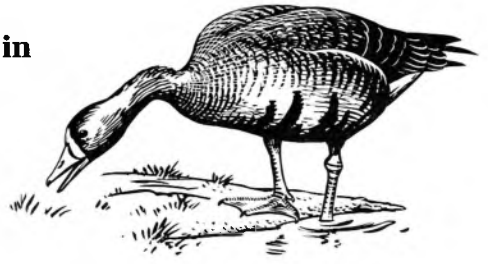
Seasonal and long-term changes in habitat selection by Greenland White-fronted Geese *Anser albifrons flavirostris* in Ireland



D.W. NORRISS and H.J. WILSON

Bogs and other semi-natural wetlands have provided traditional feeding habitats for Greenland White-fronted Geese wintering in Ireland, although many flocks now feed predominantly in farmland. Use of the wettest habitats and arable crops predominates in autumn, most feeding is on various grasslands in winter and on dry grasslands in spring. Habitat loss and disturbance pressures now restrict the range of feeding habitats available to most flocks, resulting in marked inter-flock variability in habitat use. Shifts to farmland feeding have coincided with beneficial farmland changes rather than with losses of traditional habitats. The implications for the retention of traditional feeding patterns are discussed.

Regular international counts of Greenland White-fronted Geese *Anser albifrons flavirostris* in Ireland have taken place from 1982 to 1990, during which period maximum counts in Ireland have risen from 8800 to 14,800 (Stroud *et al.* in press). Seventy percent of the Irish total winter at one site in Wexford, but elsewhere in Ireland geese occurred in about 35 small flocks (<10-600) with discrete feeding ranges scattered throughout the midlands and counties of the western seaboard.

Historically Greenland Whitefronts wintered on bogland. Ruttledge & Ogilvie (1979) recorded callows and rough grasslands as additional important feeding habitats with minor use of marsh, saltmarsh, arable and root crops. In recent times geese have increasingly deserted semi-natural habitats and low-intensity grassland to feed on intensively-managed farmland. Nevertheless Greenland Whitefronts still generally preferred wetter, poorer vegetation and sympatric species selected improved grassland where they occurred together (Fox *et al.* 1989a, Easterbee *et al.* in press).

The subspecies feeds by both grazing and probing throughout the year (Pollard & Walters-Davies 1968, Ruttledge & Ogilvie 1979), by pulling submerged vegetation (Mayes 1991) and occasionally by stripping seeds in autumn (Cramp & Simmons 1977, Fox & Stroud 1986). On bogland, Greenland Whitefronts probe for storage organs of *Rhyncospora alba* and *Eriophorum angustifolium* (Pollard & Walters-Davies 1968). Temperature may limit the goose's winter distribution by preventing probing in frequently frozen ground (Fox & Stroud 1986). Even within this range geese must frequently move to grasslands and feed by grazing during severe ground frosts. Thus a variety of alluvial grassland habitats have probably also been used since pre-agricultural times. Despite considerable inter-flock variability in habitat use, consistent patterns were apparent within flocks from year to year. This suggested that factors other than food choice may be of primary importance in determining habitat selection.

Studies of habitat selection in geese have concentrated on the comparative nutritional and energetic value of food plants and the consequences of repeated grazing in terms of plant digestibility and protein levels (e.g. Drent *et al.* 1979, Prins *et al.* 1980, Ydenberg & Prins 1981, Boudewijn 1984). However, disturbance plays a particularly pronounced role in the winter ecology of Greenland White-fronted Geese because of extensive fragmentation of traditional feeding ranges. Recent changes in individual flock sizes in Ireland were correlated with the number and size of feeding sites and with disturbance rates (Norriss & Wilson 1988, Stroud *et al.* in press). A relationship has also been suggested between relative disturbance levels of individual feeding sites and their use

on Coll, Inner Hebrides by Fox *et al.* (1989a). Thus habitat selection could be influenced through site selection by disturbance pressures.

Greenland White-fronted Geese have used farmland at Wexford since the 1920s (Ruttledge & Ogilvie 1979). More recently grassland management has intensified,

