3.1.4 Home range analysis of marked individuals and family units

Introduction

The movements of ringed birds sighted repeatedly during the 1991-92 and 1992-93 winters were analysed in further detail, using Range Analysis techniques, to assess the home ranges of individual birds. A study of seven Greenland White-fronted Geese wintering on the Wexford Slobs found that overall range areas were between 700-800 ha, but that 80% of time was spent in a core area of some 200 ha (Bell 1990). Methods used to quantify the ranges of individuals or groups include linking the outermost sightings (to produce an "outer convex polygon"), then defining core ranges and range utilisation in terms of the distance and frequency of sightings from the centre of the range. More complex models involve describing contours which reflect the frequency of sightings (or frequency of radio "fixes" in studies using radio telemetry). Bell (1990) used an incremental clustering technique, using a nearest-neighbour criterion to group sightings/fixes which allows the identification of more than one range nucleus. The same technique was used in the present study since it seemed appropriate for animals such as the Greenland White-fronted Geese which may feed in several different fields but rarely or never use the areas in between. The 80% range area was also to define the core area used by the birds, since Bell (1990) considered that this represented the maximum amount of information on the sites regularly used by the birds whilst excluding most or all "excursive movement" away from the main home range. The range analyses used were on the RANGES IV software package (Kenward 1990). Birds with at least 20 resightings were included in the analyses, although Kenward (1990) indicates that 30 is the minimum number required to establish a home range, in order to improve the sample size.

Results

The numbers of sightings of each bird, and the number of fields in which each bird was sighted, are listed in Tables 3.1.4.1a,b,c (for the 1991-92 and 1992-93 winters, and for the two seasons combined). Some 26 birds were included in the 1991-92 analyses, although due to the tendency for certain individuals to associate with each other, and thus to use the same fields at the same time (see below), these birds could be grouped into just 8 units. Similarly 27 individuals and 13 units were considered in the 1992-93 analyses. Six of the units seen in 1991-92 were also seen in 1992-93. The s^2/mean ratios are an index of dispersion, where values >1 indicate that the sightings are aggregated or clustered, a value of 1 indicates random dispersal according to Poisson probabilities, and values <1 indicate regular or uniform dispersal (Southwood 1966). Uniformity is hard to interpret in practical terms, since the biological reason for a perfectly regular distribution is unclear, but may perhaps be due to an insufficiency of data. The chi-squared statistics in Tables 3.1.4.1a,b,c test the significance of departure from randomness, where $X^2 = s^2(N-1)/mean$ (and s^2 is the variance, Southwood 1966). Some 17 birds (5 units) in 1991-92 and 14 birds (8 units) in 1992-93 showed aggregated dispersion. In other words, out of all the fields that they visited, they were significantly more likely to be seen in some fields than in others. The resightings of four birds (members of social unit 7HC-4) were uniformly distributed across the fields used by these birds (ie further apart than would be expected at random; X^2 outside the 0.95 probability level) in both 1991-92 and 1992-93, and the reason for the regularity of their distribution is unclear. The distribution of the 7HC-4 group appeared to be random, however, when data from the two winters were combined (Table 3.1.4.1c). Several birds showed apparently random dispersal (as indicated by non-significant chi-squared values) within their home range when the two winters were considered separately. Only the 7HC-4 group gave non-significant results when data from the two seasons were combined, however; resightings of the 15 other birds (6 units) indicated clustered distributions at less than 1% probability levels (Table 3.1.4.1c). It seems, therefore, that the birds concentrate on a small number of favoured fields both within and between winters (the raw data for social groups seen in both winters is presented in Table 3.1.4.2). The question of why geese select some fields in preference to others is addressed in Section 3.1.5.

Twenty-nine birds seen in 1991-92 and 31 birds seen in 1992-93 were selected for further analysis of the distribution of individuals within their home ranges. Movements between fields were recorded by incorporating the co-ordinates of the central point of the field in which a bird was re-sighted (in units of 100m) into the analyses. The resolution (or precision) with which each sighting was recorded was set at 50m, so that the area in which the bird might occur for each sighting was 0.786 ha (ie $22/7(50)^2=0.786$ for a radius of 50m). The maximum range area used by each bird therefore corresponds with the outer convex polygon plus a 50m wide strip around the outside (to allow for the resolution factor), as illustrated by the home ranges for birds 2HA, 5CA and 9CC in the 1991-92 and 1992-93 winters (Figures 3.1.4.1a,b).

The maximum home range used by an individual bird was 982.5 ha in the 1991-92 winter (goose 5CP), and 1444.0 ha (goose 4HH) in 1992-93 (as indicated by the "outer core" values in Table 3.1.4.3a,b). Many of the fields within these areas were rarely or never used by the individual birds, however, although they may have flown over them when moving between feeding and/or roosting areas. The extent to which the geese used areas within their home ranges was determined by multinuclear cluster analysis (Kenward 1990), and the results are illustrated in Table 3.1.4.3a,b. Range areas are given in hectares. The number of nuclei (given in brackets) recorded for the distribution indicate whether the birds are concentrating in two or more parts of their home range. Thus the outer core values gives the total range of the bird (as represented by the outer convex polygon), whereas the 100% multinuclear values for birds with more than one nucleus identified in its distribution gives the sum of the areas used around each nucleus, but excludes the areas in between. The distribution recorded for six of the 29 birds seen in 1991-92, and 16 of the 31 birds seen in 1992-93 was centred around a single nucleus. The outer core values therefore were the same as the 100% multinuclear values for these individuals. Up to six nuclei per bird were recorded in 1991-92 and 4 nuclei per bird in 1992-93, when all sightings per bird were included in the analyses, and in most cases the nuclei persisted even at the 40% level, indicting that there is a genuinely patchy use of the range.

Further consideration of the percentage utilisation of sections of the home range recorded for the 29 birds in 1991-92 and 31 birds in 1992-93 (Figures 3.1.4.2a,b) found a steep drop in the range area at the higher (80% to 100%) levels. The number of hectares covered at different levels of utilisation fell from mean values of 195.7 ha and 488.3 ha at the 100% level (ie when all sightings were included) in 1991-92 and 1992-93 respectively, to 65.8 ha and 152.9 ha at the 95% level, and to 13.3 ha and 20.1 ha at the 80% level (Fig. 3.1.4.2a,b). This indicates that some limited excursive activity takes place but that the large majority of sightings of an individual occur within a comparatively small area; almost any level of utilisation below 90% could be taken as the "core" section of the home range. Kenward (1990) suggests that core areas could also be identified, "if all the animals are behaving similarly", by the variance in range size which "tends to be a minimum at the percentage of fixes which excludes most of the excursive activity". Plots of standard error estimated as a percentage of the mean range area indicated that variation in the ranges obtained for individual birds was minimal at the 80% and 85% levels in both winters, and at the 65% level in 1991-92 but not in 1992-93. The 80% utilisation level is therefore thought to represent the core section of the home range, which agrees with the results obtained by Bell (1990) in his analysis of resightings of Greenland White-fronted Geese wintering on the Wexford Slobs. The average size for this core area was 13.3 ha (+/-2.6 ha) in 1991-92 and 20.1 ha (+/- 4.8 ha) in 1992-93, which was less than 10% of the of the total (100%) range.

Associations between individual birds were determined by analysing the 80% core range and determining the extent to which the birds' distribution overlapped. A triangular similarity matrix was constructed by averaging symmetrical terms in the overlap matrix, for instance the similarity between D7C and D1C was the average of the percentage overlap of D7C's range on D1C and that of D1C's range on D7C (as described by Bell 1990). Thus the similarity of birds with identical ranges would be 100%. Average link cluster analysis was used to define groupings between the birds, and the results are illustrated as a dendrogram, showing the level of similarity/overlap of the home ranges of individual birds, for each of the two winters (Figs. 5.1.5.3a,b). The results confirmed associations between the birds noted during the fieldwork, when certain individuals were generally found to be in close proximity to each other within the wintering flock. Six main groupings were recorded during fieldwork in 1991-92 (6HA with 4HC; 2HA+4HA+5HA+8HA; 0HA+1HA+7HA+9HA+0HC+1HC+2HC+5HC; 5CA+6CA; 8CF+7CJ+5CP; 2HH+3HH; and 0HH+6HC+7HC+8HC) with the remaining geese (3HA, 8CC, 0CC/49D and 9CC) not recorded with other ringed birds. Eight main groups were recorded during 1992-93 (D7C+D1C+0CC/C9D; 8HC+7HC+6HC+0HH; 3HH+2HH; 5HC+0HC+0HA; 5CA+6CA; C7D+C9L+D3C+8CC+C4D; 8HA+5HA+4HA+2HA; and 6HA+4HC) with the remaining geese (9CC, 1HA, 3HA, A2Z, 3XX, 4HH and A4Y) not recorded with other ringed birds. In most cases (at least for the birds ringed on Islay where family histories are known), groups of three or more adults seen together are due to the continued association of parent birds and their offspring, or of siblings with each other, even when the offspring are in their second or their third winters (Table 3.1.4.4). The dendrograms (Figs. 5.1.5.3a,b) indicate that, whilst these associations are reflected in the overlap of the core ranges recorded for group members, other individuals may also have similar distributions without being recorded as forming part of a social unit in the field. Goose 3HA, for instance, was often recorded in the same fields as the 2HA-4 unit during the 1991-92 winter, but did not associate closely with these birds within the flock. Their distribution was less similar in 1992-93, however. Conversely, members of a social unit may occasionally be sighted away from other members of a group. The similarity levels recorded for group members exceeded 75% in 1991-92, however, and 60% in 1992-93. Groupings of birds other than those from known social units probably represent separation at a sub-population level, although detailed monitoring of ringed individuals wintering in different parts of Islay (rather than a single study area) would be necessary to confirm this point.

Conclusions

(1) The maximum home ranges recorded for individual birds ranged from 42.0 - 982.5 ha in 1991-92 and from 205.5 - 1444.0 ha in 1992-93, but many of the fields within the home range were seldom or never used by the geese. When fields in which the birds were not sighted were excluded by cluster analysis, the average home range was found to be 195.7 ha in 1991-92 and 488.3 ha in 1992-93.

(2) Further analysis of the frequency with which birds were re-sighted in different parts of their home ranges found a steep drop in the range areas at the higher levels of utilisation. Whereas 100% of sightings were recorded in areas of 195.7 ha and 488.3 ha (mean values) in 1991-92 and 1992-93 respectively, some 80% of resightings were made in areas of only 13.3 ha and 20.1 ha in the two winters. The 80% utilisation level was thought to represent the core section of the home range, and occasional sightings elsewhere to represent some limited excursive activity.

(3) Up to six "nuclei" or groupings of sightings were recorded within the home range, even when excursive movements were excluded by considering only the core section of the home range. A separate analysis similarly showed that the geese have an aggregated or clustered distribution and that they tend to use a small number of favoured fields both within and between winters.

(4) These results confirmed (i) that individual birds have a limited distribution, utilising only a very small area in winter (ii) that they make only patchy use of their home range, thus proving highly selective in their choice of sites on a field-by-field basis and (iii) that they show an exceptionally high level of winter site fidelity.

(5) Analysis of the extent to which core ranges of individuals overlapped confirmed associations between individuals noted during fieldwork, the associations being mainly between parents and their offspring and/or between siblings. Long-term associations between family members was implicated; only one bird ringed as a gosling in 1990-91, and known to be still alive in 1992-93 (1HA), was definitely NOT associating with its parents or siblings during its third winter on Islay (Table 3.1.4.4).

Table 3.1.4.1:

Field use and its dispersion in frequently observed individually-marked Greenland White-fronted Geese (Index of Dispersion = s^2/mean where s^2 is the variance and mean is the mean number of sightings per field, following Southwood, 1966).

(a) 1991-92 winter

Ring No.	No. of Fields	No. of Sightings	Mean per Field	s^2	s^2/mean	X^2	p.	Group
2HA	11	36	3.273	2.418	0.739	7.390	0.68	2HA-4
4HA	11	36	3.273	2.418	0.739	7.390	0.68	2HA-4
5HA	11	36	3.273	2.418	0.739	7.390	0.68	2HA-4
8HA	12	37	3.083	2.629	0.853	9.378	0.59	2HA-4
4HC	16	76	4.750	18.467	3.888	58.316	<0.001	4HC-2
6HA	16	73	4.563	19.863	4.353	65.301	<0.001	4HC-2
0HH	13	23	1.769	0.692	0.391	4.696	0.97	7HC-4
6HC	13	23	1.769	0.692	0.391	4.696	0.97	7HC-4
7HC	13	23	1.769	0.692	0.391	4.696	0.97	7HC-4
8HC	13	23	1.769	0.692	0.391	4.696	0.97	7HC-4
3HA	12	35	2.917	2.811	0.964	10.600	0.47	
5CA	17	40	2.353	4.118	1.750	28.000	0.03	5CA-2
6CA	17	40	2.353	4.993	2.122	33.950	<0.01	5CA-2
2HH	7	32	4.571	14.286	3.125	18.750	<0.01	2HH-2
3HH	7	32	4.571	19.619	4.292	25.750	<0.001	2HH-2
5CP	15	39	2.600	20.971	8.066	112.923	<0.001	5CP-3
7CJ	14	39	2.786	22.643	8.128	105.667	<0.001	5CP-3
8CF	14	37	2.643	19.940	7.545	98.081	<0.001	5CP-3
0HA	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
1HA	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
7HA	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
9HA	21	65	3.095	10.290	3.325	66.492	<0.001	2HC-8
0HC	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
1HC	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
2HC	21	66	3.143	10.329	3.286	65.727	<0.001	2HC-8
5HC	21	65	3.095	10.490	3.389	67.785	<0.001	2HC-8

Table 3.1.4.1 (cont.):

(b) 1992-93 winter.

