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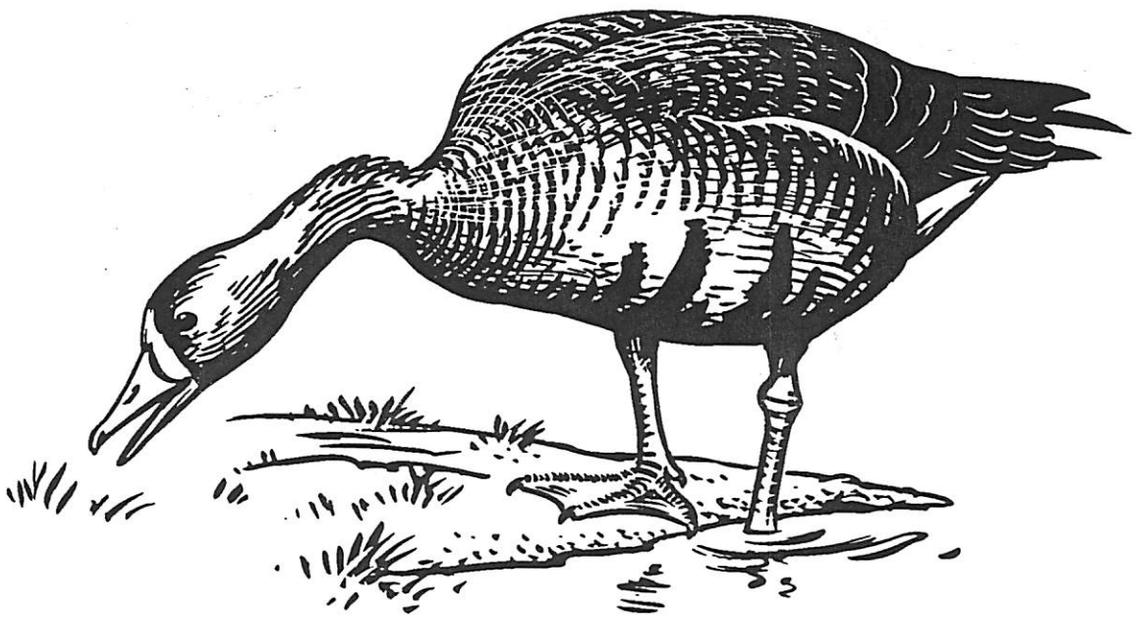
Population dynamics and management of Greenland White-fronted Geese on Islay



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POPULATION DYNAMICS AND MANAGEMENT OF GREENLAND WHITE-FRONTED GEESE ON ISLAY

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Report to Scottish Natural Heritage

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1.0 INTRODUCTION

Greenland White-fronted Geese *Anser albifrons flavirostris* breed in the west of Greenland and winter exclusively in Great Britain and Ireland. About a third of the total population winters on Islay, off the west coast of Scotland. Historically, Greenland Whitefronts have been associated with boglands (Owen 1976); more recently geese have come into increasing proximity with agriculture.

This report examines the dynamics of Greenland Whitefronts on Islay in the context of the total winter population. A simple model of population dynamics is adopted in an attempt to predict how the Islay population should be managed in order to minimise conflict with agriculture.

2.0 THE TOTAL POPULATION

2.1 Total population size

Since 1982/83 total numbers of Greenland White-fronted Geese have almost doubled to attain present levels of about 30,000 birds. Figure 1 illustrates the growth of the total population and the Islay component in autumn and winter (data from Table 1.2.3.1 of Stroud 1992). The total population has been increasing at an estimated annual rate of 7.80% (4.64 - 11.06%, 95% C.L.) in autumn and 7.19% (5.96 - 8.42%, 95% C.L.) in spring. The rate of increase appears not to differ significantly between wintering areas (from ANCOVA, $F_{6,47}$=1.75, P=0.129 in autumn, $F_{6,49}$=0.786, P=0.585 in spring).

2.2 Exchange between wintering areas

Wintering Greenland White-fronted Geese are highly site-faithful: Wilson *et al.* (1991) estimated that about 85% of birds return to the same wintering grounds in successive years, whilst within winters less than 1% of birds move between sites. However, comparison of productivity (proportion of young) and population size data from different wintering grounds suggests that there is at least some exchange between sites, despite the similar overall rates of increase.

