Breeding success of Icelandic Pink-footed Geese *Anser brachyrhynchus* and Greylag Geese *A. anser* in different areas of Iceland in 1987 and 1988

I.J. PATTERSON and J-F. GIROUX

Brood sizes in Pink-footed Geese and Greylag Geese were measured just after hatching, before fledging and after fledging in south and northeast Iceland in 1987 and post-fledging brood sizes were measured in south, north and northeast Iceland in 1988. In both years brood sizes were also measured after the birds' arrival in Scotland. Brood sizes after hatching were considerably lower than known clutch sizes in both species and Pinkfoot broods continued to decline until after fledging. There was no change in Pinkfoot brood size following migration but Greylag broods were smaller in Scotland than in Iceland in one of the two years of the study. Post-fledging brood sizes did not vary between areas in either species in 1988, or in Pinkfeet, between south and northeast Iceland in 1987. In Greylags, post-fledging brood size in 1987 was significantly higher in south Iceland than in the northeast, where egg harvesting occurred. It is suggested that the lack of any decline in breeding output as the populations of both goose species increased is likely to be due to extension of breeding range into new areas where breeding success was comparable to that in the former range.

The Icelandic populations of Pink-footed Geese *Anser brachyrhynchus* and Greylag Geese *A. anser* increased steadily from the first systematic counts in 1950 (Pinkfeet) and 1952 (Greylag). In the first part of this period of increase, there was some evidence of a concurrent decrease in the birds' breeding success, estimated from proportion of juveniles and mean family size soon after arrival in Britain (Ogilvie & Boyd 1976, Ogilvie 1982, Ebbinge 1985), but sample sizes were small in some years and the data must be interpreted cautiously. Excluding these early years, the percentage of juveniles in November showed no significant decrease and mean family size increased slightly but significantly in Greylags. The proportion of adults breeding successfully also showed no decline (Fox *et al.* 1989). Thus there was no clear density-dependent decrease in breeding success as the population expanded, either because any increase in density in the wintering or breeding areas had no effect on breeding success or, perhaps more likely, because the population increase involved an extension of range rather than increasing density. The number of pairs of Pink-footed Geese breeding in the main nesting area at Thjorsarver in the south central highlands of Iceland (Fig. 1) did not increase over the period of general population increase, while higher numbers were reported elsewhere in the highlands (A. Gardarsson pers. comm.). Greylag breeding areas were already dispersed around the coastal strip so that the population increase must have involved an increase in density or purely local extensions of breeding range but detailed information is lacking. In both species, the stable or increasing breeding success from 1967 to 1987 suggests that output in any new breeding areas was as

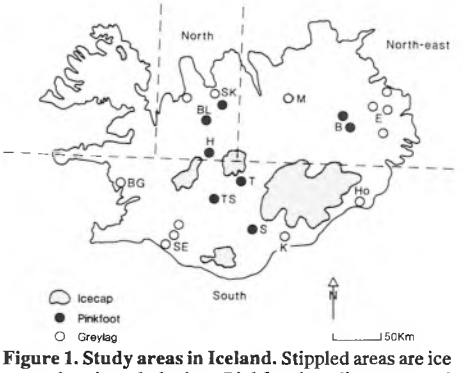

Figure 1. Study areas in Iceland. Stippled areas are ice caps; closed symbols show Pinkfoot breeding areas and open ones, Greylag breeding areas. Key to initial letters of sites: B - Bru; BG - Borgarnes; BL - Blondudalur; E - Egilstadir; H - Hvellavellir; Ho - Hofn; K - Kirkjubaejarklaustur; M - Myvatn; S - Skafta; SE Selfoss; SK - Skagafjordur; T - Thjorsarver; TS - Thjorsa.

high as in the original ones.

The aims of the present study were, to compare breeding success in Pink-footed and Greylag Geese in different parts of their breeding range in Iceland, to test the prediction that there would be no significant variation between areas and to measure changes in brood size from just after hatching until after migration in sample areas.