Ring No.	No. of Fields	No. of Sightings	Mean per Field	s^2	s^2/mean	X^2	p.	Group
2HA	14	38	2.714	7.912	2.915	37.895	<0.001	2HA-4
4HA	11	33	3.000	9.880	3.267	32.667	<0.001	2HA-4
5HA	11	33	3.000	8.200	2.733	27.333	<0.01	2HA-4
8HA	11	34	3.091	9.491	3.071	30.706	<0.001	2HA-4
4HC	14	78	5.571	32.264	5.791	75.282	<0.001	4HC-2
6HA	17	74	4.353	27.743	6.373	101.973	<0.001	4HC-2
0HH	17	23	1.353	0.368	0.272	4.348	0.99	7HC-4
6HC	16	22	1.375	0.383	0.279	4.182	0.99	7HC-4
7HC	16	21	1.313	0.363	0.276	4.143	0.99	7HC-4
8HC	17	22	1.294	0.346	0.267	4.273	0.99	7HC-4
3HA	9	22	2.444	3.028	1.239	9.910	0.28	
5CA	13	43	3.308	9.564	2.891	34.698	<0.001	5CA-2
6CA	12	42	3.500	9.910	2.831	31.143	<0.001	6CA-2
A4Y	13	55	4.231	13.129	3.118	37.418	<0.001	
A2Y	15	104	6.933	88.067	12.702	177.827	<0.001	
3XX	14	80	5.714	46.527	8.142	105.850	<0.001	
2HH	11	24	2.182	3.163	1.450	14.500	0.15	2HH-2
3HH	11	24	2.182	2.564	1.175	11.750	0.30	2HH-2
8CC	19	40	2.105	3.099	1.472	26.500	0.08	8CC-5
C4D	18	39	2.167	3.206	1.480	25.154	0.09	8CC-5
C7D	20	41	2.050	2.997	1.462	27.780	0.09	8CC-5
C9L	19	37	1.947	2.830	1.453	26.162	0.09	8CC-5
D3C	19	40	2.105	3.099	1.472	26.500	0.08	8CC-5
0HC	17	54	3.176	19.654	6.188	99.000	<0.001	9HA-3
5HC	17	54	3.176	19.654	6.188	99.000	<0.001	9HA-3
9HA	17	55	3.235	21.191	6.550	104.000	<0.001	9HA-3
1HA	12	35	2.917	4.629	1.587	17.457	0.10	

Table 3.1.4.1 (cont.):

(c) 1991-92 and 1992-93 winters combined.

Ring No.	No. of Fields	No. of Sightings	Mean per Field	s^2	s^2/mean	X^2	p.	Group
2HA	16	74	4.625	16.117	3.485	52.270	<0.001	2HA-4
4HA	15	69	4.600	16.829	3.658	51.217	<0.001	2HA-4
5HA	15	69	4.600	14.971	3.255	45.565	<0.001	2HA-4
8HA	16	71	4.438	16.129	3.635	54.521	<0.001	2HA-4
4HC	20	154	7.700	64.221	8.340	158.468	<0.001	4HC-2
6HA	23	147	6.391	59.067	9.242	203.320	<0.001	4HC-2
0HH	21	46	2.190	2.262	1.033	20.652	0.40	7HC-4
6HC	20	45	2.250	2.303	1.023	19.444	0.41	7HC-4
7HC	20	44	2.200	2.168	0.986	18.727	0.47	7HC-4
8HC	21	45	2.143	2.129	0.993	19.867	0.46	7HC-4
3HA	15	57	3.800	8.886	2.338	32.737	<0.01	
5CA	22	83	3.773	15.994	4.239	89.024	<0.001	5CA-2
6CA	21	82	3.905	17.290	4.428	88.561	<0.001	5CA-2
2HH	15	56	3.733	21.638	5.796	81.143	<0.001	2HH-2
3HH	14	56	4.000	23.692	5.923	77.000	<0.001	2HH-2
1HA	26	101	3.885	11.946	3.075	76.881	<0.001	2HC-8 / -
9HA	28	120	4.286	26.138	6.099	164.667	<0.001	2HC-8 / 9HA-3
0HC	28	120	4.286	24.878	5.805	156.733	<0.001	2HC-8 / 9HA-3
5HC	28	119	4.250	25.083	5.902	159.353	<0.001	2HC-8 / 9HA-3

Table 3.1.4.2. Number of occasions on which marked individuals or social units were seen in particular fields during the 1991-92 and 1992-93 winters; for units where the same birds were present in the group in both years.

2HA-4 1991-92:

Bird	SU22	AO51	AO39	SU18	SU19	AO34	AO50	SU06	SU10	SU11	SU25	SU13
2HA	6	5	4	4	4	3	3	3	2	1	1	0
4HA	6	5	4	4	4	3	3	3	2	1	1	0
5HA	6	5	4	4	4	3	3	3	2	1	1	0
8HA	6	5	4	4	4	3	3	3	2	1	1	1

2HA-4 1992-93:

Bird	AO51	AO50	SU05	AO22	AO39	SU18	SU19	SU22	AO15	AO28	AO34	SU06	SU10	SU17
2HA	10	8	4	2	2	2	2	2	1	1	1	1	1	1
4HA	10	8	4	1	0	2	2	2	1	0	0	1	1	1
5HA	9	8	4	2	0	2	2	2	1	0	0	1	1	1
8HA	10	8	4	2	0	2	2	2	1	0	0	1	1	1

7HC-4 1991-91:

Bird	CS01	KW10	KW15	BH01	BH02	BH07	BH09	BH03	BH06	BH41	CS27	KW14	KW17
0HH	3	3	3	2	2	2	2	1	1	1	1	1	1
6HC	3	3	3	2	2	2	2	1	1	1	1	1	1
7HC	3	3	3	2	2	2	2	1	1	1	1	1	1
8HC	3	3	3	2	2	2	2	1	1	1	1	1	1

7HC-4 1992-93:

Bird	KW10	BH06	BH09	BH11	CS01	BH02	BH07	BH21	CS05	CS06	KW14	KW15	KW16	KW17	KW18	KW24	SU35
0HH	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
6HC	3	2	2	2	2	1	1	1	1	1	1	1	1	1	0	1	1
7HC	3	2	1	2	2	1	1	1	1	1	1	1	1	1	0	1	1
8HC	3	2	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1

4HC-2 1991-92:

Bird	SU18	SU19	SU10	SU22	SU07	SU09	SU17	SU27	SU05	SU03	SU16	SU25	AO34	AO39	AO52	SU06
4HC	14	13	11	6	5	5	5	4	3	2	2	2	1	1	1	1
6HA	14	13	12	6	5	4	4	2	3	2	2	2	1	1	1	1

4HC-2 1992-93:

Bird	SU05	SU18	SU06	SU19	SU22	AO18	AO39	AO28	SU07	SU11	SU16	SU17	SU03	SU08	AO15	AO22	SU26
4HC	17	17	12	7	6	4	3	2	2	2	2	2	1	1	0	0	0
6HA	14	16	14	7	6	4	1	2	1	2	1	1	1	1	1	1	1

5CA-2 1991-92:

Bird	RK09	RK10	RK02	RK08	RK11	SU06	RK04	SU10	CO04	CO07	RK06	RK13	RK14	RK18	RK32	SU03	SU05
5CA	8	6	4	3	3	3	2	2	1	1	1	1	1	1	1	1	1
6CA	9	6	4	3	3	3	2	1	1	1	1	1	1	1	1	1	1

5CA-2 1992-93:

Bird	RK11	RK04	SU05	RK02	RK08	RK10	RK09	CO06	CP04	RK32	RK33	SU01	SU02
5CA	10	9	5	4	4	3	2	1	1	1	1	1	1
6CA	10	9	5	4	4	3	2	1	1	1	0	1	1

2HH-2 1991-92:

Bird	RK02	CO04	RK04	CO03	CO05	RK06	RK31	RK32
2HH	12	6	6	2	2	2	2	0
3HH	12	8	7	1	1	2	0	1

2HH-2 1992-93:

Bird	RK04	RK02	CO06	CO11	CO13	CO13	CO07	CO25	CO40	RK03	RK06	RK32	CO19
2HH	6	5	2	2	2	1	1	1	1	1	1	1	0
3HH	6	4	2	3	2	0	0	1	1	1	2	1	1

3HA 1991-92:

Bird	AO51	SU06	SU18	SU19	SU22	AO39	SU11	SU10	AO52	SU05	SU09	SU25
3HA	5	5	5	4	4	3	3	2	1	1	1	1

3HA 1992-93:

Bird	SU05	SU18	AO51	AO39	AO50	AO44	SU06	SU17	SU19
3HA	5	5	4	2	2	1	1	1	1

Table 3.1.4.3: Range Areas identified by multinuclear clustering and the equivalent Outer Core range which includes all sightings. Range areas are in hectares and the number of nuclei are in brackets.

(a) 1991/92 winter:

Ring No.	Outer Core	100% MNuc	95% MNuc	80% MNuc	65% MNuc	40% MNuc	Group
5CA	360.5	160.5 (2)	113.0 (2)	18.5 (5)	6.0 (6)	4.0 (4)	5CA-2
6CA	360.5	160.5 (2)	113.0 (2)	14.0 (5)	6.0 (6)	3.0 (3)	6CA-2
8CC	292.0	292.0 (1)	47.0 (1)	6.0 (4)	3.0 (3)	2.0 (2)	8CC-5
9CC	134.5	49.5 (2)	38.5 (2)	29.5 (2)	8.0 (3)	3.0 (2)	
C9D(0CC)	414.5	414.0 (1)	194.0 (1)	33.0 (2)	13.5 (2)	7.0 (1)	C9D-3
8CF	975.5	975.5 (1)	39.5 (4)	12.0 (4)	5.0 (3)	1.0 (1)	5CP-3
7CJ	975.5	975.5 (1)	105.0 (1)	12.0 (4)	3.0 (3)	1.0 (1)	5CP-3
5CP	982.5	982.5 (1)	43.5 (4)	12.0 (4)	5.0 (3)	1.0 (1)	5CP-3
1HA	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
0HA	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
2HA	293.5	39.0 (6)	20.0 (6)	7.0 (7)	6.0 (6)	4.0 (4)	2HA-4
3HA	316.0	52.5 (4)	32.5 (5)	7.0 (7)	6.0 (6)	4.0 (4)	
4HA	293.5	39.0 (6)	20.0 (6)	7.0 (7)	6.0 (6)	4.0 (4)	2HA-4
5HA	293.5	39.0 (6)	20.0 (6)	7.0 (7)	6.0 (6)	4.0 (4)	2HA-4
6HA	299.0	101.5 (3)	50.0 (4)	8.0 (8)	7.0 (7)	6.0 (6)	4HC-2
7HA	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
8HA	307.0	51.0 (4)	30.5 (6)	8.0 (8)	6.0 (6)	4.0 (4)	2HA-4
9HA	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
0HC	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
1HC	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
2HC	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
4HC	101.5	101.5 (3)	43.0 (5)	9.0 (9)	8.0 (8)	6.0 (6)	4HC-2
5HC	538.5	123.0 (3)	107.0 (3)	14.0 (8)	7.0 (7)	4.0 (4)	2HC-8
6HC	142.5	44.0 (2)	32.0 (2)	19.0 (3)	7.0 (4)	3.0 (3)	7HC-4
7HC	142.5	44.0 (2)	32.0 (2)	19.0 (3)	7.0 (4)	3.0 (3)	7HC-4
8HC	142.5	44.0 (2)	32.0 (2)	19.0 (3)	7.0 (4)	3.0 (3)	7HC-4
0HH	142.5	44.0 (2)	32.0 (2)	19.0 (3)	7.0 (4)	3.0 (3)	7HC-4
2HH	66.0	66.0 (1)	8.0 (4)	5.0 (3)	3.0 (3)	2.0 (2)	2HH-2
3HH	42.0	16.5 (3)	8.0 (3)	3.0 (3)	3.0 (3)	2.0 (2)	2HH-2