Stroud (1992) gives data on population sizes (his Table 1.2.3.1) and productivity (his Table 1.2.4.1.2) for each wintering area for the period 1982/83 to 1990/91. Using these data, between-winter losses may be calculated for each wintering area by subtracting numbers of adults from population size in the preceding winter. Overall mortality rates for the total population may calculated in a similar way by summing losses across wintering areas. Assuming that mortality rates are the same for each wintering component, net emigration rates can be estimated for each wintering area in each year by finding differences between loss rates and overall mortality rate.

Estimates derived in this way are given in Table 1 (note that negative emigration rates imply net immigration). Estimated overall mortality rates differ from those given by Choudhury & Owen (1993, Table 1.1); these authors estimated mortality on the basis of the larger of the two census totals in each winter, arguably the best estimates of total population size. In some respects these mortality estimates are better, despite ignoring within-winter mortality; they are in the range 4.23% to 19.10%, mean 11.55%, compared with 0.92% to 19.13%, mean 10.96% from Table 1. However, for the calculation of emigration rates consistency is required across

population segments - the larger census total for a segment does not necessarily correspond with the larger overall census total for a winter. For this reason, autumn data were used throughout; productivity data generally is collected in autumn. Northern and Southern Irish totals (outside Wexford) were combined, and the productivity assumed to be the same; the same was applied to the Welsh and English data. Missing data (Ireland in 1982/83) were estimated using the Underhill index technique (Underhill 1989).

Mortality of Greenland Whitefronts is largely a between-winter process - migration mortality and hunting, especially on the Icelandic staging grounds. Winter hunting has contributed relatively little to overall mortality since 1982/83 (see section 3.2 below). However, there is evidence from ringing recoveries that winter distribution reflects stratification of the summer population (Kampp *et al.* 1988). Breeding success differs between wintering areas (Stroud, 1992) and mortality may be similarly heterogeneous.

There is no information by which to separately estimate both mortality and im/emigration rates. The 'emigration' rates given in Table 1 are more properly estimates of the amounts by which emigration and mortality for a wintering area exceed overall mortality. It is clear, however, that the differences are not entirely accounted for by differences in mortality rates. In many cases apparent survival exceeds 100%; for example, between autumn 1987 and autumn 1988 there was apparently 107.2% survival. The discrepancy between this and the overall mortality rate of 8.5% is more than can reasonably be accounted for by counting errors alone, hence immigration from other wintering areas must have occurred. Whilst the magnitude of the estimates in Table 1 may be misleading, it is reasonable to suppose that their *pattern* over time indicates changes in exchange processes.

Table 2 gives correlation coefficients between emigration rates for each wintering area. The only significant correlation describes an inverse relationship between emigration in the two main resorts, Wexford and Islay (r=-0.792, d.f.=6, P=0.019), which implies between-winter exchange of birds between these sites. The pattern of exchange between sites can be further explored by use of partial correlation analysis (Sokal & Rohlf 1981, pp.656-661). Holding Wexford emigration constant, there are significant first-order partial correlations between Islay emigration rates and those of the rest of Scotland (r=-0.886, d.f.=5, P=0.034) and Wales/England (r=-0.761, d.f.=5, P=0.047). There is a similar pattern of first-order correlations for Wexford when Islay emigration is accounted for (r=-0.886, d.f.=5, P=0.008 and r=-0.756, P=0.049 for Scotland and Wales/England respectively). The conclusion must be that both Islay and Wexford exchange birds with Britain, especially Scotland, but that this exchange is smaller in magnitude than that between the two main resorts. Second-order partial correlation coefficients suggest that there are exchanges, yet smaller in magnitude, between Ireland and other wintering areas: between Scotland and Ireland, with Wexford and Islay accounted for (r=-0.929, d.f.=4, P=0.007); between Islay and Ireland, with Wexford and Scotland accounted for (r=-0.909, d.f.=4, P=0.012); between Wexford and Ireland, with Islay and Scotland accounted for (r=-0.926, d.f.=4, P=0.008).