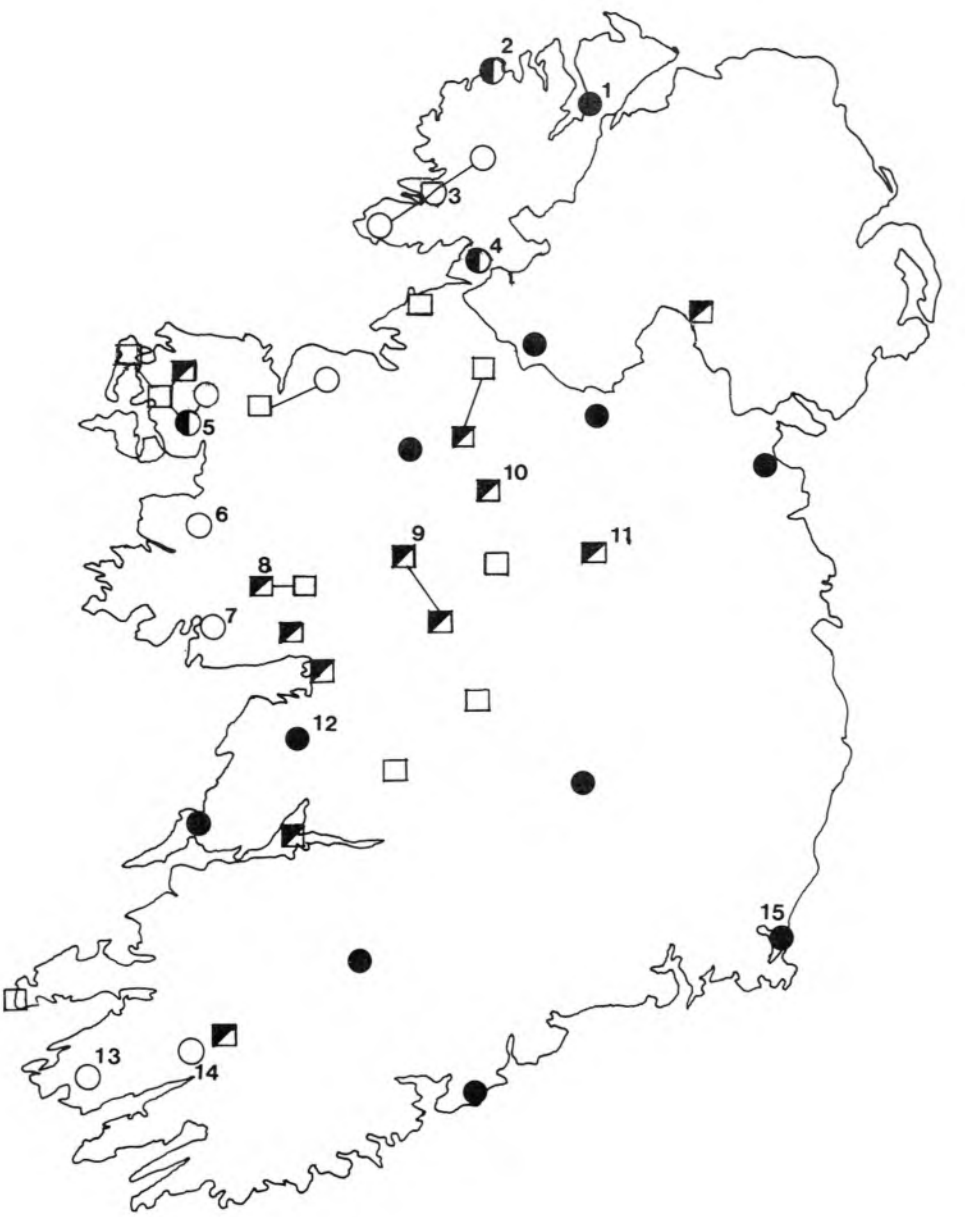


Figure 1. Distribution and major feeding habitats of Greenland White-fronted Goose flocks in Ireland: bogland ○: other wetlands □: farmland ●: partially filled symbols indicate use of both farmland and other categories. Numbers show the location of flocks referred to in the text: Swilly 1: Dunfanaghy 2: Sheskinmore 3: Pettigo 4: Owenduff 5: Errif & Derrycraff 6: Connemara 7: Rostaff 8: Glenamaddy 9: Castleforbes 10: Midlands 11: North Co. Clare 12: Inny valley 13: Killarney valley 14: Wexford 15. Symbols joined by a line denote a flock complex.

further flocks have moved to farmland and farmland flock sizes have increased (Wilson *et al.* 1991), leading to damage complaints from farmers. At the same time smaller flocks, often on traditional habitats, have declined. A desirable objective therefore would be to maintain traditional habitat use as far as possible, so as to conserve geese on the habitats in which they have recently evolved (Owen 1976a) and to counter problems of range contraction and agricultural conflict.

In this paper we consider the effects of site attractiveness on the seasonal pattern of habitat use in Ireland and the implications for conservation of Greenland Whitefronts on natural and semi-natural habitats.

Methods

The location of Greenland White-fronted Goose flocks within the Republic of Ireland and Northern Ireland are shown in Figure 1. A 'flock' is defined here as a group of birds occupying a discrete wintering range. Counts were conducted at least monthly during the winters 1982-83 to 1984-85. Subsequently (1985-86 to 1989-90), count frequency was reduced to three per winter. Habitat use and disturbance data were collected concurrently and have been compiled (except where otherwise stated) from the period 1982-83 to 1985-86 when counts were most frequent.

The following categories and definitions of habitat were used:

bog:	acidic peat-forming plant communities
marsh:	permanently waterlogged area on mineral soils
callows:	seasonally-flooded grasslands adjacent to lakes, rivers and turloughs
wet grassland:	wet rough pasture with clumps of *Juncus* sp.
dry grassland:	dry meadows, pastures and silage fields including reseeded areas.

A feeding site is delimited by all the recorded observations or field signs of geese within 1 km of each other. A feeding area >1 km from another is defined as a separate feeding site.

Mean attendance at a site was expressed as the mean proportion of site count to the estimated total flock present. Since geese were occasionally missed during counts, sum attendance of all sites may not total 1.00. Boundaries of feeding sites were determined from 6-figure grid references compiled from site visit cards. Feeding areas (A) were then measured using a perspex grid with squares corresponding to 1 ha. R was the observed disturbance rate (*n* per hour) at a feeding site. We calculated a disturbance index as 200-A/R, for individual feeding sites (Norriss & Wilson 1988).

The residence period of geese in Ireland was divided into three: autumn (October and November), winter (December to February) and spring (March and April).

Friedman two-way ANOVA (Siegel 1956) was applied to test whether distributions of geese between habitats were similar among flocks and within flocks over time. Consistent patterns produced summed rank distributions between habitats which differed significantly from random.