(b) 1992/93 winter

Ring No.	Outer Core	100% MNuc	95% MNuc	80% MNuc	65% MNuc	40% MNuc	Group
5CA	630.0	630.0 (1)	56.0 (3)	6.0 (6)	5.0 (5)	3.0 (3)	5CA-2
6CA	630.0	630.0 (1)	48.0 (3)	6.0 (6)	4.0 (4)	3.0 (3)	6CA-2
8CC	1381.5	799.5 (2)	130.5 (4)	18.0 (5)	6.0 (6)	5.0 (5)	8CC-5
9CC	597.5	597.5 (1)	72.5 (2)	39.5 (2)	39.5 (2)	12.5 (1)	
C9D(0CC)	1058.0	1058.0 (1)	826.5 (1)	25.5 (3)	21.5 (2)	5.0 (2)	C9D-3
1HA	1092.0	175.0 (3)	107.5 (3)	6.0 (6)	5.0 (5)	3.0 (3)	
2HA	1092.0	106.5 (3)	39.0 (4)	19.0 (4)	7.0 (4)	3.0 (3)	2HA-4
3HA	328.5	27.5 (4)	27.5 (4)	13.0 (3)	3.0 (3)	2.0 (2)	
4HA	339.0	86.5 (2)	25.0 (4)	11.5 (4)	3.0 (3)	2.0 (2)	2HA-4
5HA	339.0	33.0 (4)	33.0 (4)	11.5 (4)	3.0 (3)	2.0 (2)	2HA-4
6HA	430.5	161.5 (2)	88.5 (3)	6.0 (6)	4.0 (4)	3.0 (3)	4HC-2
8HA	339.0	33.0 (4)	33.0 (4)	11.5 (4)	3.0 (3)	2.0 (2)	2HA-4
9HA	327.5	113.0 (4)	101.5 (3)	11.0 (5)	5.0 (5)	4.0 (4)	9HA-3
0HC	327.5	113.0 (4)	101.5 (3)	11.0 (5)	5.0 (5)	4.0 (4)	9HA-3
4HC	317.0	88.5 (3)	70.5 (3)	7.0 (7)	4.0 (4)	3.0 (3)	4HC-2
5HC	327.5	113.0 (4)	101.5 (3)	11.0 (5)	5.0 (5)	4.0 (4)	9HA-3
6HC	581.5	581.5 (1)	76.5 (2)	29.0 (4)	20.5 (3)	7.0 (3)	7HC-4
7HC	581.5	581.5 (1)	76.5 (2)	24.5 (4)	20.5 (3)	7.0 (3)	7HC-4
8HC	581.5	581.5 (1)	81.5 (2)	29.5 (4)	25.5 (3)	7.0 (3)	7HC-4
0HH	581.5	581.5 (1)	81.5 (2)	29.5 (4)	25.5 (3)	7.0 (3)	7HC-4
2HH	205.5	205.5 (1)	131.0 (1)	18.0 (3)	8.0 (3)	2.0 (2)	2HH-2
3HH	238.5	238.5 (1)	182.5 (1)	20.0 (3)	9.0 (3)	3.0 (3)	2HH-2
3XX	270.5	270.5 (1)	14.0 (7)	7.0 (7)	6.0 (6)	2.0 (2)	
A2Y	442.5	163.5 (2)	69.5 (2)	9.0 (9)	6.0 (6)	2.0 (2)	
A4Y	400.0	130.5 (2)	37.5 (5)	7.0 (7)	6.0 (6)	3.0 (3)	
C9L	1340.5	1340.5 (1)	133.5 (4)	52.0 (4)	10.0 (5)	4.0 (4)	8CC-5
C4D	1337.5	1337.5 (1)	130.5 (4)	23.0 (5)	6.0 (6)	4.0 (4)	8CC-5
C7D	1443.5	1443.5 (1)	80.0 (6)	52.0 (4)	6.0 (6)	5.0 (5)	8CC-5
D1C	1058.0	1058.0 (1)	826.5 (1)	32.5 (2)	11.0 (3)	3.0 (2)	C9D-3
D3C	1381.5	799.5 (2)	130.5 (4)	30.5 (5)	6.0 (6)	5.0 (5)	8CC-5
D7C	1058.0	1058.0 (1)	826.5 (1)	32.5 (2)	11.0 (3)	3.0 (2)	C9D-3
4HH	1444.0	543.5 (4)	153.5 (8)	13.0 (13)	11.0 (11)	4.0 (4)	

Table 3.1.4.4. Relationships (noted upon ringing) and subsequent associations for Greenland White-fronted Geese ringed on Islay. Y=Yes (ie consorting with family members). n/s = not seen in the winter. A - indicates no information, since birds not ringed (so identity uncertain).

Family party (1990-91)

ID	Age	Sex	In same group 91/92	In same group 92/93
1HC	Ad	M	Y	n/s
2HC	Ad	F	Y	n/s
0HA	Juv	M	Y	Y
1HA	Juv	F	Y	*
7HA	Juv	M	Y	n/s
9HA	Juv	M	Y	n/s
0HC	Juv	F	Y	Y
5HC	Juv	F	Y	Y
Unr	Juv	-	-	-

* 1HA on Islay but not with her siblings.

Family party (1990-91)

ID	Age	Sex	In same group 91/92	In same group 92/93
Unr	Ad	M	-	-
Unr	Ad	F	-	-
2HA	Juv	F	Y	Y
4HA	Juv	F	Y	Y
5HA	Juv	F	Y	Y
8HA	Juv	F	Y	Y
Unr	Juv	-	-	-

Family party (1990-91)

ID	Age	Sex	In same group 91/92	In same group 92/93
Unr	Ad	M	-	-
6HA	Ad	F	Y	Y
4HC	Juv	F	Y	Y
Unr	Juv	-	-	-
Unr	Juv	-	-	-
Unr	Juv	-	-	-

Family party (1990-91)

ID	Age	Sex	In same group 91/92	In same group 92/93
Unr	Ad	M	-	-
Unr	Ad	F	-	-
3HA	Juv	M	*	*
Unr	Juv	-	-	-
Unr	Juv	-	-	-
Unr	Juv	-	-	-
Unr	Juv	-	-	-
3HC (hanger on)	Juv	M	n/s	n/s

* 3HA returned in both years, but rest of family not ringed.

Table 3.1.4.4 (cont.)

Family party
(Ringed 1990-91)

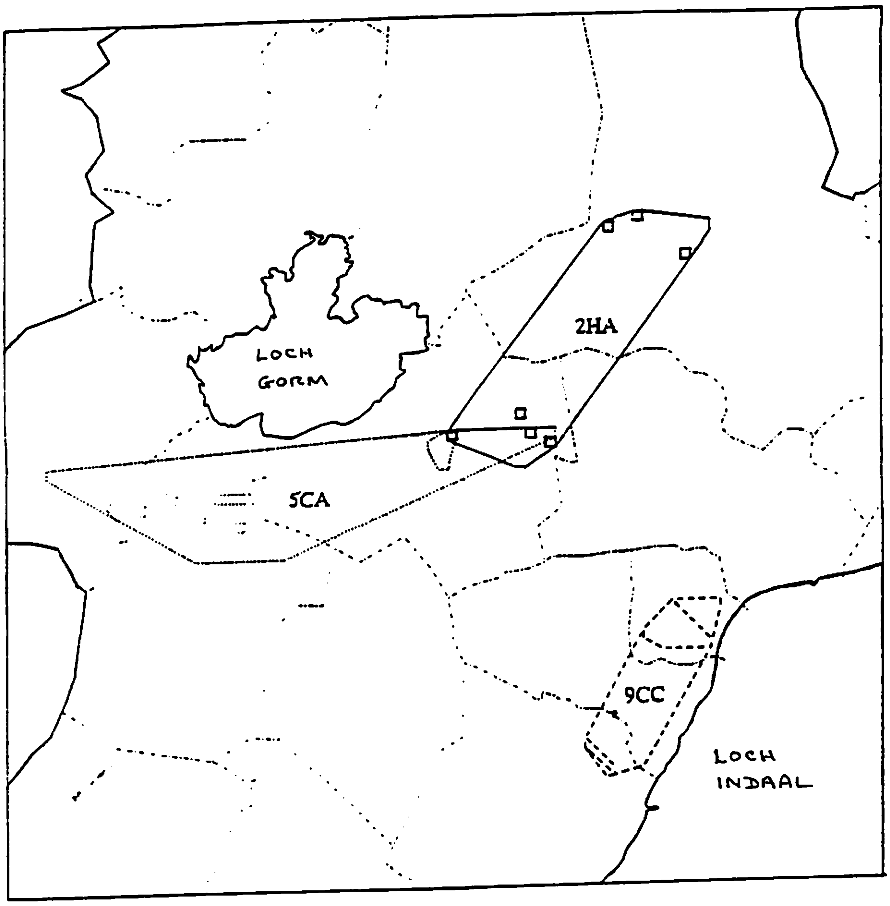
ID	Age	Sex	In same group 91/92	In same group 92/93
7HC	Ad	M	Y	Y
6HC	Ad	F	Y	Y
8HC	Juv	F	Y	Y
9HC	Juv	F	n/s	n/s
0HH	Juv	M	Y	Y
1HH	Juv	M	n/s	n/s
Unr	Juv	-	-	-

Paired birds
(Ringed 1991-92)

ID	Age	Sex	In same group 92/93
2HH	Ad	?	Y
3HH	Ad	?	Y

Figure 3.1.4.1. Examples of outer core and 80% multinuclear clustering for three marked birds (2HA, 5CA and 9CC) in (a) the 1991-92 winter and (b) the 1992-93 winter.

(a) 1991 - 92



(b) 1992 - 93

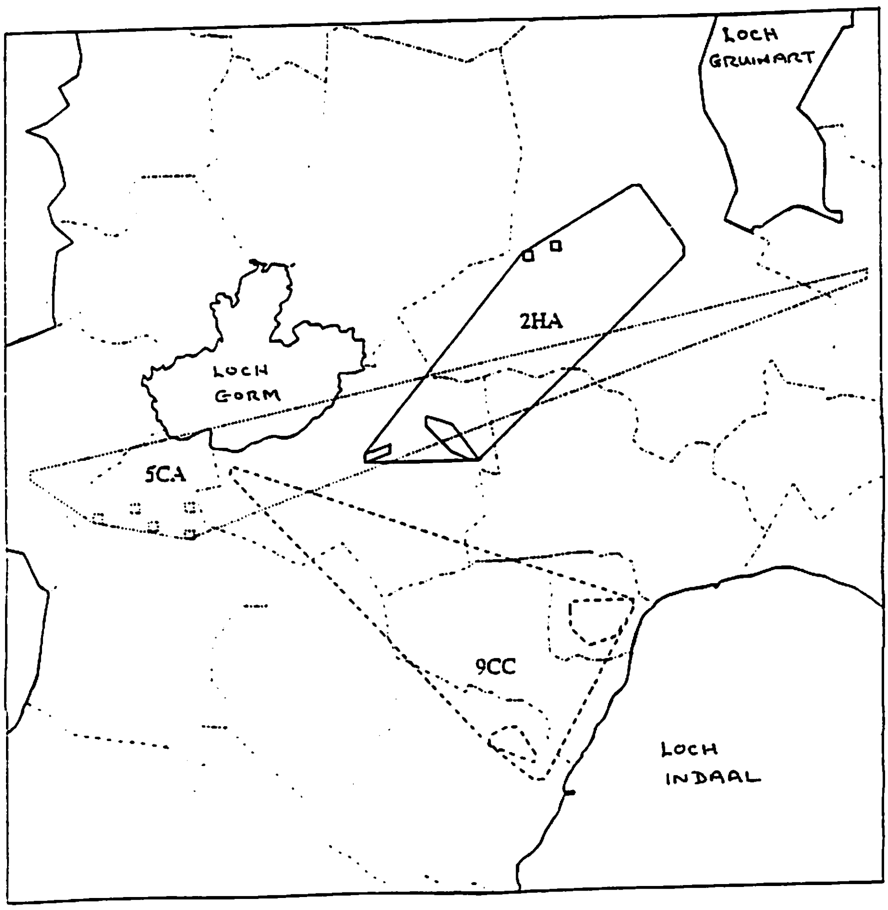
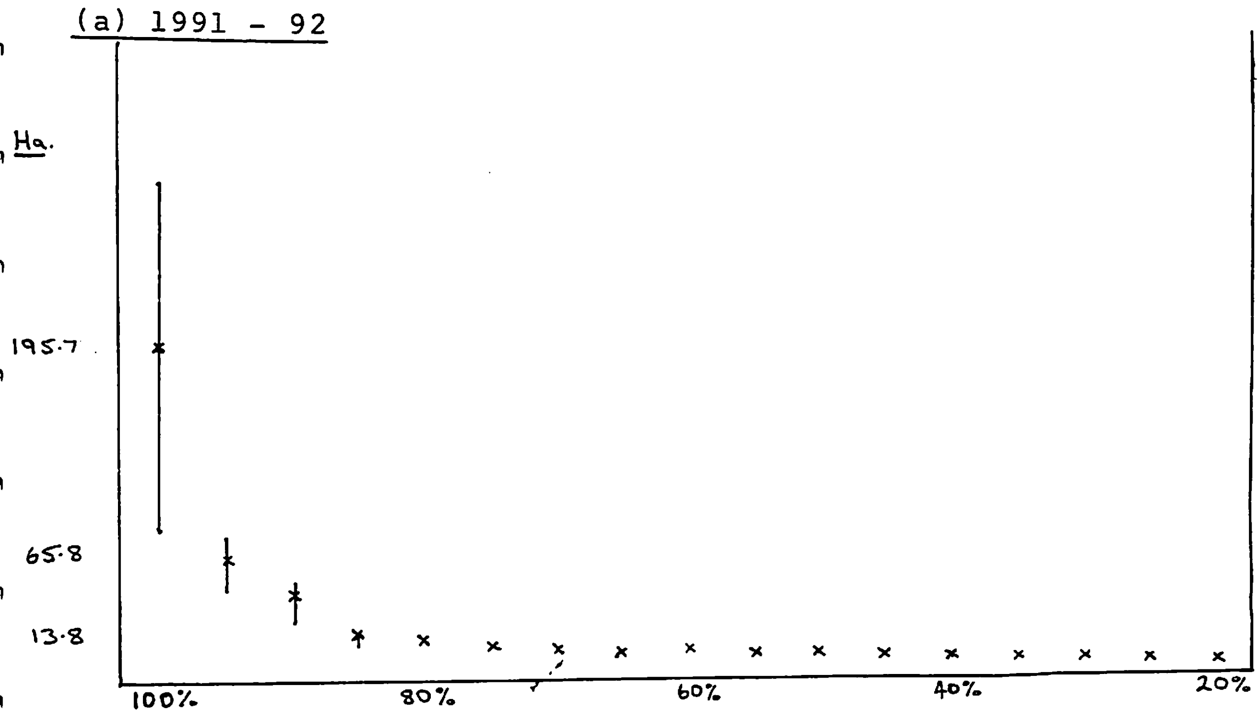


Figure 3.1.4.2. Percentage utilisation of areas within their home ranges for (a) 29 marked birds monitored in the 1991-92 winter and (b) 31 marked birds monitored in the 1992-93 winter.