Pattern in the emigration rates seems to relate to changing shooting practices at Wexford and Islay. Data on shooting are given by Stroud (1992) and Easterbee *et al.* (in prep.). From 1982/83 Greenland White-fronted Geese became protected in Scotland under the Wildlife and Countryside Act 1981. Following the granting of 13 licences to shoot Greenland Whitefronts on Islay in winter 1987/88, during which 76 geese were killed, consistent net immigration into the Islay component changed to net emigration between winters 1987/88 and 1988/89. It is perhaps significant that Wexford experienced unusually high net immigration at this time. During the next winter, 1988/89, four licences were granted to shoot Greenland Whitefronts

on Islay, but only six birds were killed. The result appears to have been unusually high net immigration into Islay between this winter and the next and correspondingly high net emigration from Wexford. This apparent exchange included, perhaps, the return of previous emigrants. In 1989/90 two licences were granted and 45 geese were shot on Islay; net emigration resumed.

Shooting of geese at Wexford seems to have a smaller effect on exchange of birds. Since 1982/83, when suspension of shooting Greenland Whitefronts was imposed throughout the Republic of Ireland, the moratorium has twice been lifted at Wexford. Following the shooting of 448 geese in 1985/86 there was increased net emigration, whilst in Islay and the rest of Scotland there was net immigration. In 1989/90 432 geese were killed, coinciding with shooting on Islay. Net emigration was slight and, together with emigration from Islay, was absorbed by net immigration into Ireland, Scotland, England and Wales. (It is interesting to note that the number of birds estimated to emigrate from Islay is almost exactly equal to the number estimated to immigrate to the rest of Scotland, whilst Wexford emigrants are equal in number to Irish and Welsh/English immigrants.)

3.0 THE ISLAY POPULATION

3.1 Population size

Greenland White-fronted Geese have been counted on Islay at least twice in each winter since 1982/83. Data are considered to be reliable since 1983/84 when a consistent census technique was finalised. Data for 1983/84 to 1985/86 and 1987/88 to 1991/92 are given in full by Easterbee *et al.* (in prep.) and for 1986/87 by GWGS (1988). Monthly totals for these years are given in Table 3; each 'month' period is approximately mid-month to mid-month. Missing values were estimated using the Underhill index technique (Underhill 1989).

The average annual rate of increase for 1983/84 to 1991/92, estimated using year index numbers (which use information from all months), is 10.82% (8.62 - 12.28%, 95% C.L.), larger than the rate of increase in the population as a whole (see section 2.1), but not significantly so. During this period the Greenland Whitefront population on Islay increased by a factor of about 2.4. The only exception to the trend of increase was for 1987/88 to 1988/89, when the peak population on Islay decreased from 7,888 to 7,159. This followed the resumption of shooting on Islay in 1987/88 and probably resulted from emigration of geese to Wexford (see section 2.2) rather than increased mortality; certainly, direct shooting mortality was a relatively small contribution to overall apparent mortality on Islay between 1987/88 and 1988/89 (see Table 5 and section 3.2). Current population size is about 10,000 Greenland Whitefronts on Islay.

3.2 Population dynamic processes

Annual rates of gain (recruitment) and loss (mortality compounded with im/emigration) can be estimated for Greenland Whitefronts on Islay using data on population size and productivity, as was done for the whole population in section 2.2. These data are given in Table 4 for each winter 1983/84 to 1991/92; population sizes are autumn totals for Islay, given as November-December in Table 3; productivity data are taken from Stroud (1992). Numbers of Greenland Whitefronts shot on Islay in each winter are also given in Table 4, data from Easterbee *et al.* (in prep.).

Annual apparent survival rates (i.e. survival compounded with exchange processes) are estimated as:

$$S_i = 100 \times \frac{N_i - N_i P_i}{N_{i-1}},$$

where S_i is the percentage survival rate between winters i and i-1 and N_i and P_i are population size and productivity in winter i respectively. Total apparent mortality can be partitioned into shooting mortality and 'natural' apparent mortality. Estimates of apparent survival, shooting mortality and natural apparent mortality based on the data of Table 4 are given in Table 5. Wilson & Norriss (1985) reported that crippling loss of Greenland Whitefronts shot at Wexford in 1981/82 was an additional 20% on top of numbers known to be killed by shooting, and used this as a correction factor in all estimates of shooting mortality. Crippling losses for Islay are an unknown quantity, so no correction factor has been applied to the estimates in Table 5. Given the low level of known shooting mortality on Islay, crippling loss in the order of 20% should have very little impact on overall mortality.