Results

Seasonal patterns

The phenology of habitat use differed between flocks on bog, wetlands or farmland. Although the distinctions are somewhat artificial in that feeding was seldom confined to a single category, the groupings are useful in reducing the variation in seasonal feeding patterns and establishing features in common.

Figure 2 shows the seasonal habitat use of flocks using bog and wetlands, omitting flocks which fed for the most part on farmland and large flocks which split up to such a degree that complete coverage became a problem.

Bogland flocks showed no consistent seasonal use of other habitats, apart from a decline in the use of marsh and callows from autumn to spring (Fig. 2A). Two flocks were recorded feeding only in bogland, apparently because of an absence of suitable alternatives. Two flocks used wet and dry grasslands more in autumn and bogland more in spring, whilst two others had a reverse pattern of use and one showed no seasonal change. These flocks wintered in agriculturally poor districts, where grassland was scarce and intensively used. A possible explanation for the lack of a consistent sea-

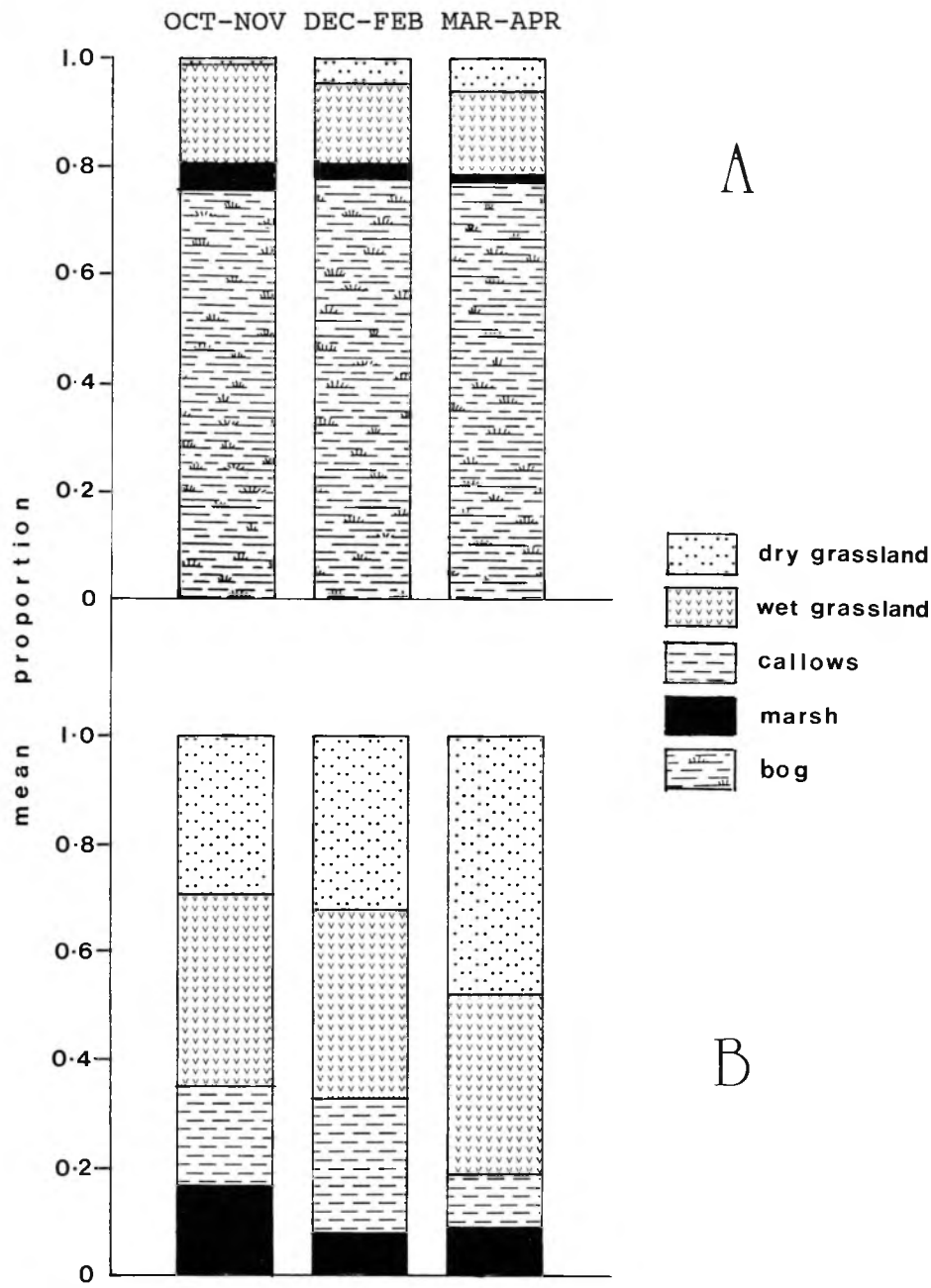


Figure 2. Seasonal habitat use (mean proportion of the flock recorded in each habitat) by Greenland White-fronted Geese using (A) blanket boglands, *n* = 6 flocks; (B) other wetlands, *n* = 9 flocks. Two bogland flocks which shifted to farmland during the survey and one for which data were unreliable have been omitted.

Table 1. Constancy of autumn and winter habitat use within (1) and between (2) flocks of Greenland White-fronted Geese. Habitat use is ranked from the lightest (score 1) to the heaviest usage (score 4) and (1) summed for the four years 1982-83 to 1985-86 or (2) summed for all flocks.