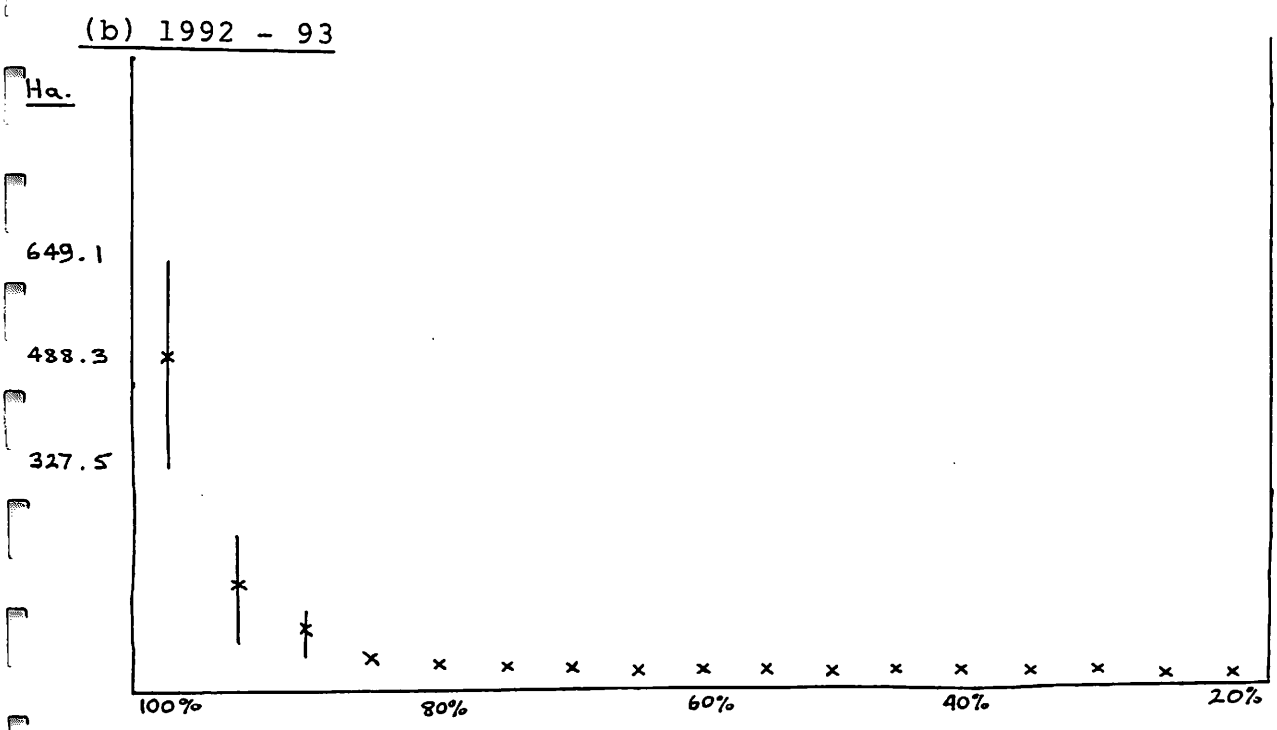


Figure 3.1.4.3a. Dendrogram illustrating the extent to which the core ranges of individual birds overlap during the 1991-92 winter; birds with similar distributions generally occurring in the same fields.

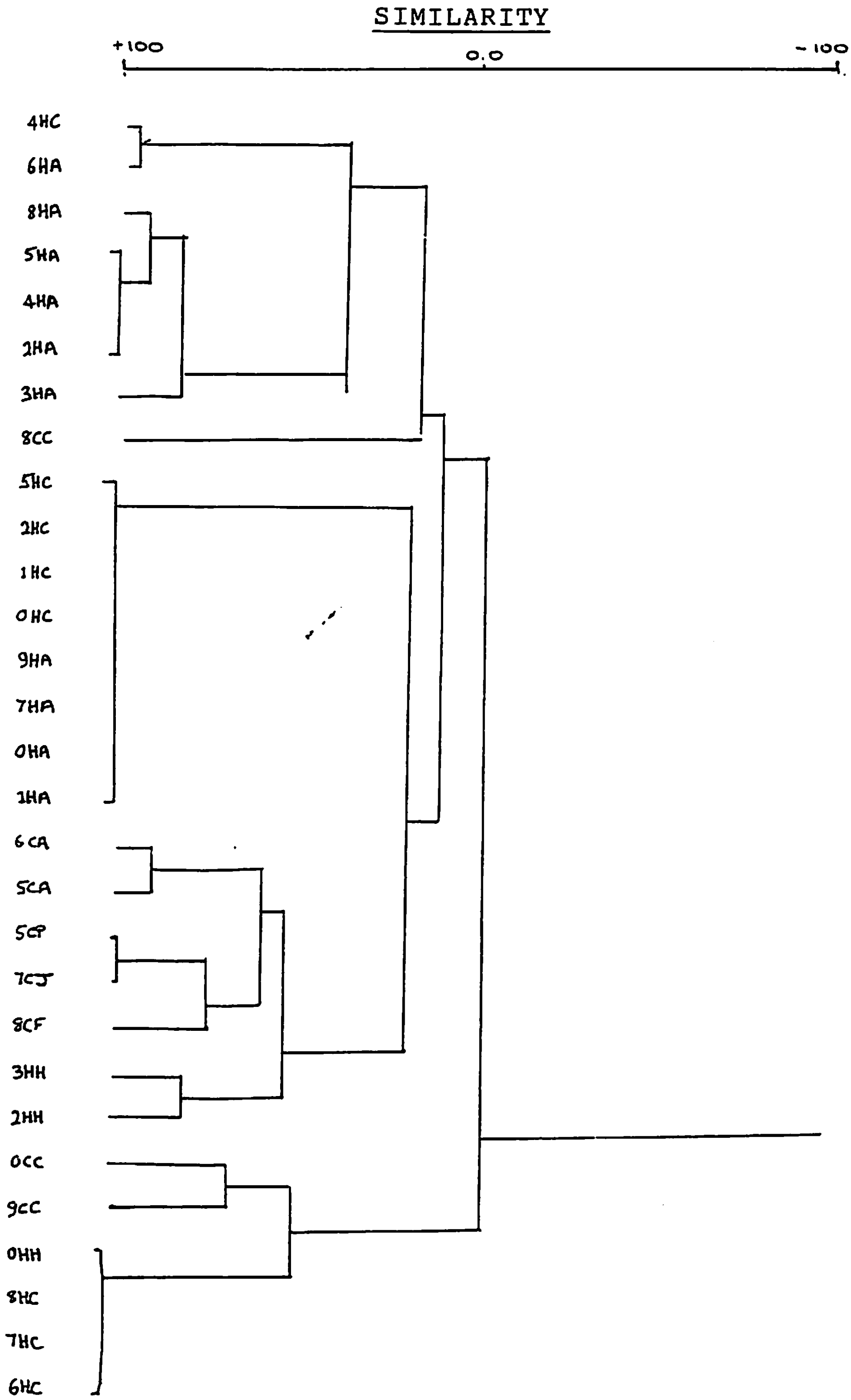
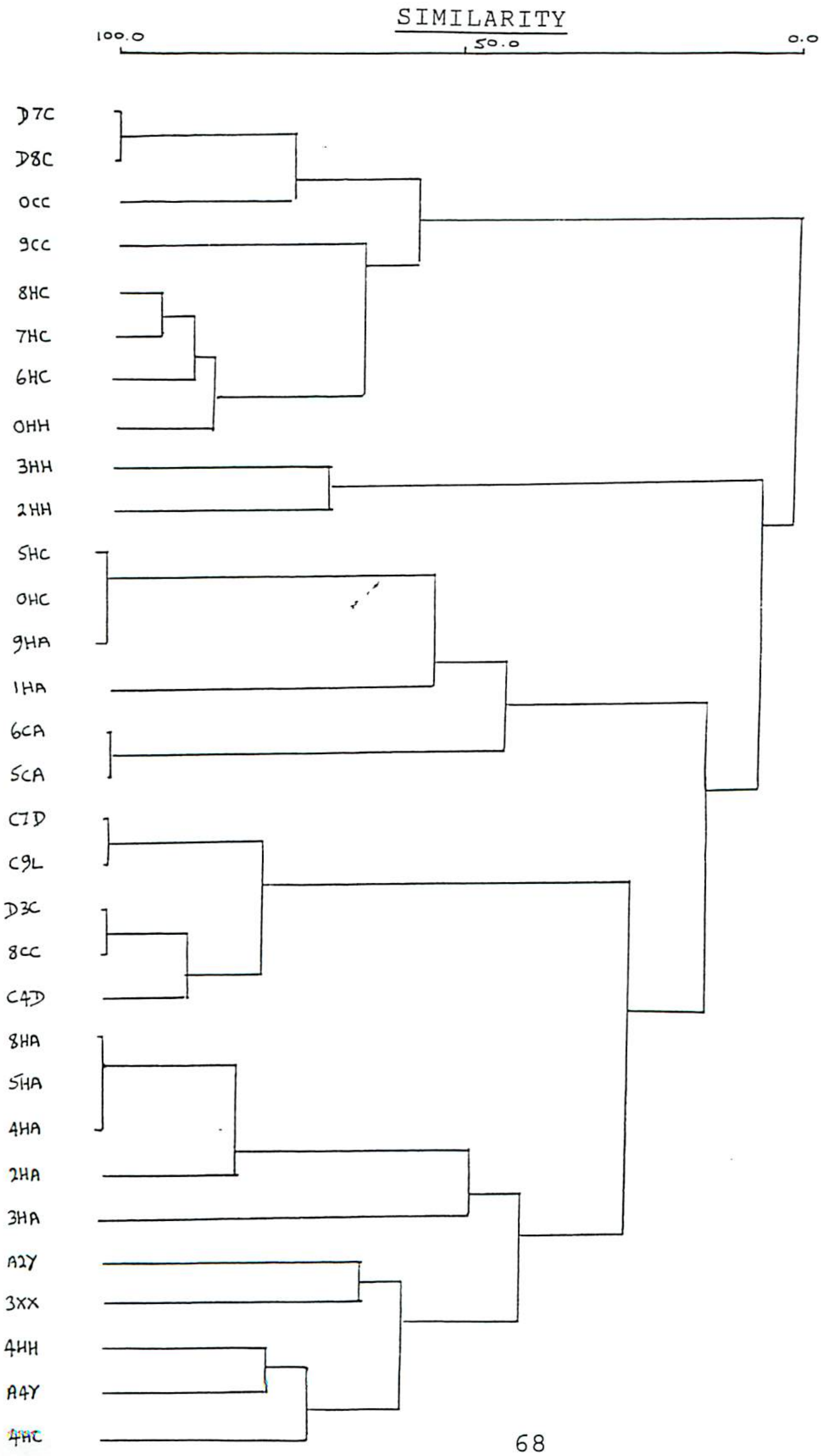


Figure 3.1.4.3b. Dendrogram illustrating the extent to which the core ranges of individual birds overlap during the 1992-93 winter; birds with similar distributions generally occurring in the same fields.