Measurement of breeding success

Measurements of breeding success were confined to the gosling period, since there was no evidence of a change in clutch size in either species (Table 1) and an intensive study of Pinkfeet in 1970-74 found little variation in hatching success between years (Gardarsson 1976). It was not possible to measure the proportion of pairs which lost their entire broods, since such failed breeders were likely to separate from successful pairs and move to moulting areas, so breeding success was estimated from mean brood size. This measure, however, when made on November flocks was strongly correlated with the proportion of juveniles in the same year (Pinkfeet; $r = 0.684$, $P<0.001$: Greylags, $r = 0.779$, $P<0.001$: 1967-87 data from The Wildfowl and Wetlands Trust), and it was assumed that the same relationship held in comparisons between areas.

Table 1. Clutch size of Pink-footed and Greylag Geese in Iceland

	Location	Year	Mean clutch SE	*n*	Reference
Pinkfooted	Thjorsarver	1971	4.1 ± 0.09		Gardarsson 1976
	Thjorsarver	1972	4.1 ± 0.06		Gardarsson1976
	Thjorsarver	1973	3.9 ± 0.06		Gardarsson 1976
	Thjorsarver	1974	4.1 ± 0.10		Gardarsson 1976
	Grafarlond	1980	4.3 ± 0.19	(37)	Einarsson 1983
	Hvannalindir	1981	3.9		
	Thjorsarver	1981	4.3		A. Gardarsson pers. comm.
	Thjorsarver	1982	4.0	(11; all 4)	RSPB unpubl.
Greylag	Iceland	1964-69	4.0 ± 0.13	(140)	Petersen 1970
	Iceland	1974-77	4.2 ± 0.40	(23)	Petersen pers. comm.
	Iceland	1979-86	4.7 ± 0.34	(23)	Petersen pers. comm.

Study areas and methods

In 1987, Pink-footed Geese were studied mainly at Thjorsarver in the central highlands (Fig. 1), the traditional breeding area of most of the Icelandic population (Kerbes *et al.* 1972). Four study areas were used, two (around Oddkelsalda and around Arnarfellsalda) on the west side of the Thjorsa River and two (Thufuver and Evindarkofaver) on the east side. After fledging, late broods were observed in Thufuver and near Oddkelsalda and families which had already dispersed prior to migration were found in and to the east of the Skafta valley, in the southern highlands (Fig. 1). Observations were also made around Bru in the northeast highlands, by A.D. Fox. In 1988, families which had dispersed presumably from Thjorsarver (the nearest nesting area) were found in the Thjorsa and Skafta valleys; those from the northeast highlands were found around Bru and those from the north highlands (including many which had almost certainly returned from Greenland) in upper Blondudalur, upper Skagafjordur and Hvellavellir (Fig. 1). In both years Greylags were studied in the southern lowlands from Borgarnes to Hofn, in northeast Iceland from Egilstadir to Myvatn and in north Iceland in Skagafjordur and Blondudalur (Fig. 1). Where possible, samples were taken from both coastal and inland breeding areas.

Observations were made in Iceland during three periods in 1987: post-hatching, 18 June to 2 July (I.J.P.), pre-fledging, 17 July to 7 August (J.-F.G.) and pre-migration, 19 August to 2 September (I.J.P.). In 1988 measurements were made from 24 August to 12 September (I.J.P.). During each visit, observations were made first on Greylags then on Pinkfeet, to allow as far as possible for the difference in mean laying date between the two species (Owen 1980). After the return of the geese to Britain, family size was measured in October and November in Grampian, Scotland, by both observers, so that the data were comparable with those collected in Iceland.

In Iceland, goose broods were observed with a telescope from high vantage points at 1-2 km. Counts of small goslings were accepted only if the birds were on water or if the adults' legs could be seen clearly as the family crossed an

area of short vegetation. Greylag broods in tall vegetation could usually be counted only when they emerged on a river or lake bank or when they were swimming.

Goslings were classified in the field into nine age groups by size, shape and feather development (Yocom & Harris 1965) but for analysis these were grouped into three classes; up to 20 days, 21-40 days and over 40 days. The mean ages of goslings in these classes (using the age group mid point for each group) were: Pinkfeet, 6.2 ± 0.3, 30.3 ± 0.3 and 67.8 ± 0.2 days respectively: Greylags; 10.3 ± 0.4, 30.1 ± 0.4 and 58.5 ± 0.8 days respectively. The Greylag goslings in the first age class were significantly older when observed than were the Pinkfeet ($t = 8.20$, $P<0.001$), in spite of the Greylag measurements being made earlier than those on the Pinkfeet. Variations in brood size with gosling age and between areas were analysed on the Aberdeen University Honeywell DPS 8/70 computer, using the S.P.S.S.x. statistical package (S.P.S.S. inc., 1986).