If these estimates are taken to be representative of the current population dynamics of the Greenland Whitefront population on Islay, we can predict future population growth, with and without further shooting. Mean productivity is 16.2 ± 5.59% (S.D.) and mean natural apparent mortality is 7.98 ± 8.59% (S.D.). Considering the effects of shooting on emigration noted in section 2.2, the latter statistic probably overestimates the mean and variability of natural losses. Natural apparent mortality is not significantly related to shooting mortality (r=0.385, d.f.=7, P=0.347), but nevertheless the constant from regression of natural apparent mortality on shooting mortality may be taken as an estimate of mean natural apparent mortality in the absence of shooting; this estimate is 5.60 ± 3.82% (S.D.).

3.3 Heterogeneity on Islay

Heterogeneity of Greenland Whitefront population behaviour at the level of wintering areas has already been discussed in section 2.2. It is possible that heterogeneity also exists at a much finer scale. Wilson *et al.* (1991) and unpublished data demonstrate an extremely high level of very local site fidelity at Wexford and Islay; geese will often return to the same individual fields in successive years. The stability of social groupings may be enhanced by the extended cohesion of extended family parties (Warren *et al.* 1992). The Islay population is divided between 40-50 more-or-less discrete flocks (Wilson *et al.* 1991). Stroud (1992) lists total numbers of Greenland Whitefronts on eight separate areas of Islay, which, apart from one area (Ardtalla), have remained proportionally fairly stable over the period 1981/82 to 1990/91. Data on productivity in each area are not available, so that it is difficult to assess whether there are differences in breeding success and mortality. If there *are* significant differences, the implications for future management are profound. Each discrete sub-population is separately susceptible to the effects of management.

4.0 MODELLING POPULATION BEHAVIOUR

4.1 Predicting population growth

Estimates of mean productivity and natural apparent mortality (see 3.2) can be used to predict population growth in the absence of shooting. It is obvious that, on average, the population should grow at an annual rate of 16.2% (recruitment) - 5.6% (mortality) = 10.6% (this

estimate incorporates the effects of im/emigration since *apparent* mortality is used). However, given uncertainty about the true values of recruitment and mortality parameters, the actual population growth rate may be very different from this.

Figure 2 shows the results of a simple simulation exercise. Normally distributed random numbers, with means and standard deviations equal to those of the recruitment and mortality rates (in the absence of shooting) given in section 3.2, were used to simulate population growth over ten generations from a starting size of 10,000 individuals. The population size in one year was found by applying the random values of recruitment and mortality rates to population size in the previous year.

The results in Figure 2 are means and 95% confidence limits derived from 1000 simulations over ten generations. Confidence limits were determined by finding the appropriate upper and lower percentiles of population size at a given generation. The increasing width of confidence intervals reflects increasing uncertainty, owing to the dependence of population size in one year on that in the previous year. Given variability in recruitment and mortality, the population can decrease as well as increase - in the simulations, a reduction in population size occurred on about 6% of occasions. Figure 2 also shows the results of a single simulation; after four generations, population size in this simulation was about 4,000 more than the average value, whilst after seven generations population size was close to the average expected.

The conclusions from these simulations are: (a) given what we know of processes of gain and loss in the Greenland Whitefront population on Islay, we would expect the population to grow from its present size to about 27,500 geese in ten generations; (b) given our uncertainty about these processes and their variability, population size after ten generations would probably lie between about 18,100 and 38,700 geese.

These conclusions rely, of course, on the unlikely premise that there are no factors on Islay likely to limit population size. It is highly probable that there would be a density-dependent effect of carrying capacity on population growth, so that population size after ten generations would be much less than predicted from these simulations. Choudhury & Owen (1993) suggest that the carrying capacity of Islay for Greenland Whitefronts has not yeat been reached, so that there is scope for some population increase; however, there is no information on which to base a more realistic model of population growth. The effects of density-dependence on population growth have elsewhere been simulated for the Islay Barnacle Goose *Branta leucopsis* population, for which it was postulated that net emigration increases as carrying capacity is approached (Bell 1993). The general conclusions outlined by Bell (1993) can also be applied to the Islay Greenland Whitefront population.