3.1.5 Variation in distribution within the main study area in the 1992-93 winter

Introduction and methods

The number of birds using fields at the five farms within the main study area (SU, RK, FO, EO and OV) was counted 2 to 3 times each week during the 1992-93 winter. Data recorded included the total number of birds in each field on the farm, the percentage of juveniles in the flock, the identity of any ringed birds present and whether they were paired or with young, the proportion of birds feeding and, from January onwards, the type of feeding activity (ie pecking surface swards or tugging at the root stem; feeding activity is described in Section 3.3). Information on the type of crop or pasture being used by the geese, the "green-ness" and length of the sward of the pasture fields, and the number of livestock and Barnacle Geese present, were also recorded during the regular counts to determine whether these habitat variables influenced feeding site selection by the geese. The seven different types of habitat recorded with geese present during the counts: arable cereal, arable root crop, bog/moor, loch, old improved pasture (OIP), permanent pasture (PP) and recently improved pasture (RIP) were given numeric codes 1 to 7 respectively. Grass colour was coded: Y=Yellow, YG=Yellow/Green, GY=Greeny-Yellow, G=Green, VG=Very Green, then allocated numeric values of 1 to 5 for statistically analysis. Sward length was coded: S=Short (<5cms), M=Medium (5-15cms) and L=Long (>15cms), with intermediate values MS (Medium-Short) and ML (Medium-Long) also being used. Numerical values of 1 to 5, indicating swards of increasing length, were again allocated. The abundance of Juncus was coded as 0=none, 1=little present, 2=some present and 3=wide-spread. Information on the year in which a field was re-seeded, and the acreage of each field, was available for Sunderland farm; their effect on the distribution of the geese was considered separately.

Variation in the number of geese recorded on each farm in each half month was investigated to assess the level of movements of the birds during the winter season. Similarly, variation in the distribution of geese within the boundaries of each farm was investigated on a field by field basis each month to determine whether the birds tended to use the same fields throughout the winter or whether their distribution changed as the winter progressed. Daily estimates of the mean number of geese recorded on each farm were calculated only for the days when all the fields on the farm had been counted. The average count for each field on that day was determined, and the average field counts summed to give the mean daily count for the farm, thus controlling for movements of birds between fields and between farms. These figures were in turn used to estimate the mean numbers of geese recorded on the farm each day for each half month period from late October (ie 15 to 31 October) to late April (15 to 30 April). Changes in the birds' use of different fields at each farm were described initially by estimating the total number of geese counted on a field in each month (again using only whole farm counts), measured as a percentage of the total number of birds recorded on the farm in that month. This "field usage" by the geese was also estimated on a half-month basis and arcsin transformed for analysis of distribution in relation to the habitat variables. The mean number of cattle, sheep and Barnacle Geese recorded in each field in each half month was log transformed for analysis. There was very little variation in the sward length, "green-ness" and abundance of Juncus records for particular fields within a half-month period, but if some change was recorded the predominant category was used.

Results

The mean daily counts of Greenland White-fronted Geese on farms in the main study area throughout the winter are illustrated in Figure 3.1.5a. The results indicate that more geese were seen on Octovullin farm in early autumn and winter compared with later in the season, and that few birds used Foreland farm before late February. The geese made more consistent use of Eorrabus farm throughout the winter. The low counts at Rockside and Sunderland farms in January may reflect exceptionally poor visibility at this time, rather than a genuine decrease in numbers. Further consideration of changes in the birds' use of the different fields each month indicated that the birds concentrated on a small number of fields on each farm early in the season, but dispersed over a greater number of fields as the winter progressed (Fig. 3.1.5b). The large numbers of birds recorded at Octovullin in October, November and December (Fig. 3.1.5a) were mostly located on just one field (field OV2, Fig. 3.1.5b) containing fodder beet. A comparison of counts made of the adjacent Sunderland and Rockside farms found that a decrease in the numbers on one farm was not matched by higher numbers on the same at the other (correlations of the whole farm counts were all non-significant, Table 3.5.1a). It seemed, therefore, that the geese at Sunderland and Rockside formed separate flocks; there was no evidence from the count data to suggest that they comprised a single flock shifting between the two farms on a daily basis.

The distribution of geese in relation to the habitat variables was analysed using the General Linear Model (GLM) in the Minitab statistical package. Half-month, green-ness of the sward, sward length, Juncus cover, and the mean number of livestock and of Barnacle Geese recorded (log transformed) were included as continuous variables, and the broad habitat category as a categorical variable. Results confirmed that the extent to which the geese used the different fields on the five farms in the main study area was affected by the time of year, with a high proportion concentrating on a small number of fields early in the season and becoming more widely dispersed as the winter progressed (Table 3.1.5b, Fig. 3.1.5b). The geese also appeared to select fields containing high quantities of Juncus (Table 3.1.5b, Fig. 3.1.5c) and those with greener swards (Table 3.1.5b, Fig. 3.1.5d). Sward length did not prove significant when considered together with the time of year (measured in half-months, Table 3.1.5b). The tendency for the birds to disperse more widely towards the end of the winter may, however, be associated with a decrease in the food supply; the sward lengths recorded from late January onwards were certainly shorter than from October to early January ($r = -0.48$, $P<0.01$, Pearson Correlation between sward length and half month). The association between sward length and the percentage of geese recorded on the different fields did prove significant when considered separately (F=3.94, df=247, P<0.05, Fig 3.1.5e). There was no evidence to suggest that site selection was influenced by the broad habitat categories when the other variables were included in the analysis (Table 3.1.5b), again maybe because the use of arable crops in autumn and of pasture thereafter was attributed to the time of year. Further consideration of the counts of geese at Sunderland farm found that although the birds appeared to prefer the larger fields (measured in acres, log transformed) (F=4.47, df=1, P=0.038), the number of years since the fields were re-seeded did not appear to affect their distribution (F=1.35, df=1, P>0.2).

Separate analysis of the distribution of Greenland White-fronted Geese in relation to the numbers of sheep, cattle and Barnacle Geese recorded in each field again found that a smaller percentage of the geese present were recorded in a larger number of fields as the winter progressed (r= -0.234, n=390, P<0.01 Pearson Correlation between the percentage of geese in each field and half-month; Fig. 3.1.5f). Moreover, smaller numbers of Greenland White-fronted Geese were found in fields used by large numbers of Barnacle Geese (r= -0.178, n=184, P<0.02, Pearson Correlation, Fig. 3.1.5g), and there was also a negative correlation between Greenland White-fronted Goose counts and the number of sheep (r= -0.239, n=97, P<0.02, Fig. 3.1.5h). The presence of cattle did not appear to affect the distribution of the Greenland White-fronts (r= 0.105, n=41, not significant) but there was a positive associations between the number of cattle and the number of Barnacle Geese (r= 0.469, n=34, P<0.01).

Analysis of the distribution of juveniles throughout Islay in relation to habitat variables found that although the time of year and the count area were important, the number of geese in the flock and the type of habitat did not prove significant (see Section 3.1.2 above). A further analysis of the distribution of juveniles was made, using the more detailed habitat classifications (sward length, green-ness, etc), for birds seen in the main study area. The percentage of juveniles in each field (estimated from the number of birds whose ages were checked) was arcsin transformed, and the size of the flock was loge transformed. The results were similar to those described in Section 3.1.2; only half-month and farm code had an effect on the percentage of juveniles recorded (F=2.73, df=12, P=0.002 for half-month and F=7.64, df=4, P<0.001 when these two variables were considered together). Habitat type, *Juncus* abundance, green-ness of the sward, sward length, and flock size all proved non-significant (Table 3.1.5c). The percentage of juveniles was lowest on Foreland farm (4.95% juveniles, SE+/-1.26) and Sunderland farm (6.06% +/-1.57), and highest at Octovullin (15.3% +/-1.98) and Rockside (16.00% +/- 1.84). There was marked variation in the percentage of juveniles recorded at Sunderland and Octovullin from month to month, however, indicating some changes in the distribution of the family parties, although the percentages recorded for the other farms were more consistent (Figure 3.1.5i). Further consideration of the percentage of juveniles recorded on different types of habitat indicated that families may select recently improved pasture (11.32% juveniles) rather than old improved pasture (8.94% juveniles), but again the difference was not significant (N1=90, N2=145, W=6.0, P>0.6, Mann-Whitney U test). There was no association between the percentage of juveniles and the abundance of Juncus (r= -0.16, n=231, not significant) or with the green-ness of the sward (r= -0.001, n=197, not significant) when these variables were considered separately. There was a positive correlation between the percentage of juveniles and sward length (r=0.12, n=201, P<0.01), but this due to the very low numbers of juveniles seen on short swards in comparison with the medium-short swards (Fig. 3.1.5j).

Conclusions

1. The geese concentrated on a small number of fields early in the season but dispersed into smaller flocks using a larger number of fields as the winter progressed

2. The geese also selected fields with comparatively high abundance of Juncus, and those with greener swards. The latter finding suggests that they prefer improved (fertilised) pasture, although Section 3.2 below found that different liming and fertilising treatments in summer did not affect the distribution of birds within a field the following winter. The number of years since the field was re-seeded did not have a significant effect on the number of geese using the field.

3. Sward length decreased as the winter progressed, and the reduction in food supply was thought to be a possible reason for the birds being more widely dispersed towards the end of the season.

4. Greenland White-fronted Geese occurred in smaller numbers in fields used by sheep and by Barnacle Geese. Barnacle Geese appeared to use fields grazed by cattle.

5. The percentage of juveniles varied between farms, and also with the time of year, but the different habitat measurements did not appear to affect site selection by the family parties.

Table 3.1.5a Results of Pearson Correlations between the numbers of Greenland White-fronted geese counted on Rockside and Sunderland farms during the 1992-93 winters. Only four whole-farm counts were made during the month of January, so the January data is excluded from the analyses. ns = not significant.

	Nov	Dec	Feb	Mar	Apr	All Winter
r	-0.004	0.506	0.225	-0.142	0.437	0.136
n	13	8	8	13	9	51
P	ns	ns	ns	ns	ns	ns

Table 3.1.5b. Results of GLM analysis of field usage by Greenland White-fronted Geese in relation to habitat variables.

	F	df	P
Half month	3.54	12	<0.001
Broad habitat type	0.63	2	ns
Green-ness of sward	3.70	1	<0.1
Sward length	0.60	1	ns
Juncus abundance	7.19	1	<0.01

Table 3.1.5c. Results of GLM analysis of the effects of habitat variables on the percentage of juveniles recorded in the flock.

	F	df	P
Half month	3.12	12	<0.001
Broad habitat type	0.04	2	ns
Green-ness of sward	0.16	1	ns
Sward length	0.05	1	ns
Juncus abundance	0.11	1	ns
Flock size	2.13	1	<0.2

Figure 3.1.5a Mean number of Greenland White-fronted Geese recorded per half month during the 1992-93 winter at farms in the main study area: Eorrabus, Foreland and Octovullin.