Results

1. Brood size in relation to gosling age

a) *Pink-footed Geese.* There was a considerable drop from the average clutch size of around 4.1 (in 1971-82, Table 1) to the mean size of broods in the first age category in 1987 (2.82, Table 2) and a progressive decrease in brood size with increasing age prior to migration (one-way ANOVA, $F = 3.50$, $P = 0.031$). This involved a progressive loss of larger broods and an increasing proportion of broods of one. Brood sizes observed in northeast Scotland, however, were not significantly different from those before migration (Tables 2 and 3).

Table 2. Brood size in relation to gosling age in Pinkfeet and Greylags in Iceland and Scotland, 1987. Mean clutch size was calculated from data in Table 1.

	Pinkfoot			Greylag		
	Mean	SE	*n*	Mean	SE	*n*
Clutch size	4.1		23	4.7		524
After hatching	2.82	0.11	139	3.37	0.18	85
Before fledging	2.59	0.08	224	3.09	0.10	203
Before migration	2.32	0.14	50	3.03	0.13	147
					***	
Scotland (Oct - Nov)	2.28	0.15	40	2.27	0.16	32

*** $P<0.001$

b) *Greylag Geese.* There was a substantial drop from the average clutch size of 4.7 (1979-86, Table 1) to the mean age of broods under 20 days of age (3.37) but no significant drop in brood size among older goslings (Table 2). In 1987, broods seen in northeast Scotland were significantly smaller than broods observed in Iceland in August and September (Table 2), but there was no such difference in 1988 (Table 3). (Although the sample from Scotland was small, it was consistent with other data collected by The Wildfowl and Wetlands Trust; mean brood size, 2.51 ± 0.06, n = 195).

2. Post-fledging brood size in different parts of Iceland

a) *Pink-footed Geese.* In 1987 the mean brood size among birds which had apparently dispersed from Thjorsarver was not significantly different from that among Pinkfeet in the northeast highlands studied by The Wildfowl and Wetlands Trust (A.D. Fox unpublished). Similarly, in 1988 there was no significant variation in brood size between different parts of Iceland (Table 3) and no tendency for birds in the north and northeast to have smaller broods than those which bred in Thjorsarver.

b) *Greylag Geese.* Post-fledging brood sizes in Greylags in northeast Iceland in 1987 were significantly smaller than those in the south (Table 3). However, no such difference occurred in 1988, when there was no significant variation in brood size between different parts of Iceland. There was also no significant difference in either 1987 or 1988 between coastal breeding sites and those up to 25 km inland in south Iceland.

3. Grouping of Greylag broods

Each Greylag brood found in June 1987 was

Table 3. Brood sizes of Greylags and Pinkfeet before migration in different parts of Iceland (Fig. 1) and in Scotland. Pinkfoot data in northeast Iceland in 1987 from The Wildfowl and Wetlands Trust (A.D. Fox unpublished).

	Pinkfoot			Greylag		
	Mean	SE	*n*	Mean	SE	*n*
1987						
South Iceland	2.32	0.14	50	3.03	0.13	147
					*	
Northeast Iceland	2.52	0.14	44	2.04*	0.22	25
1988						
South Iceland	2.12	0.13	52	2.56	0.15	84
Northeast Iceland	2.39	0.17	56	2.74	0.14	91
North Iceland	2.28	0.21	38	2.66	0.17	55
Overall Iceland	2.28	0.10	146	2.65	0.09	230
Scotland	2.19	0.24	26	2.67	0.42	6

*$t = 3.84$, $P = 0.04$

close to at least one other brood. Fourteen groups were seen, most commonly containing four broods (mean 4.64 ± 0.44, range 2-8). The pairs with their young, although clearly in a group far from other similar ones, were usually spaced 10-15 m apart and some aggressive encounters between pairs were seen. Some adult pairs without young (21.6% of the 138 pairs seen) were associated with the groups, maintained the same spacing and were attacked by brood parents. Such pairs were commoner in northeast Iceland (59.3% of 27 pairs) than in the south (18.0% of 111 pairs; $X^2 = 19.16$, $P<0.001$), one week later.