Flock	Marsh	Callows	Wet Grass	Dry Grass	X^2r	*P*
(1) Within flocks						
Caledon	4.5	12.5	14.5	8.5	8.85	<0.014
Belmullet	7.5	16	5.5	11	9.53	<0.012
Glenamaddy	4.5	11	9.5	15	8.48	<0.019
Rostaff	8.5	10	5.5	16	8.78	<0.014
Rahasane	4	14	12	10	10.8	<0.002
Carran	7	7	10	16	8.1	<0.033
Killower	11.5	11.5	5	12	5.03	N.S.
Lr L Corrib	8.5	13	8.5	10	2.02	N.S.
Turkenagh	10.5	8.5	4.5	6.5	4.0	N.S.
(2) Between flocks						
	19	28.5	19.5	23	3.83	N.S.

sonal pattern is that goose use of grassland was closely dependant on field management, particularly stock grazing pressures and agricultural disturbance which themselves were highly variable. Spring grazing of quiet river terraces used to be common when they were regularly manured (Pollard & Walters-Davies 1968, Ruttledge & Ogilvie 1979), which also suggests that a pattern of spring grazing has been restricted by changes in farming practice.

Over three-quarters of Irish flocks now feed on grassland, callows and marsh along the edges of lakes and rivers (Fig. 1). Amongst nine flocks feeding in marsh and/or callows, combined use of both categories was more frequent before February than after (Fig. 2B; Wilcoxon's matched-pairs test, T = 7, one-tailed, $P<0.05$). In spring geese fed more on dry grassland than in autumn and winter (Wilcoxon's test, T = 7, one-tailed, $P< 0.05$). Use of wet grassland showed no seasonal trend.

Marshland usage was more variable (coefficient of variation, cv = 1.5) than usage of other habitats (cv = 0.6-1.1), reflecting its restricted availability and its heavy use by geese when it was available. Variation was particularly pronounced in spring due to one flock's continued high level of marsh feeding in the absence of suitable areas of dry grassland. Figure 2B suggests a more prolonged use of callows than of marsh, but the differences were not statistically significant. However sequential use of marsh, then callows, followed by dry grassland was repeated annually where all three habitats were available, indicating that the pattern amongst other flocks was necessarily modified by variations in habitat availability or other factors such as disturbance.

The Friedman test was used to examine the year-to-year constancy of habitat use within and between small flocks from October to February (Table 1). The selection was limited to flocks whose ranges contained the same suite of wetland and grassland categories. Six out of nine flocks examined showed significantly consistent patterns of use over four years ($P< 0.033$); in two exceptions to this pattern, habitat changes were associated with moves to new intensively-managed grass fields during the period of study. Conversely habitat use between flocks varied considerably ($X^2r = 3.83$, df = 3, n.s.).

On mixed farmland geese fed on waste cereal grain and root crops from harvesting until these foods were exhausted. Only two flocks outside Wexford currently do so to a significant degree. However, this habitat was more widespread elsewhere in Ireland until the 1950s, when farming was more diverse than at present. We suspect geese were also more tame 40 or 50 years ago since we heard many reports of birds feeding on tillage crops close to houses then. Increased hunting was probably also a factor in changing feeding habits.

Effect of site attractiveness

The rate and proximity of disturbances are known to control goose distribution on a small scale within large farms in European Whitefronts *A. a. albifrons* (Owen 1972b) and Pink-footed Geese *A. brachyrhynchus* (Meire *et al.* 1991, Madsen 1985). Feeding ranges of

Table 2. Usage of a Greenland Whitefront flock's preferred feeding site in relation to range size. Site use was calculated as the mean proportion of the total flock present per visit, data from 1982-83 to 1987-88.

Number of feeding sites in range		
>10	3-10	1-2
0.35	0.64	1.0
0.34	0.60	0.96
0.25	0.58	0.95
0.22	0.52	0.82
	0.41	0.64
		0.61
		0.60
		0.49

Preferred sites were more heavily used on medium-sized than on large ranges and more heavily used on small than on medium-sized ranges (Mann-Whitney U test; U = 0, P = 0.008 and U = 8, P = 0.047 respectively).

Greenland White-fronted Geese are generally more fragmented, varying between two and 35 scattered feeding sites with a median size <10 ha (unpubl. data). Whitefronts are very vulnerable to disturbance on such small sites and disturbance may be expected to play a key role in site selection.

Figure 3 shows the relative use of feeding sites, in relation to disturbance, for three flocks with contrasting sizes of feeding range. In all three flocks, a site's use was negatively correlated with its disturbance index, preferred sites being larger and/or having lower rates of disturbance. Individual exceptions to the pattern of site use (where site use was considerably less than expected from its disturbance index) appear due to the limited seasonal availability to geese of food such as stubbles (one site each in Midlands and Rostaff ranges).

The use of preferred sites increased with declining range size (Table 2). Presumably disturbance increasingly constrained the use of poorer alternative sites and feeding concentrated on the best available option.

Changes in habitat use

Greenland White-fronted Geese have generally retained use of traditional feeding habitats to a larger degree than other European *Anser* species (Owen 1976a, Ruttledge & Ogilvie 1979). However, the feeding habits of the Irish population outside Wexford have changed appreciably since 1982.

Several flocks have shown an increased use of intensively-managed grassland at the expense of traditional habitats (see below). No flocks have sustained a reverse pattern, although the rate and permanence of new site use has been influenced by grassland location in relation to traditional feeding areas. Blanket bog flocks have established new feeding sites in neighbouring lowland farmland up to 10 km from traditional feeding sites. By contrast flocks on other wetlands have been able to use intensified grass fields that were available within or close to existing feeding sites because of the smaller-scale nature of habitat mosaics outside blanket bog.