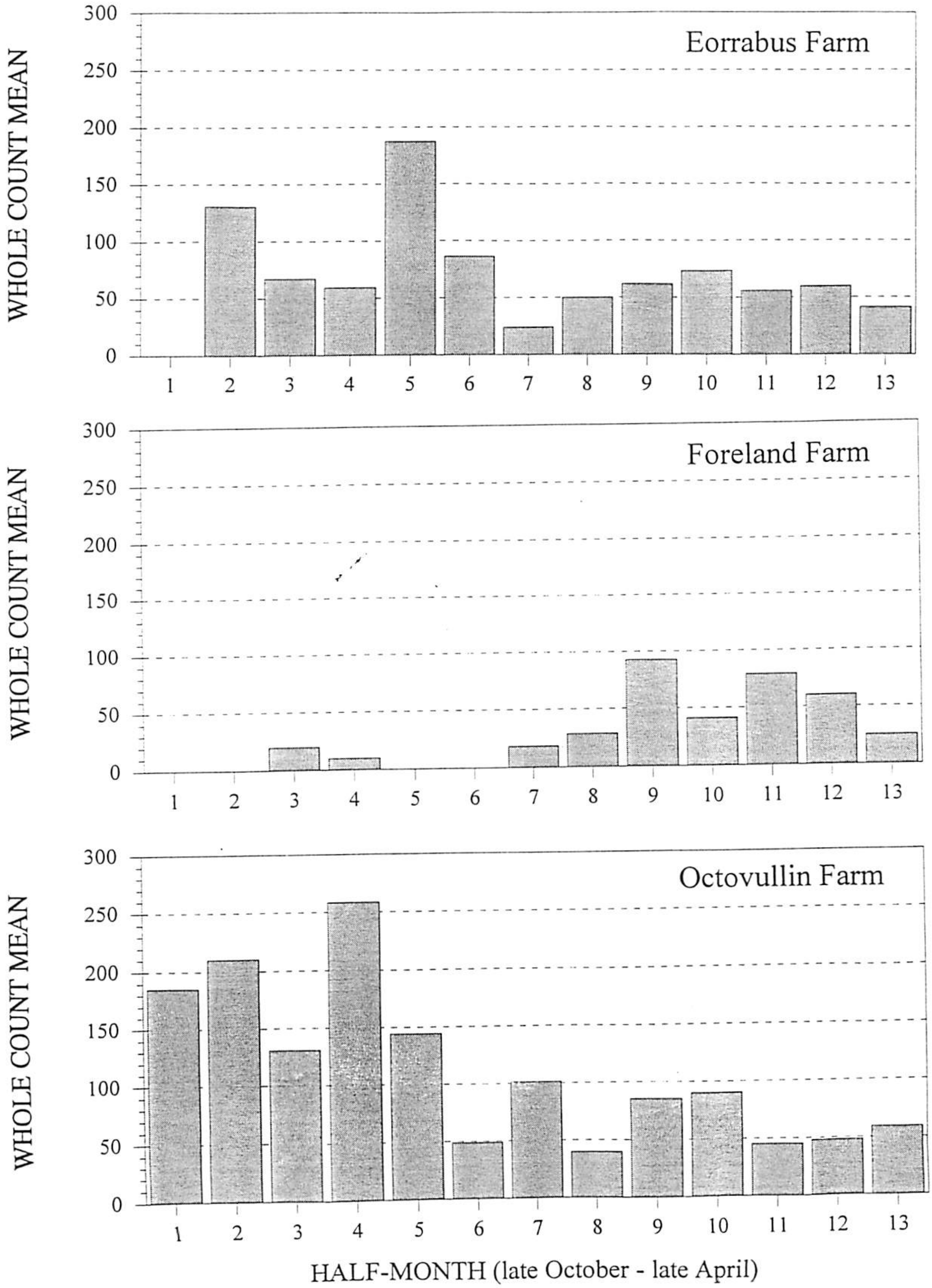
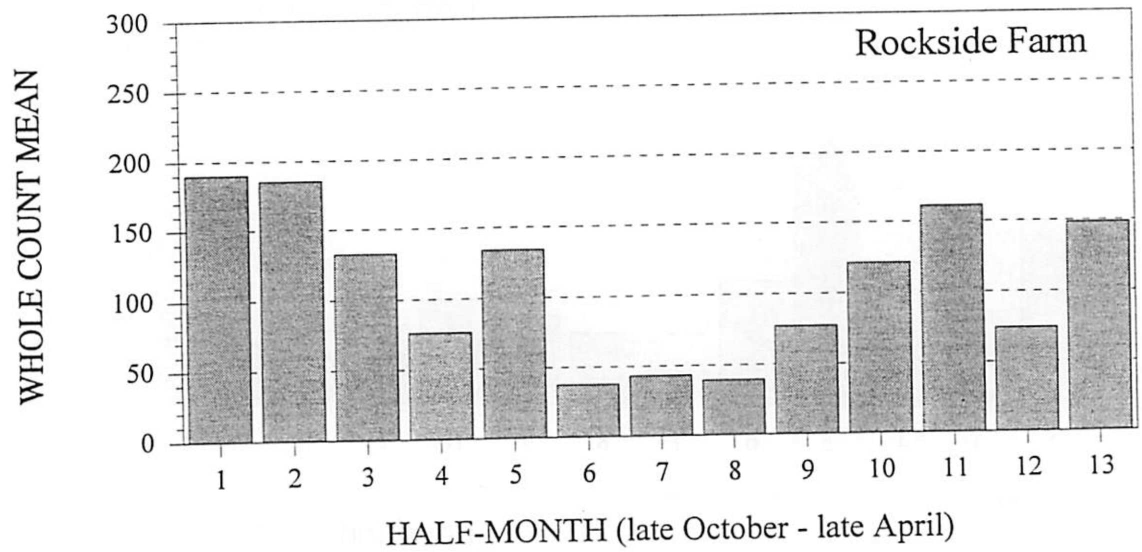


Figure 3.1.5a cont. Mean number of Greenland White-fronted Geese recorded per half month during the 1992-93 winter at farms in the main study area: Rockside and Sunderland.



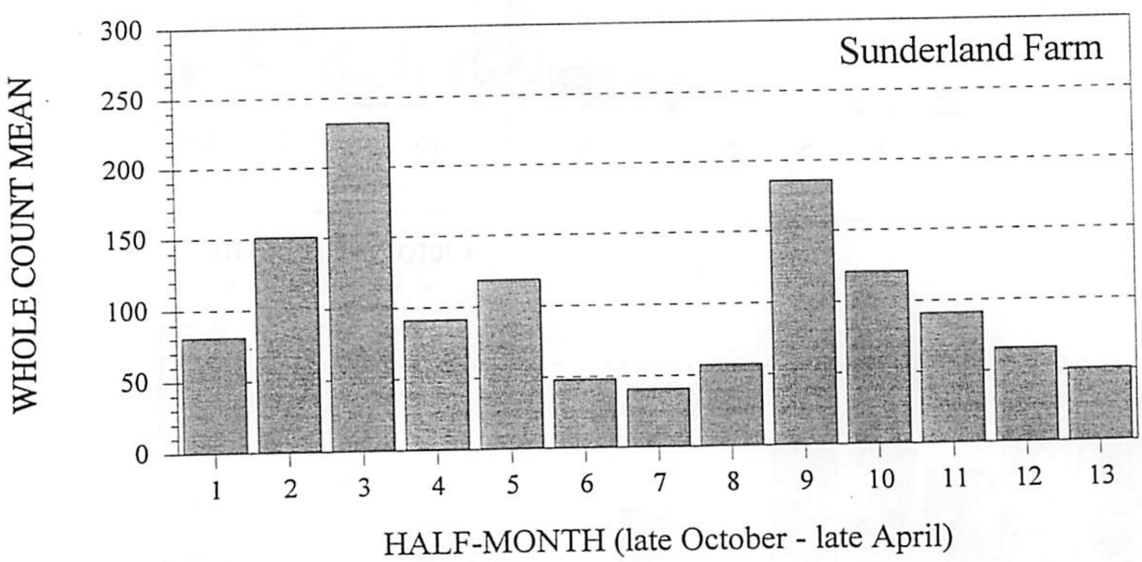
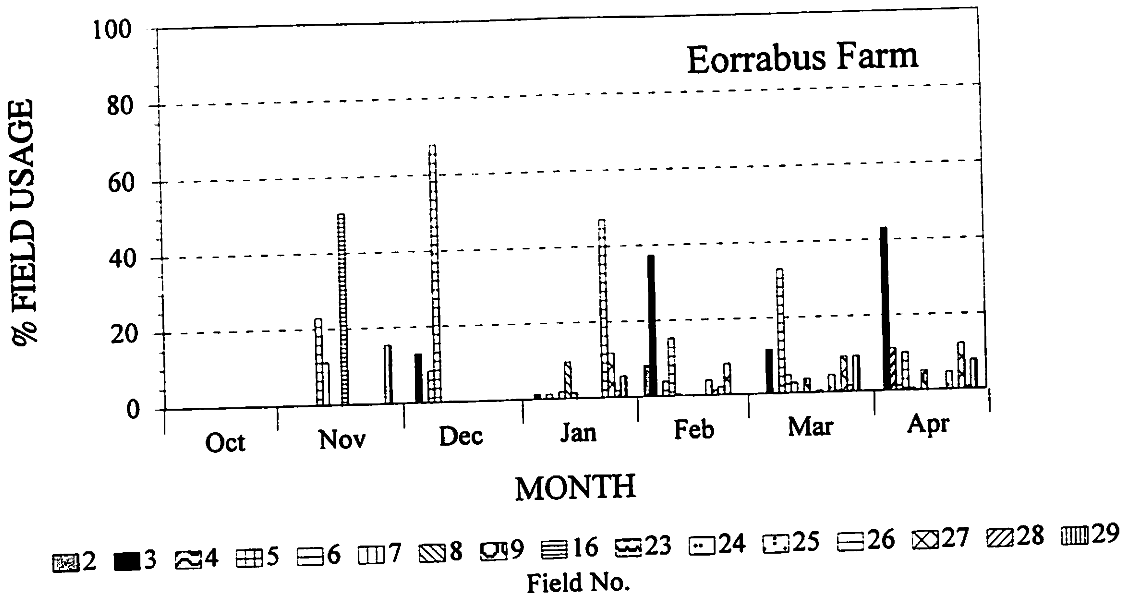
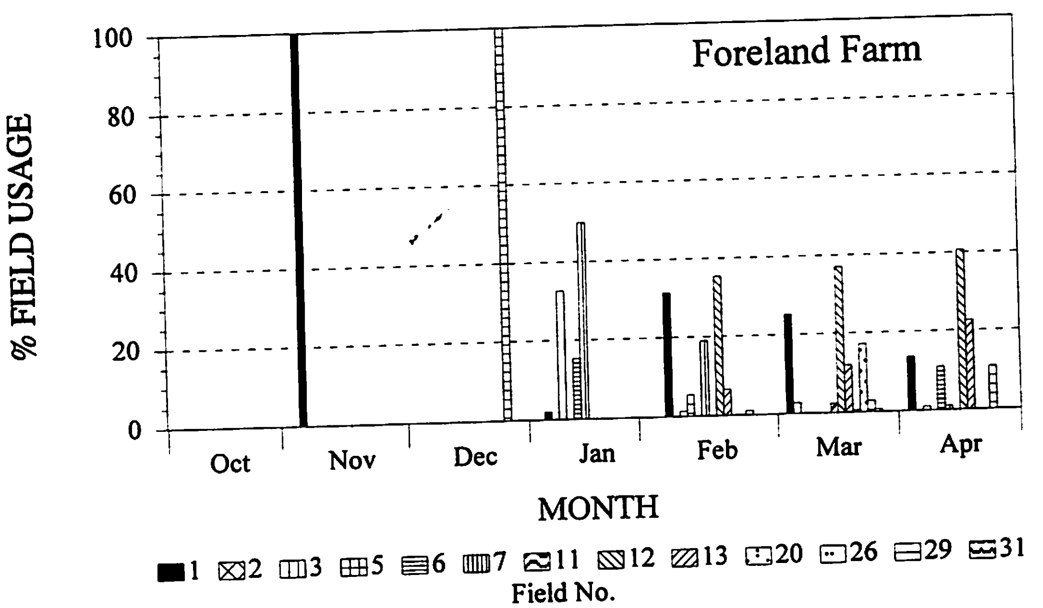
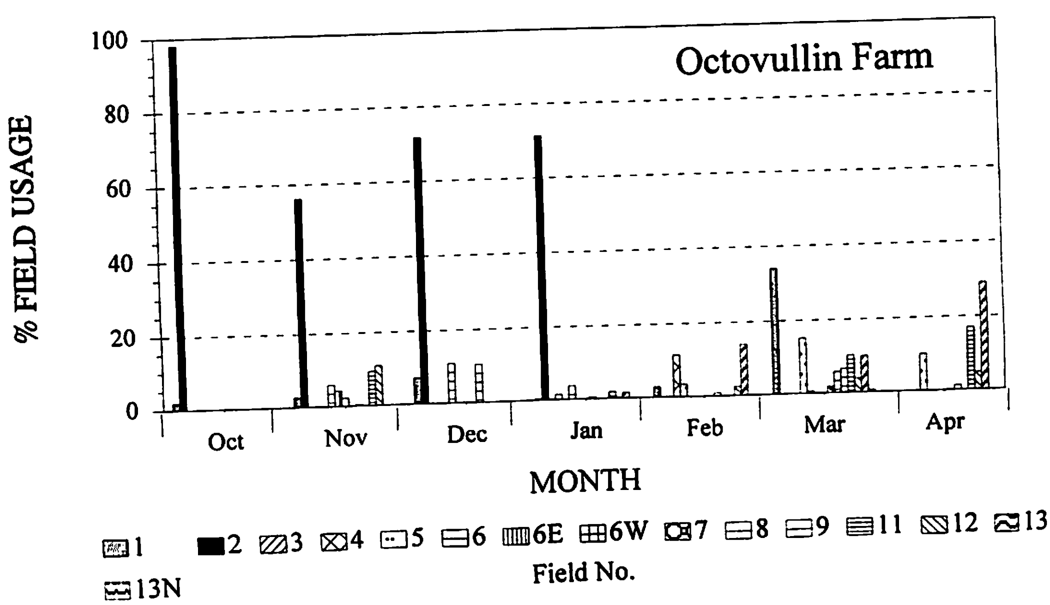