4.2 Management to prevent population growth

A similar simulation exercise can be applied to predict how many geese need to be removed in order to maintain population size at a given level. Table 6 shows the results of 1000 simulations for population sizes ranging from 1,000 to 20,000 geese. The simulations assume that there is carrying capacity on Islay to support both the target population and the projected increase. As would be expected from current population growth, on average, 10-11% of geese are in excess of the target population size after a year's population growth. Given what we know of processes of birth, death and im/emigration, the excess is likely to lie between zero (i.e. no increase or a decrease) and about 23% of population size in the previous year.

Numbers to be removed from the population given in Table 6 do not necessarily equate with numbers to be shot. Removal could be also be effected by reduction of effective carrying capacity (e.g. by scaring). Even if direct control of numbers by shooting were adopted, a substantial part of the removal could take the form of emigration in response to shooting. The data of Tables 1, 4 and 5 can be used to assess how large an effect emigration might have. For example, in 1987/88 76 Greenland Whitefronts were directly killed by shooting; this contributes to an apparent mortality of $7373 \times (1 - 0.7943) = 1517$ geese, of which $7373 \times 0.0731 = 539$ geese were estimated to be emigrants. In this example, for every bird killed another seven emigrated. The actual effect may be even larger, since in previous years there had been net immigration to Islay.

5.0 CONCLUSIONS

The main conclusions from this study are: (a) Greenland White-fronted Geese are increasing on Islay at an annual rate of 10.8%, faster than the population as a whole; (b) in this increase, the excess of recruitment over mortality is augmented by net immigration from other wintering areas; (c) shooting of geese on Islay causes large increases in the apparent mortality rate, probably owing to net emigration.

Any management strategy on Islay should have regard to the possible effects of population heterogeneity, noted in section 3.3. Stroud (1992) also points out the dangers of management, considering the low productivity and high winter site-fidelity of the species (see also Wilson *et al.* 1991). It is crucial to manage Greenland Whitefronts on Islay in the context of the whole population.

6.0 SUMMARY

6.1 The total winter population of Greenland White-fronted Geese has been increasing at an average annual rate of 7.8% since 1982/83, to reach current levels of about 30,000 birds.

6.2 About a third of the total population winters on Islay; population size on Islay is currently about 10,000 birds.

6.3 Despite the high winter site-fidelity of Greenland Whitefronts, there are net exchanges between wintering areas.

6.4 The most important exchanges are between the two main winter resorts, Wexford and Islay, probably driven by shooting of birds.

6.5 In the absence of shooting there has tended to be net immigration into the Islay population.

6.6 Shooting mortality contributes relatively little to overall mortality of Greenland Whitefronts on Islay, but causes large increases in apparent mortality owing to emigration of birds.

6.7 Overall annual mortality of Greenland Whitefronts has varied between 0.9% and 19.1% since 1982/83, average 11.0%.

6.8 Apparent annual mortality on Islay has varied between -1.0% and 20.6% since 1983/84, average 8.3%.

6.9 Natural apparent mortality on Islay in the absence of shooting is estimated to average 5.6% p.a..

6.10 In the absence of density-dependent limitations on population growth, it is predicted that the Islay population would grow to 27,500 geese in ten generations.

6.11 Numbers of geese required to be removed from the Islay population in order to maintain the population at a given level are predicted. Owing to uncertainty about rates of gain and loss and their variability these predictions have very wide confidence limits.

6.12 An overall management strategy for Greenland White-fronted Geese should consider the population as a whole, and also consider the possible effects of heterogeneity within each wintering component.

7.0 ACKNOWLEDGEMENTS

I am grateful to Lyndsey Kinnes of Scottish Natural Heritage for provision of Islay count data.

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FIGURE 1. Growth in total and Islay population sizes of Greenland White-fronted Geese, 1982/83 to 1990/91. Data from Stroud (1992).