Goose use of reseeded fields located within existing feeding sites was typically opportunistic, areas of new reseed being quickly exploited and longer established ar-

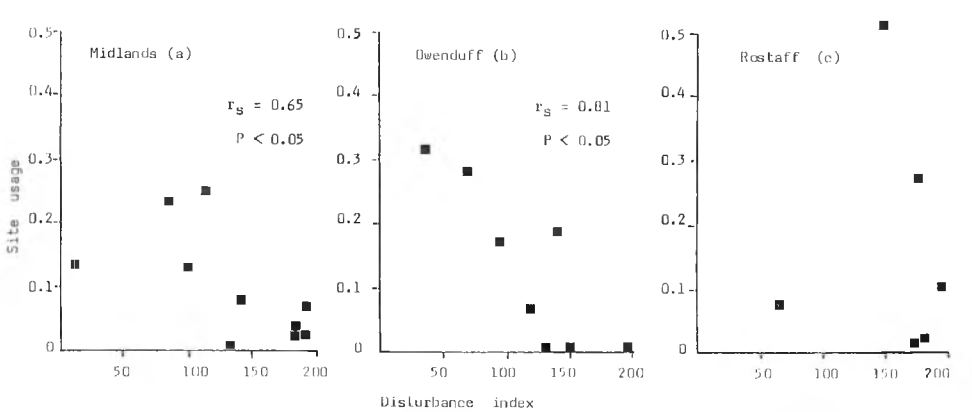


Figure 3. Use of feeding sites in relation to site disturbance indices for flocks of Greenland White-fronted Geese at (a) Midland lakes, Co. Westmeath; (b) Owenduff, Co. Mayo; (c) Rostaff, Co. Galway. The total feeding area declines from 240ha in (a) to 80ha in (c). Site use was calculated as the mean proportion of the total flock present per visit, data from 1982-83 to 1987-88 pooled. Calculation of disturbance pressures are detailed in the text. Coefficients (rs) are Spearman rank correlations.

Table 3. Relationships between development pressures on bog-feeding flocks of Greenland Whitefronts, changes in status and moves to farmland. Flocks are ranked in decreasing size of remaining bog range.

Flock	Development Pressures	Numerical trends	% feeding on bog 1982-83	1988-89
Errif & Derrycraff, Co. Mayo	Little forestry	Increase	>95	>95
Connemara, Co.Galway	Extensive forestry	Slow Increase	100	100
Owenduff, Co. Mayo	Little forestry	Stable	96	82
Sheskinmore, Co.Donegal	Turbary eliminated major feeding site.	Decreased in early 1980's now stable	74	70
Pettigo, Co. Donegal	Extensive forestry & turbary	Increase	68	1
Killarney Valley, Co. Kerry	Heavy recreational	Decrease	100	100
Dunfanaghy, Co. Donegal	Little turbary	Increase	5	0
Glencolumbkille, Co. Donegal	Little forestry	Slow decrease	70	70
Lough Barra bogs, Co. Donegal	Little forestry	Slow decrease	90	90
Inny Valley, Co. Kerry	Largest complex of sites afforested	Extinct	100	-

eas being deserted when grass quality declined. Figure 4 shows changes in seasonal habitat use by a flock in North Co. Clare before and after field enlargement and reseeding of two small fields in 1985 and 1987. After reseeding, intensified grassland was used more heavily in all periods and feeding in the wettest habitats (marsh and callows) was not recorded at all, even in autumn when it was previously most frequent.

Amongst smaller flocks (<150 geese), eight out of 18 (35% of geese outside Wexford) showed changes typified in Figure 4 and now predominantly feed on intensified grassland throughout the winter, compared with four (26% of individuals) in 1982. Larger flocks have shown little change in use of intensive grassland; 13% of individuals in two flocks on semi-natural wetlands used intensive grasslands in 1983-84, compared with a mean of 14% in 1987-88 and 1988-89. Both flocks have large feeding areas on callows which are not amenable to drainage on other than a catchment basis and consequently where extensive low-intensity farming has been maintained.

Bogland flocks have also shown a feeding habitat shift to intensive grassland (Table 3). Four of the remaining seven bogland flocks listed in Table 3 also have important feeding sites on farmland. Two of these had virtually ceased using bogs by 1988-89 and were excluded from Figure 2A. Habitat use amongst other bogland flocks has not changed significantly.

The demise of bogland feeding has been associated with habitat loss (Ruttledge & Ogilvie 1979), but contemporaneous changes on farmland have been beneficial to geese (Stroud *et al.* in press) and may also have been implicated. Four flocks can be shown to have established a regular pattern of farmland use prior to commercial peatland exploitation and their changing habits cannot be attributed to loss of bogland feeding grounds (Appendix). Establishment of new farmland feeding sites was reportedly associated with one or more of the following: (i) the severe winter of 1962-63, (ii) grassland intensification and (iii) large areas within which geese were protected from shooting (Ruttledge & Ogilvie 1979, NPWS staff pers. comm.). Infor-

mation on the sequence of habitat changes was incomplete for other flocks and some moves may perhaps have been initiated by bogland loss. During the survey though, while flocks with intact bogland ranges or some established farmland sites have remained stable or increased, bogland flocks experiencing habitat loss have not moved to other habitats and have declined in size (Table 3).

