seventh of the ringed birds *dying* were reported. Had the calculation not been made until some years had elapsed the reporting-rate would probably have appeared rather higher (reports are often belated), but it is in any case comparatively small. The problem of obtaining an estimate of the kill independent of the calculated death and reporting-rates remains, but transformed to a search for the total number of persons shooting at least one Pinkfoot during the season. If 450 gunners shot 3000 geese the estimated total kill of 12,700 geese would correspond to 1900 successful Pinkfoot shooters. Do as many people as this shoot Pinkfeet? Members of wildfowlers' organisations seem to think not, wildfowlers not in such organisations seem to think it possible. An inquiry into this point would be difficult to conduct and is only indirectly related to the population dynamics of the Pinkfoot, but would be of great value, since it is important to learn whether the shooting pressure on wildfowl in Britain remains constant, or whether it reflects the increase in human population.

General Review of the Numbers of British Pinkfeet

Figure 1 illustrates the variations in numbers of Pinkfeet in the years 1950–54. It is based on the October totals obtained from the combined use of death-rate and capture-recapture estimates, together with an estimated loss of goslings between hatching and first arrival in Britain of about 60% (see pp. 82–87). The graph demonstrates some points of importance. First, the total numbers are changing continuously, not merely from year to year but from week to week. Thus, if we are to use total counts to estimate trends, it is clearly necessary to decide with some care at what dates the comparisons of seasonal numbers should be made. Second, the number of sexually mature adults (three or more years old) bears no simple relation to the size of the total population. Third (though this is not well established by the illustration) the

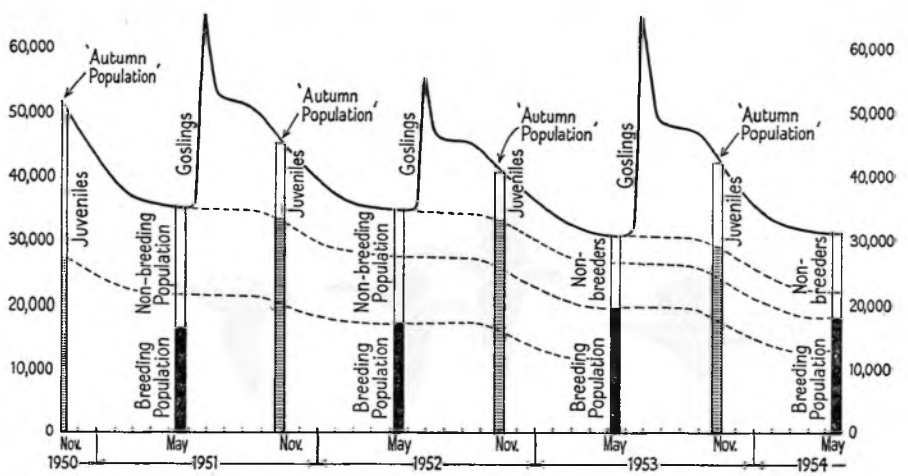

Fig. 1.—*Number of Pink-footed Geese in the British population, October,* 1950–*May,* 1954, *estimated from death-rates and recovery rates*

number of goslings produced in any year is not simply related to the number of sexually mature adults and is in any event substantially less than would be expected from knowledge of the clutch-size. A productivity analysis suggests that even in climatically favourable years like 1951 and 1953 at least a quarter of the mature females hatched no young. Much more work on the problems of breeding success will be needed before we can establish to what extent conditions in Iceland and Greenland, rather than in Britain, are responsible for determining the size of the Pinkfoot population. At the same time, it will be necessary to continue the study of losses in Britain and the factors affecting them. Despite all the deficiencies in the first years of this study which have been revealed, the Pinkfoot remains an especially favourable species for fundamental investigations on the regulation of goose numbers.

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