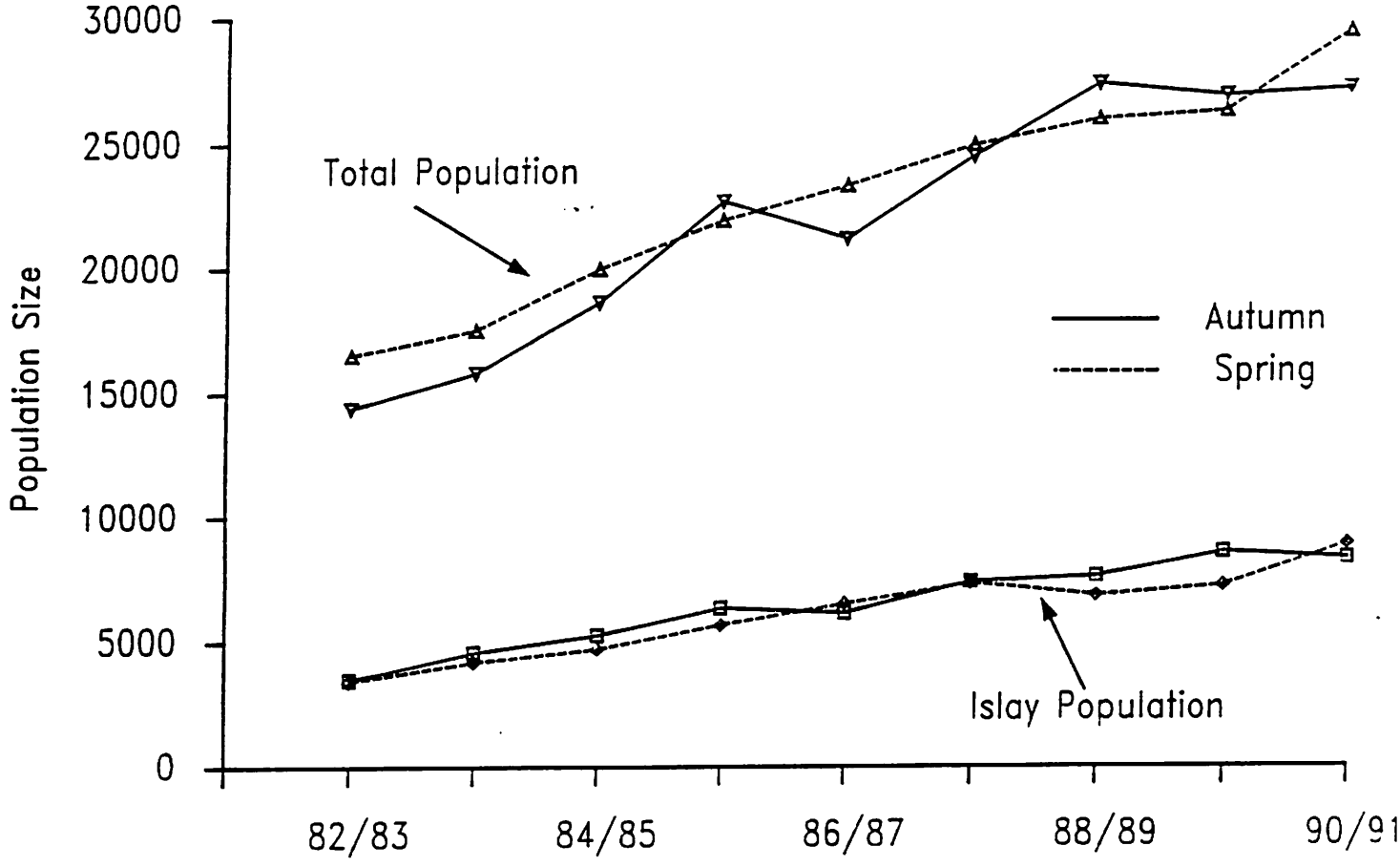

FIGURE 2. Simulated population growth over ten generations from a starting population of 10,000: mean and 95% confidence limits from 1000 simulations. ◊: results of a single simulation. See text for explanation.