Fig 3.1.5b

Field usage by Greenland Whitefronts
Winter 1992-1993

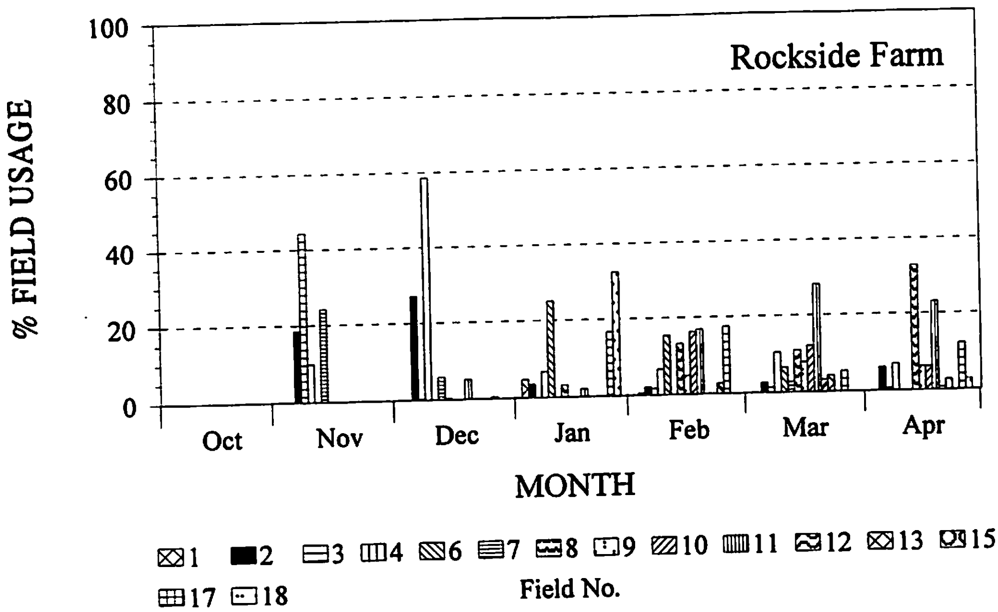






3.1.5b (cont)
Fig

Field usage by Greenland Whitefronts
Winter 1992-1993



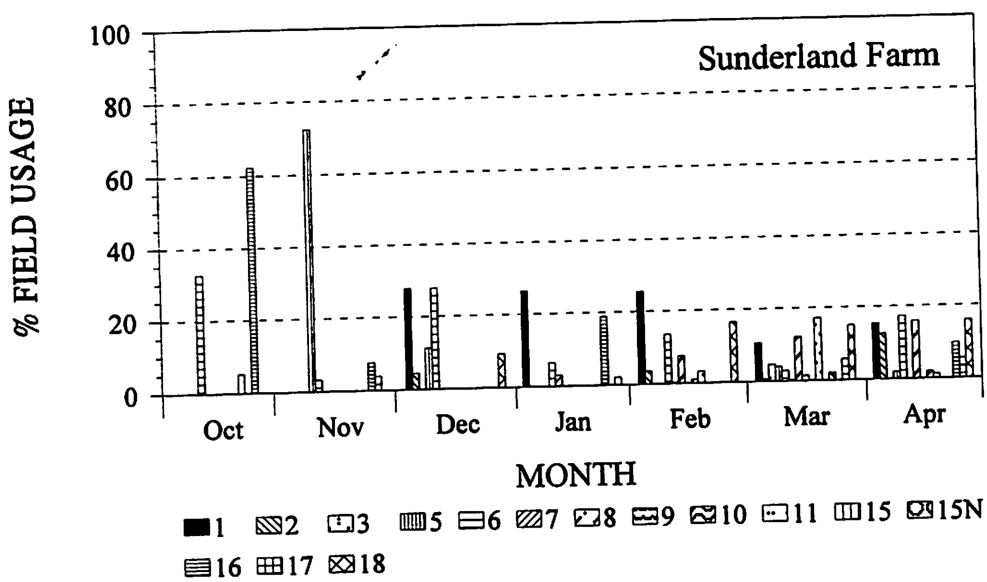


Figure 3.1.5c. Association between the abundance of <u>Juncus</u> in a field and the proportion of geese seen using the field.

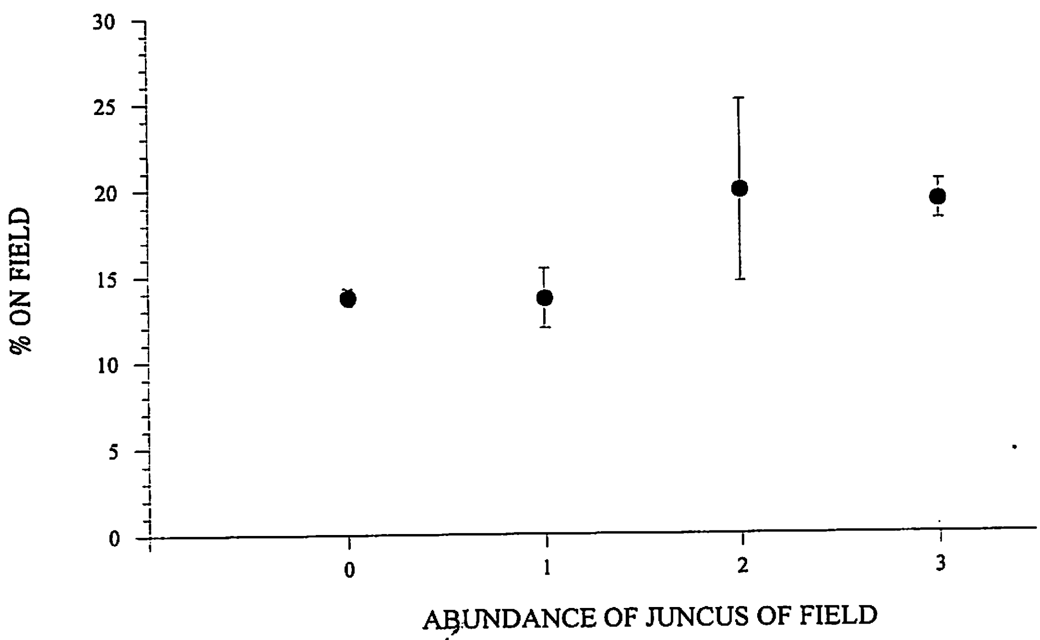


Figure 3.1.5d. Field usage by Greenland White-fronted Geese in relation to the green-ness of the sward.

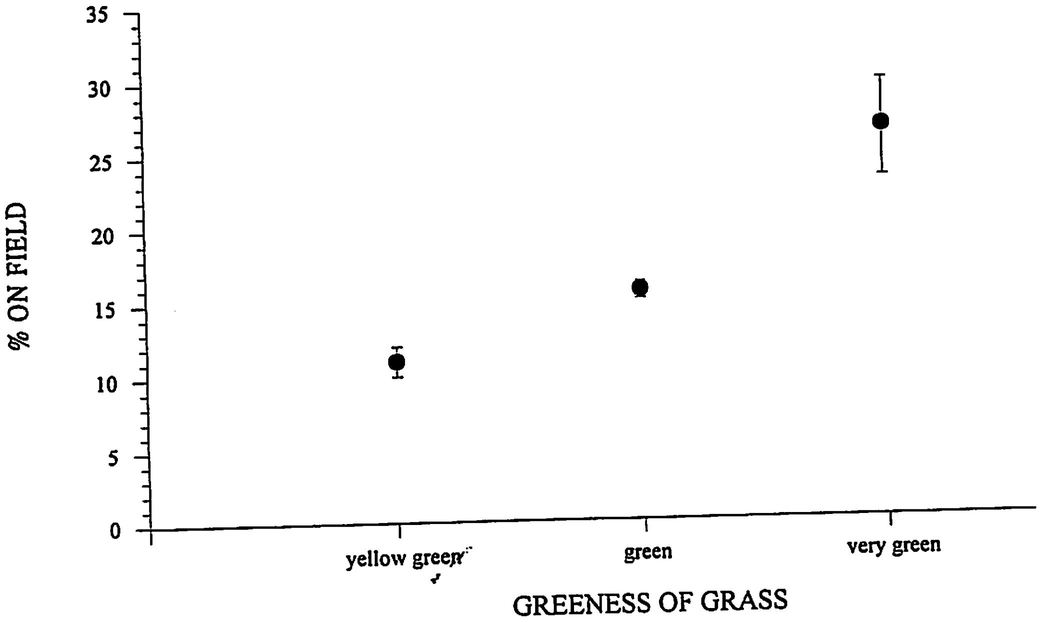
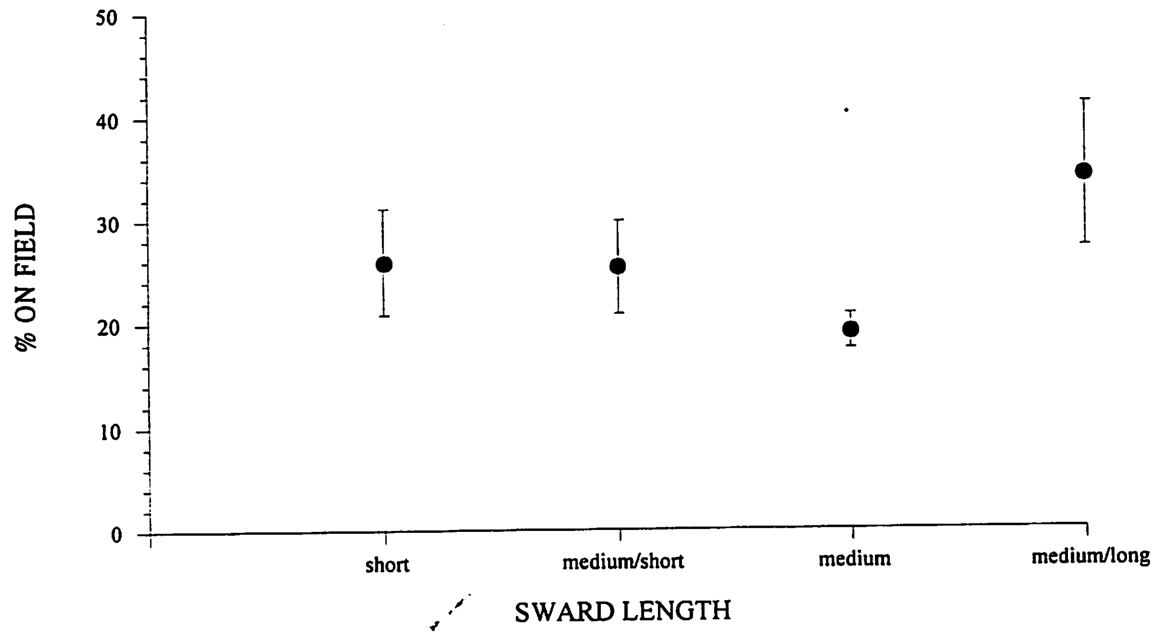


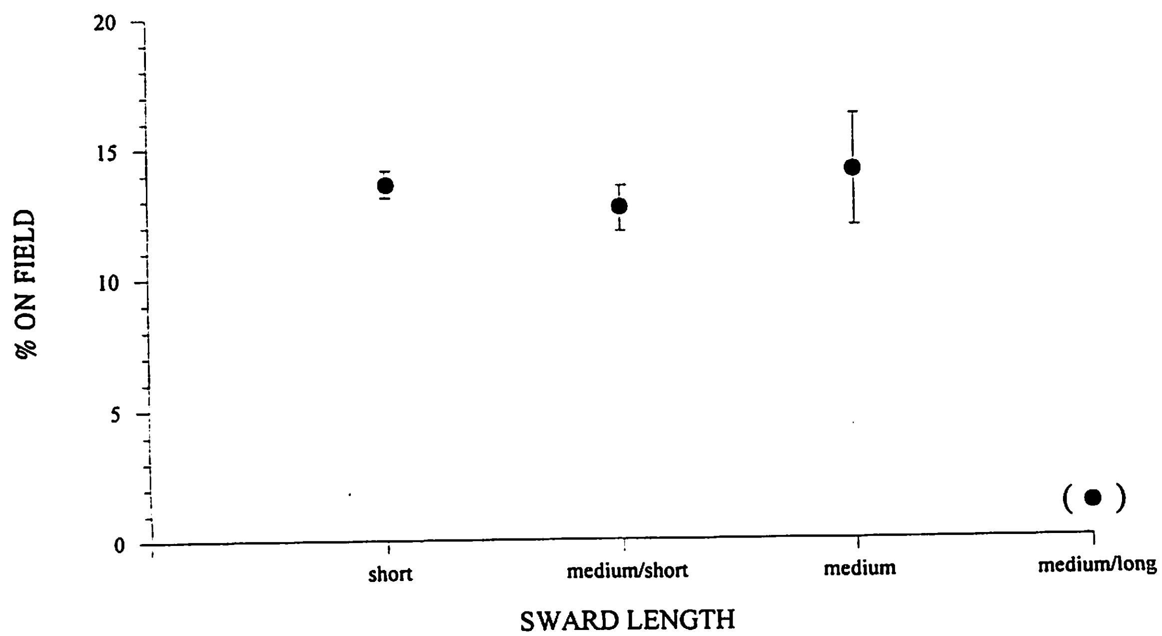
Figure 3.1.5e. Field usage by Greenland White-fronted Geese in relation to sward length.

a) October - December
b) January - April

a)



b)



3.1.5f

Fig. Percentage field usage by Greenland Whitefronts plotted against half-month (mean and S.E. bars)

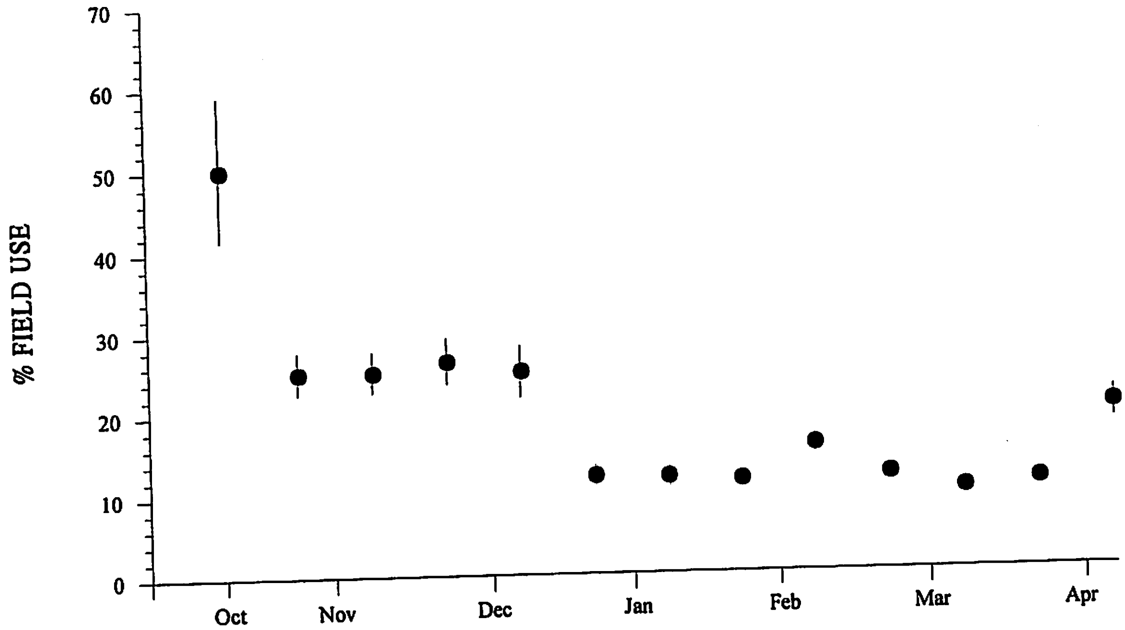


Figure 3.1.5g. Field usage by Greenland White-fronted Geese in relation to numbers of Barnacle Geese (log transformed).