Discussion

Patterns of use

Arable areas provide preferred foods when Whitefronts first arrive in autumn. A similar early-season preference for marsh is indicated by the sequence of habitat usage (Fig. 2) and by a significantly higher proportion of socially dominant juveniles recorded there than amongst neighbouring geese on adjacent habitats (Norriss & Wilson in prep.). Geese then use bog, callows or wet grassland in winter and move to dry grasslands, par-

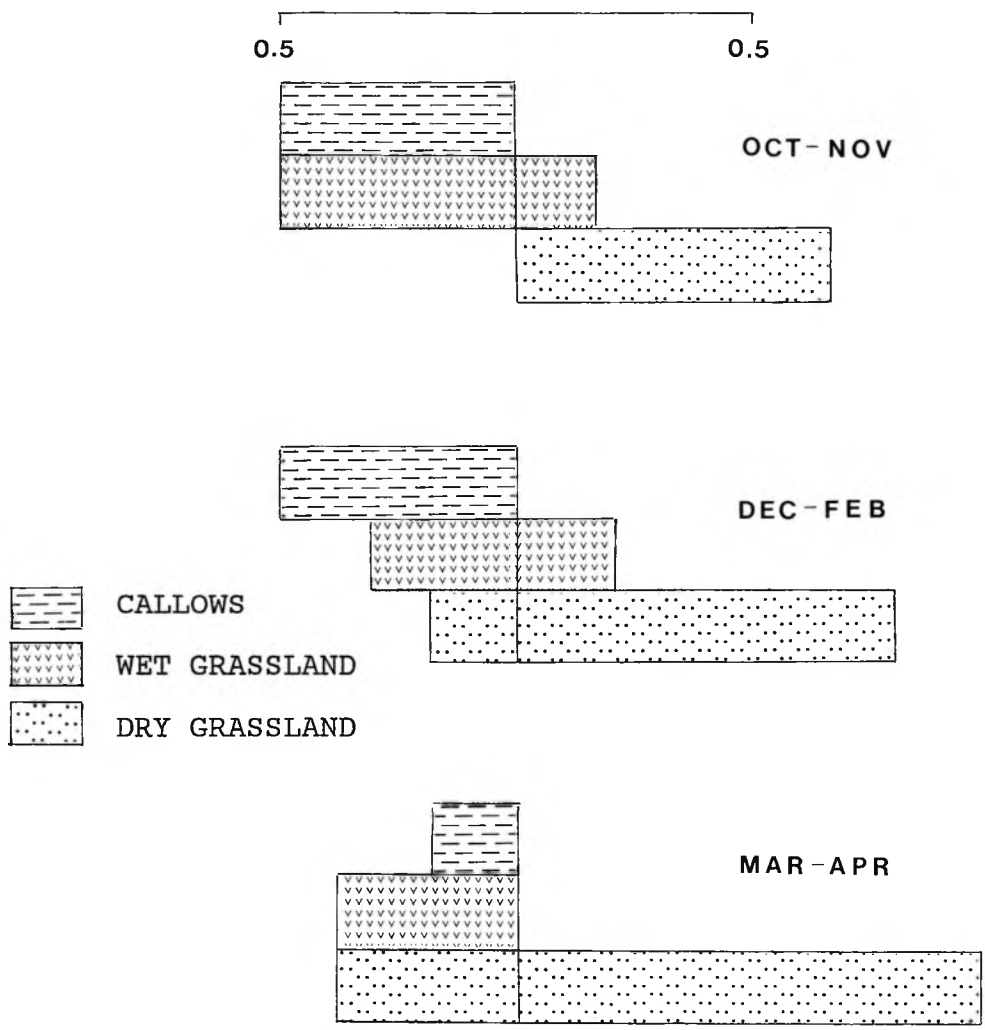


Figure 4. Changes in seasonal habitat use by feeding Greenland White-fronted Geese, Ballyeighter L., North Co. Clare, between 1982-83 (left) and 1987-88 (right of central axis). *N* = 15 for each winter's observations. Box width from the central axis represents the mean proportion of the flock recorded in each habitat.

ticularly higher-intensity fields, in spring.

In general Greenland Whitefronts show a similar seasonal pattern of food selection in winter to other goose species, eating high-energy foods such as seeds and overwinter storage organs in autumn and winter and the most digestible and protein-rich foods in spring (Owen 1980). However, wintering ranges have been so modified and fragmented over the years that habitat availability currently restricts choice to a considerable degree. Habitat selection is further restricted by the impact disturbance pressures now have on site selection.

Levels of site use were related to site disturbance indices, on occasion leading to use of unusual habitats, such as saltmarsh, or to atypical seasonal feeding patterns. Nowadays for instance, the access of bogland flocks to managed, undisturbed grassland in spring is at such a premium in the west of Ireland that these flocks no longer show any consistent seasonal habitat trends. The consequences of wintering ranges losses have thus been to restrict habitat selection within flocks but, because of the Greenland Whitefront's feeding flexibility, to broaden the range of habitats used by the population as a whole.

A consequent restriction of diet choice could affect winter energy balance in a number of ways, including overwinter condition and pre-migratory rates of weight gain. In a study of winter feeding ecology, Whitefronts in Wexford and on the Little Brosna were found to be unable to attain an energy balance in December and January solely by grazing (Mayes 1991). That abdominal profiles of geese did not decline during this period appeared to be because a significant proportion of their diets consisted of sugar beet and *Agrostis stoloinfera* stolons respectively. Whitefronts in Wexford also showed significant correlations between annual variations in early-winter weight change (expressed as the percentage difference in mean weight from November to January) and the availability of waste roots and stubbles (unpubl. data). Owen (1972a) has suggested geese eating such high-energy foods are able to withstand heavier disturbance pressures than grazing birds.