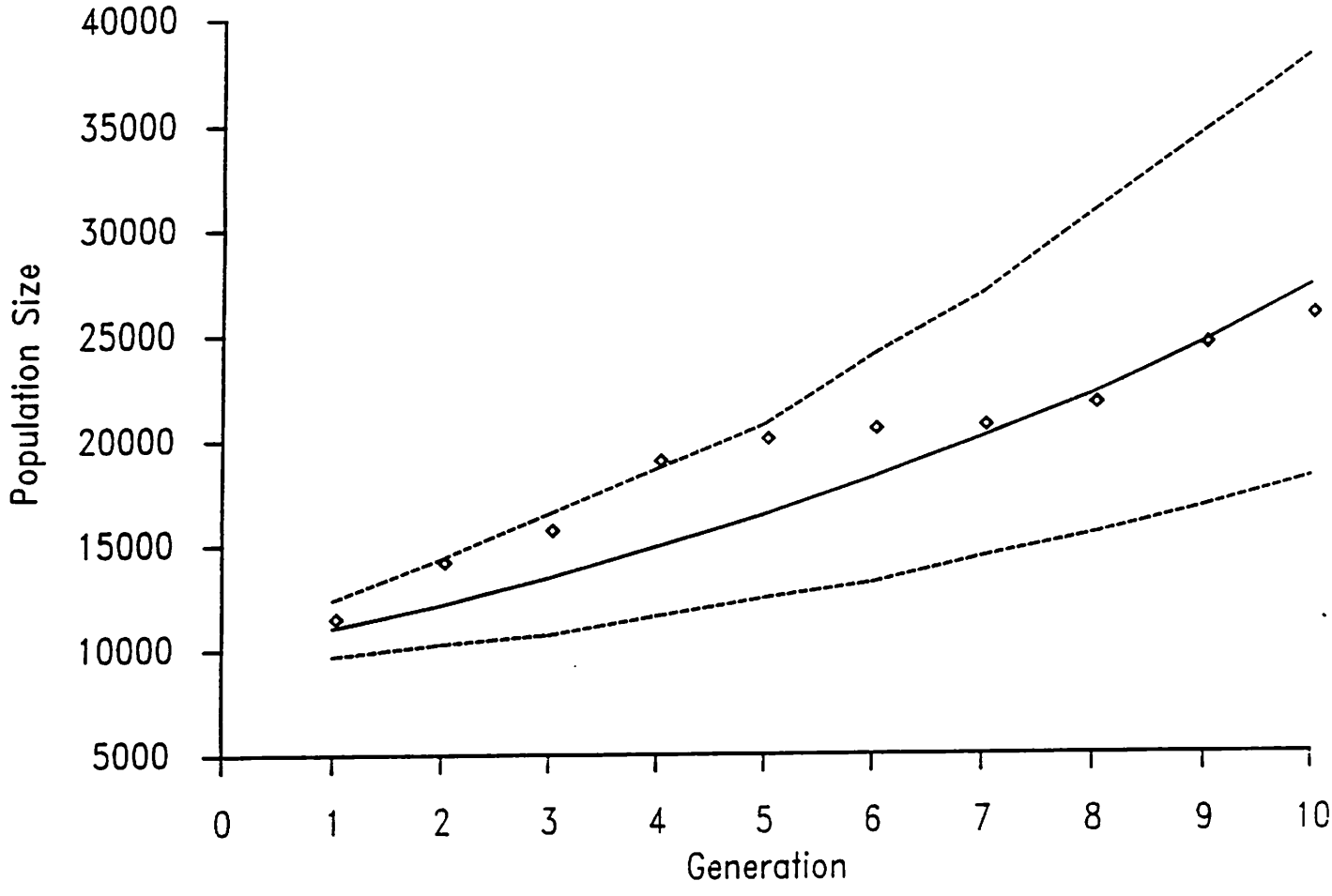

TABLE 1. Percentage net emigration rates for each component of the total Greenland White-fronted Goose population, 1982/83 to 1990/91, estimated assuming homogeneous overall mortality rate in each year.

Period	% Mortality	% Emigration Rate Wexford	Ireland	Islay	Scotland	Wales
1982 - 83	3.92	11.14	-2.10	-22.10	7.30	16.71
1983 - 84	0.92	-5.10	10.78	-1.53	-0.41	17.57
1984 - 85	13.32	1.36	-4.39	-0.91	2.83	-22.63
1985 - 86	19.08	6.95	4.44	-6.06	-6.94	1.48
1986 - 87	5.88	1.55	-3.04	-4.93	6.49	-18.44
1987 - 88	8.50	-15.73	-1.15	7.31	15.09	3.24
1988 - 89	19.13	14.95	-0.12	-10.84	-14.99	-21.72
1989 - 90	16.96	1.32	-2.09	4.53	-6.72	-17.44

TABLE 2. Pearson coefficients of correlations between estimates of emigration rates of Greenland White-fronted Geese from their wintering grounds. *: $P<0.05$. $^{+}$: $P<0.10$.