Discussion

In both species of geese the decrease from the presumed mean clutch size to the mean brood size at 6-10 days was much greater than the changes, if any, between subsequent age groups. This of course assumes that clutches in 1987 and 1988 were the same as in previous studies but there is no evidence of significant variation in clutch size between areas or between consecutive years (Table 1). Any of these losses may have occurred during incubation or hatching but it has commonly been found in other studies of waterfowl that the greatest losses of hatched young occur prior to ten days of age (Owen 1980).

In Pinkfeet, a progressive decrease in brood size continued until fledging but there was no similar effect in Greylags, possibly because the latter were significantly older when first observed, so that considerable early loss may have been undetected. Pinkfeet in both years and Greylags in 1988 showed no significant reduction in brood size over the migration period, suggesting that any losses which occurred were of whole broods rather than of individual young from surviving broods. There may, however, have been losses of Greylag goslings from broods in 1987, since the mean brood size in Scotland was significantly lower than that prior to migration (Table 2).

The changes in brood size measured in this study can of course only indicate the possible distribution of losses through the breeding season, since they reflect only the loss of some goslings from within otherwise surviving broods; broods which are totally lost become "invisible zero" broods, which cannot usually be detected. The only possible indication of total losses in the present study was the presence of Greylag pairs without young attached to groups of broods in June. The significantly higher proportion of such pairs in northeast Iceland in 1987 was consistent with a lower mean brood size there. However, it is by no means certain that the pairs without young were failed breeders and, even if they were, it is not known whether all such birds remain with groups or how long they might stay, so they at best provide only a minimum estimate of the extent of early total losses. However, if the significant correlation between brood size and the percentage of juveniles in the population in November, found in comparisons between years, applies to comparisons between areas, variation in brood size can be used as an index to variation in breeding success in different breeding areas.

In Pinkfeet there were no significant differences in mean brood size at the end of the breeding season between different areas in Iceland, suggesting that Pinkfeet in probable extensions of their range bred as successfully as those in the traditional main nesting area at Thjorsarver. This can in turn explain the lack of any reduction in breeding success as the population size increased, since there would be no penalty for breeding in new areas.

Among Greylags, the similar lack of any differences in mean brood size between areas in 1988 cannot be related so readily to the population increase, since breeding already occurred throughout lowland Iceland prior to 1950 and it is likely that numbers increased in all parts of the range, possibly through purely local extension of breeding areas. However, the lack of any difference in mean brood size between coastal and inland sites in south Iceland in both 1987 and 1988 suggests breeding success might not be affected by such extension.

The only significant difference between areas in Greylag brood size, in the northeast compared to the south in 1987, is consistent with the farmers' custom of taking eggs from nests in the northeast (A. Gardarsson pers. comm.). Since it is usual to leave one or two eggs in the nest, apparently to ensure continued incubation and brood rearing and so delay the arrival of "failed" adults on the hayfields (Orn Thorliefsson pers. comm.), such harvesting is likely to result in a reduced mean brood size in the area. It is not clear, however, why no such difference was found in 1988, although it is possible that the level of harvesting of eggs varies between years.

The results of the present study suggest that the Pink-footed and Greylag Goose populations could be limited by falling breeding output only

when all suitable breeding habitat has been occupied and breeding density rises to a level where breeding success is depressed. However, without detailed information on the amount of suitable habitat available, it is not possible to predict when such effects might occur.

We are indebted to many Icelanders, particularly Arnthor Gardarsson, Arni Einarsson, Aevar Petersen and Thora-Ellen Thorhallsdottir, for their strong support and warm encouragement before and during the study. Gudmundur A. Gudmundsson gave invaluable help with strenuous fieldwork during the first visit to Thjorsarver in 1987, Miss E. Landa contributed greatly to the collection of data on the second visit to Iceland and M. Patterson helped on the third. The study was financed by a NATO Grant for Scientific Cooperation, with a contribution by Aberdeen University towards the cost of transporting their loaned landrover to Iceland. Jean-Francois Giroux was supported by a post-doctoral fellowship from The Natural Sciences and Engineering Research Council of Canada.

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J. Patterson and J-F. Giroux[1], Aberdeen University, Zoology Department, Culterty Field Station, Newburgh, Grampian, AB4 0AA.

[1]Present address: Department des Sciences Biologiques, Universite du Quebec a Montreal, C.P. 8888, Succ. A., Quebec, Canada H3C 3P8.