The preference shown for intensive grasslands, particularly in spring, is also likely to reflect more profitable feeding opportunities (Owen 1980) which influence subsequent breeding success (Cabot & West 1973, Fox *et al.* 1989b, Norriss unpubl. data).

In general habitat losses have restricted feeding opportunities, so a reduced forage profitability can be expected to compound the effects of range losses on winter energy balance.

Habitat changes

The numbers of geese using intensified grassland have increased markedly since 1982. Many flocks now feed predominately on this habitat throughout their stay with only occasional, minor use of wetland habitats in autumn and early winter (cf. Fig. 4).

Easterbee *et al.* (in press) suggested use of intensified grassland on Islay, Scotland, occurred when traditional feeding areas were improved. However, in Ireland Whitefronts have also exploited new feeding areas. The location of new feeding opportunities has influenced the rate and permanence of habitat changes. Moves onto intensified grassland within existing feeding sites were opportunistic, rapidly responding in time and space to changes in grassland management. Heavy use of reseeded areas coincided with periods of intensive grassland management, with no other alteration on the same site, suggesting the change reflects a genuine feeding preference rather than a deterioration in conditions of traditional habitats.

In contrast, habitat moves resulting from feeding site changes were primarily dependant on comparative site-to-site disturbance indices (Fig. 3). Feeding habitat shifts from bog to farmland preceded serious bogland changes rather than resulted from them. It therefore seems likely that contemporaneous farmland changes, primarily improved protection from shooting and agricultural intensification, with larger fields and better grass swards, are the factors responsible for initiating habitat change. Thus the relative attractiveness of traditional sites and farmland alternatives may be expected to determine habitat use, irrespective of the protection given to traditional habitats. As bogland exploitation has proceeded, disturbance and direct loss of feeding grounds have become serious problems (Norriss & Wilson 1988 unpubl. data); the fragmented remainder of bogland sites have presumably even become less attractive relative to farmland sites, hastening the process of habitat change (Table 3).

In the long-term, geese are only likely to

remain on traditional habitats in the absence of within-site agricultural intensification and when the disturbance index of feeding sites compares favourably with the disturbance index of alternative sites on farmland.

Two, perhaps three bogland flocks and flocks on callows by the River Shannon offer reasonable prospects of these conditions being maintained.

We would like to take the opportunity to thank the team of 75 field-workers from the Wildlife Service (ex. Forest and Wildlife Service), the Irish Wildbird Conservancy and the Irish Shoot Promoter's Association in the Republic of Ireland and the Department of the Environment and the Royal Society for the Protection of Birds, Northern Ireland. C. Murphy, R. Nairn and N Sharkey helped with administration.

Our thanks to A. D. Fox, E. Mayes, O. J. Merne, C. Smal and D. Stroud for comments on earlier drafts and to M. McGarry who typed the manuscript.

References

Boudewijn, T. 1984. The role of digestibility in the selection of spring feeding sites by Brent Geese. *Wildfowl* 35:97-105.

Boyd, H. 1953. On encounters between wild White-fronted Geese in winter flocks. *Behav.* 5:85-129.

Cabot, D. & West, B. 1973. Population dynamics of Barnacle Geese *Branta leucopsis* in Ireland. *Proc. Royal Irish Acad.* 73:415-443.

Cramp, S. & Simmons, K.E.L. (Eds.) 1977. *The Birds of the Western Palearctic Vol I.* Oxford University Press.

Drent, R., Ebbinge, B. & Weijand, B. 1979. Balancing the energy-budgets of arctic-breeding geese throughout the annual cycle: a progress report. *Verh. orn. Ges. Bayern* 23:239-264.

Easterbee, N.,Bignal, E.M., Stroud, D.A. & Curtis, D.J. (in press). Distribution and ecology of wintering Barnacle and Greenland White-fronted Geese on Islay, Scotland, 1982/3-1988/9. *Wildfowl.*

Fox, A.D. & Stroud, D.A. 1986. The Greenland White-fronted Goose in Wales. *Nature in Wales* 4:20-27.

Fox, A.D., Francis I.S. & Stroud, D.A. 1989a. Greenland White-fronted Geese on Coll and Tiree: Numbers, distribution and conservation. Pp. 129-142. In: D.A. Stroud, (Ed.) 1989. *Birds on Coll and Tiree: status, habitats and conservation.* Nature Conservancy Council/Scottish Ornithologists' Club. Edinburgh.

Fox, A.D., Gitay, H., Owen, M., Salmon, D.G. & Ogilvie, M.A. 1989b. Population dynamics of Icelandic nesting geese. *Ornis Scandinavica* 20:289-297.

Greig, S.A., Coulsan, J.C. & Monaghan, P. 1983. Age-related differences in foraging success in the Herring Gull (*Larus argentatus*). *Anim. Behav.* 31:1237-1243.

Heery, S. 1983. A vegetation study of the Little Brosna floodplain grassland. Report to the National Association of Regional Game Councils of Ireland and The Royal Irish Academy, Dublin.

Kear, J. 1970. The experimental assessment of goose damage to agricultural crops. *Biol. Conserv.* 2:206-212.

Madsen, J. 1985. Impact of disturbance on field utilization of Pink-footed Geese in West Jutland, Denmark. *Biol. Conserv.* 33:53-63.

Mayes, E. 1991. The winter ecology of Greenland White-fronted Geese *Anser albifrons flavirostris* on semi-natural grassland and intensive farmland. *Ardea* 79(2):295-303.