	Wexford	Ireland	Islay	Scotland
Ireland	-0.148			
Islay	-0.792*	0.048		
Scotland	-0.662^{+}	-0.253	0.162	
Wales	-0.234	0.614	-0.266	0.373

TABLE 3. Monthly census totals for Greenland White-fronted Geese on Islay 1983/84 to 1991/92. Data from Easterbee *et al.* (in prep.) and GWGS (1988). ( ) indicates estimated count - see text for explanation.

Winter	Oct -Nov	Nov -Dec	Dec -Jan	Jan -Feb	Feb -Mar	Mar -Apr	Apr
1983/84	4030	4592	3936	3468	3730	4198	3164
1984/85	3362	5256	4462	4473	5358	4715	(4564)
1885/86	3221	6332	5464	5114	4885	4498	5669
1986/87	3981	6126	6274	4367	5723	6486	(5445)
1987/88	(5526)	7373	(7625)	7888	(7458)	7316	(7134)
1988/89	(5031)	7159	(6941)	(6541)	(6789)	6853	(6495)
1989/90	(5654)	8563	(7801)	7641	(7630)	6895	(7299)
1990/91	(6288)	8658	(8676)	(8176)	(8487)	8857	(8118)
1991/92	(7136)	10003	(9846)	9839	(9631)	9312	(9213)

TABLE 4. Population statistics for Greenland White-fronted Geese on Islay, 1983/84 to 1991/92. Data from Easterbee *et al.* (in prep.) and Stroud (1992).

Winter	Population Size	Number Shot	% Productivity
1983/84	4592	0	9.9
1984/85	5256	0	12.1
1985/86	6332	0	27.3
1986/87	6126	0	10.1
1987/88	7373	76	17.7
1988/89	7159	6	18.2
1989/90	8563	45	18.7
1990/91	8658	63	19.0
1991/92	10003	37	12.6

TABLE 5. Percentage rates of population processes estimated from data in Table 4.

Period	Apparent Survival	Shooting Mortality	Natural Mortality
1983 - 84	100.61	0.00	-0.61
1984 - 85	87.58	0.00	12.42
1985 - 86	86.98	0.00	13.03
1986 - 87	99.05	0.00	0.95
1987 - 88	79.43	1.03	19.54
1988 - 89	97.24	0.08	2.67
1989 - 90	81.90	0.53	17.58
1990 - 91	100.98	0.73	-1.71

TABLE 6. Numbers of Greenland White-fronted Geese on Islay required to be removed from the population in order to prevent population growth: results of 1000 simulations.

Population Size	Mean Removed	95% C.L. Lower	Upper
1000	105	0	228
2000	216	0	476
3000	324	0	702
4000	414	0	916
5000	524	0	1133
6000	641	0	1415
7000	745	0	1679
8000	859	0	1872
9000	938	0	2151
10000	1043	0	2336
11000	1155	0	2561
12000	1217	0	2746
13000	1387	0	3083
14000	1488	0	3198
15000	1599	0	3572
16000	1656	0	3724
17000	1784	0	4000
18000	1903	0	4293
19000	1933	0	4476
20000	2141	0	4680

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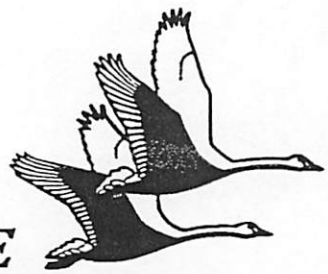
The Wildfowl & Wetlands Trust was founded by Sir Peter Scott in 1946; its Research Department is situated at the Trust's headquarters at Slimbridge in Gloucestershire. A team of more than 20 scientists studies all aspects of wildfowl biology including distribution, population dynamics and feeding ecology. The results of this research provide a sound basis for the Trust's work to promote the conservation of wildfowl and their wetland habitat, both nationally and internationally.



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