Meire, P., & Kuijken, E. 1991. Factors affecting the number and distribution of wintering geese and some implications for their conservation in Flanders, Belgium. *Ardea* 79 (2):143-157.

Norriss, D.W. & Wilson, H.J. 1988. Disturbance and flock size changes in Greenland White-fronted Geese wintering in Ireland. *Wildfowl* 39:63-70.

Norriss, D.W. & Wilson, H.J. (in prep.) Feeding strategies of Greenland White-fronted Geese in relation to social status.

Owen, M. 1972a. Some factors affecting food intake and selection in White-fronted Geese. *J. Anim. Ecol.* 41:79-92.

Owen, M. 1972b. Movements and ecology of White-fronted Geese at the New Grounds, Slimbridge. *J. Appl. Ecol.* 9:385-398.

Owen, M. 1976a. Factors affecting the distribution of geese inthe British Isles. *Wildfowl* 27:143-147.

Owen, M. 1976b. The selection of winter food by White-fronted Geese. *J. Appl. Ecol.* 13:715-729.

Owen, M. 1980. *Wild Geese of the World.* B.T. Batsford Ltd., London.

Patterson, I.W. 1991. The status and breeding distribution of Greylag Geese *Anser anser* in the Uists (Scotland) and their impact upon crofting agriculture. *Ardea* 79(2):243-251.

Patton D.L.H. & Frame J. 1981. The effect of grazing in winter by wild geese on improved grassland in west Scotland. *J. Appl. Ecol.* 18:311-325.

Pollard, D.F.W. & Walters-Davies, P.W. 1968. A preliminary study of the feeding of the Greenland White-fronted Goose *Anser albifrons flavirostris* in Cardiganshire. *Wildfowl* 19:108-116.

Prins, H.H.T., Ydenberg, R.C. & Drent, R.H. 1980. The interaction of Brent geese, *Branta bernicla*, and Sea Plantain, *Plantago maritima*, during spring staging: field observations and experiments. *Acta Bot. Neerl.* 29(5/6):585-596.

Ringelman, J.K. 1988. Examining waterfowl condition: skewed ideas on the normal procedure. Pp. 227-285. In: M.W. Weller, (Ed.) 1988. *Waterfowl in winter.* University of Minnesota Press.

Rutschke, E. & Schiele, G. 1979. The influence of geese (Gen. *Anser*) migrating and wintering in the G.D.R. on agricultural and limnological ecosystems. *Verh. orn. Ges. Bayern* 23:177-190.

Ruttledge, R.F. & Ogilvie, M.A. 1979. The past and current status of the Greenland White-fronted Goose in Ireland and Britain. *Irish Birds* 1:293-363.

Ryan, J.B. & Cross J.R. 1984. The conservation of peatlands in Ireland. *Proc. Int. Peat Congr.*, Dublin:388-406.

Siegel, S. 1956. *Nonparametric statistics for the behaviourial sciences.* McGraw-Hill, New York.

Southwood, T.R.E. 1966. *Ecological methods with particular reference to the study of insect populations.* Methuen. London.

Stroud, D.A., Fox, A.D., Wilson, H.J. & Norriss, D. (in press) Greenland White-fronted Geese in Ireland and Britain 1982-87; population monitoring and conservation. *Biological Conservation.*

Wilson, H.J., Norriss, D.W., Fox, A.D. & Stroud, D.A. 1991. Site fidelity in Greenland White-fronted Geese *Anser albifrons flavirostris*: implications for conservation and management. *Ardea* 79(2):287-294.

Ydenberg, R.C. & Prins, H.H.T-H. 1981. Spring grazing and the manipulation of food quality by barnacle geese. *J. Appl. Ecol.* 18:443-453.

D.W. Norriss and H.J. Wilson, National Parks and Wildlife Service, The Office of Public Works, 51 St. Stephen's Green, Dublin 2, Ireland.

Appendix. Timing of feeding habitat shifts in bogland flocks to farmland in relation to bogland loss.

FLOCK	FEEDING HABITAT CHANGE	BOG EXPLOITATION	REFERENCE
Glenamaddy Co. Galway	Marked decline in bog feeding since 1962/63. The flock now uses turlough grassland and adjacent intensified farmland.	No appreciable change to two major raised bog sites used by flock.	Ruttledge & Ogilvie 1979, NPWS staff.
Castleforbes Cos. Roscommon & Longford	Considerable use of protected estate farmland during 1940s and 1950s. Then, as now, raised bogs used as refuges from disturbance.	Hand-cutting of turf affected some smaller bogs but the bulk were intact until exploitation by Bord na Mona started in the 1970s.	Ruttledge & Ogilvie 1979.
Pettigo Co. Donegal	First recorded outside blanket bog sites on estate farmland about 1963. Move, involving 30-40% of the flock, variously attributed to severe winter of 1962/63 and grassland improvement.	Afforestation was the only significant land-use change in the 1960s and 1970s. Ploughing of deep peats, to which goose sites were restricted, started in 1965. Impact of forestry still localised by 1970.	Ruttledge & Ogilvie 1979, Forest Service (Ciollte) inventory material, NPWS staff.
Swilly Co. Donegal	Two farms, reclaimed from the sea in the 19th C. were used by a flock of circa 300 Whitefronts between the two the world wars.	Traditional blanket bog feeding sites in the Inishowen uplands were first opened up for commercial turf-cutting at the start of World War 2.	NPWS staff.