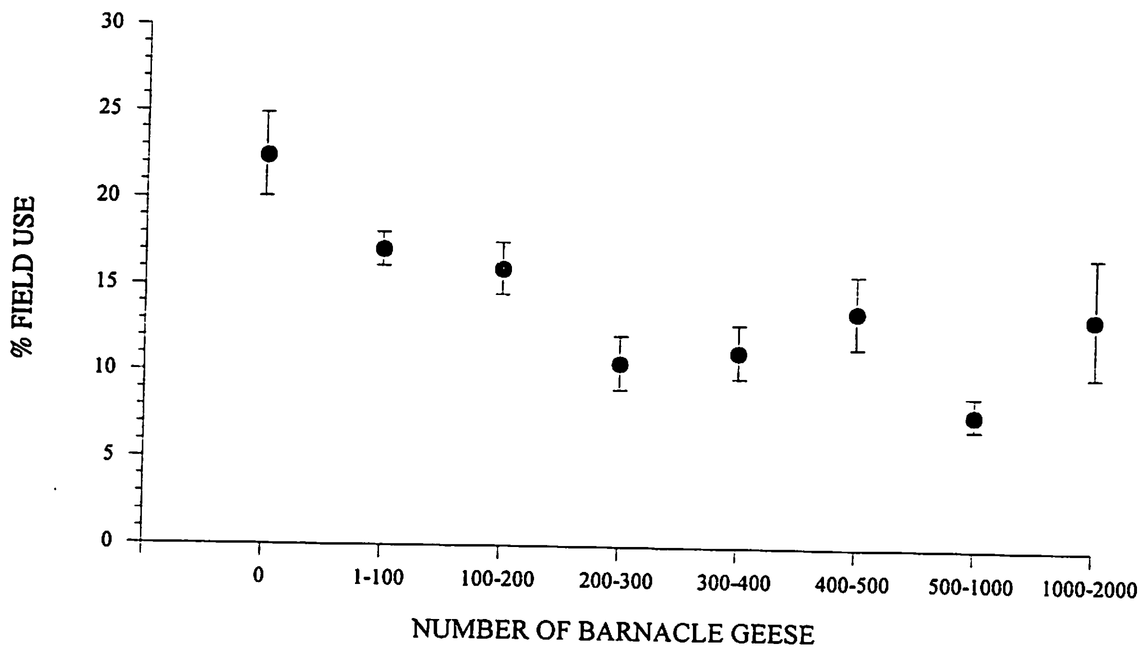
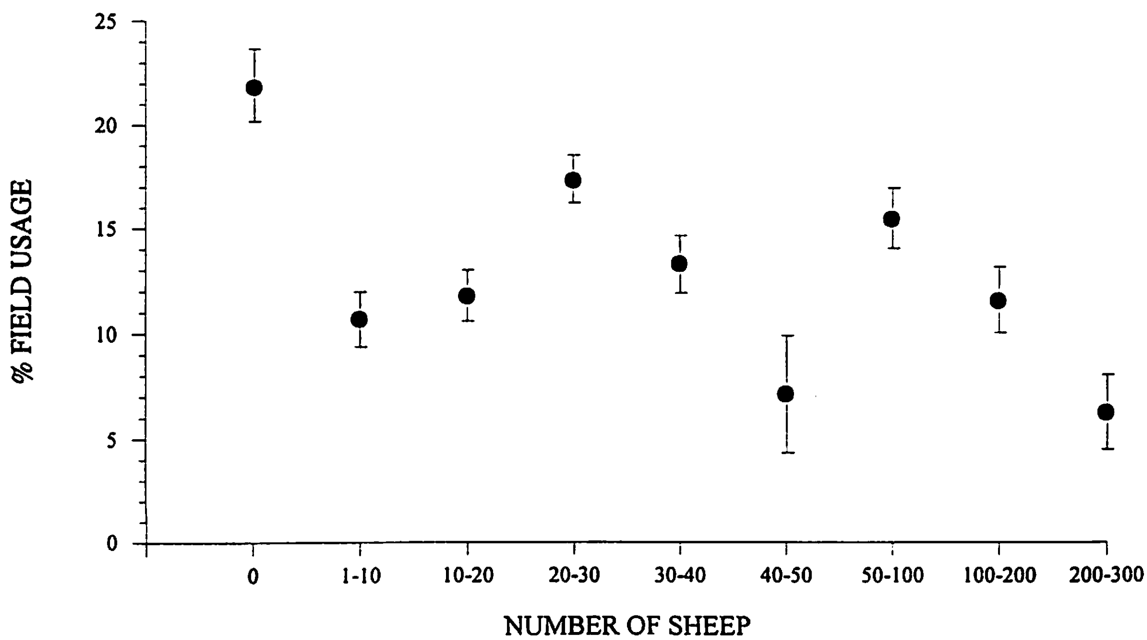
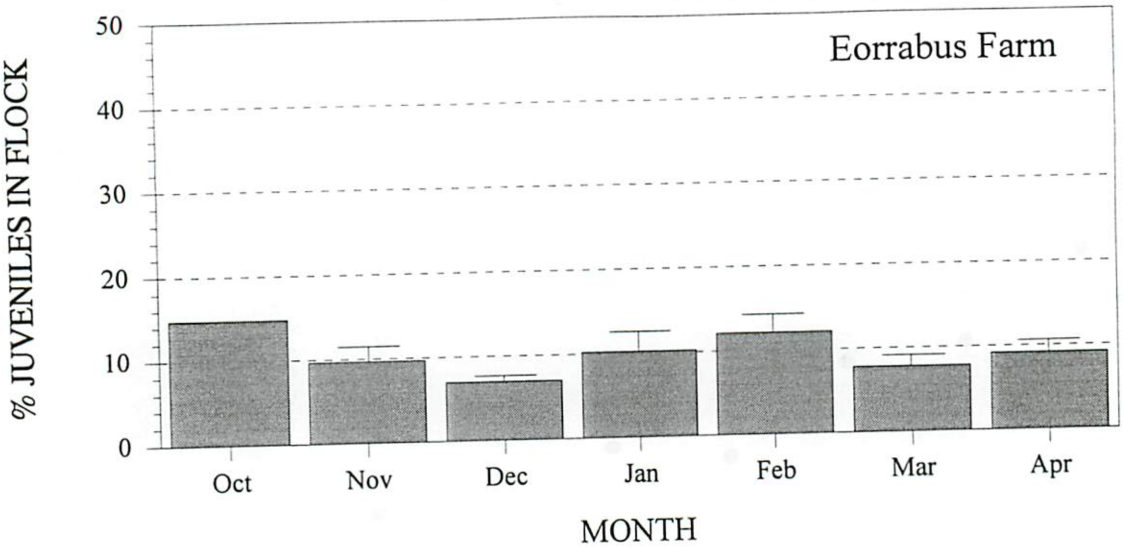


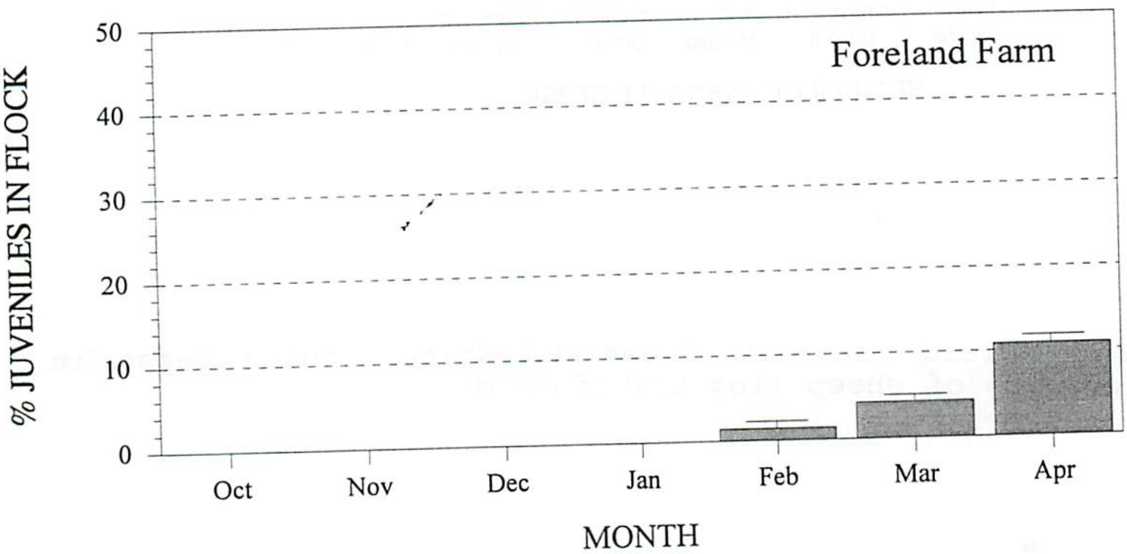
Figure 3.1.5h. Field usage by Greenland White-fronted Geese in relation to numbers of sheep (log transformed).

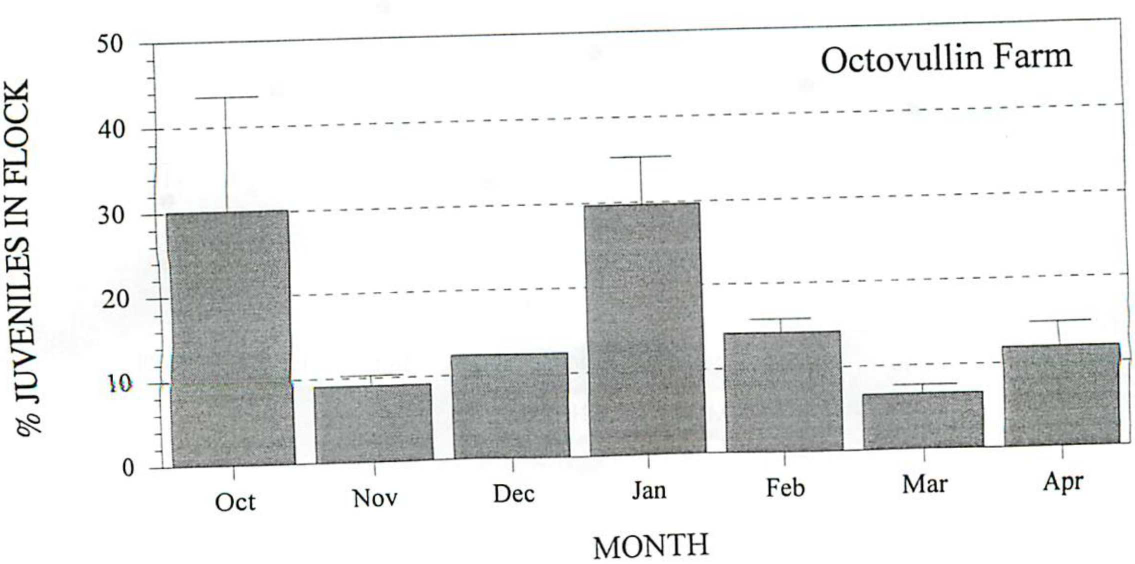


3.1.5i

Fig Percentage of juvenile Greenland Whitefronts per month - Winter 1992-1993 (histogram and S.E. bar)

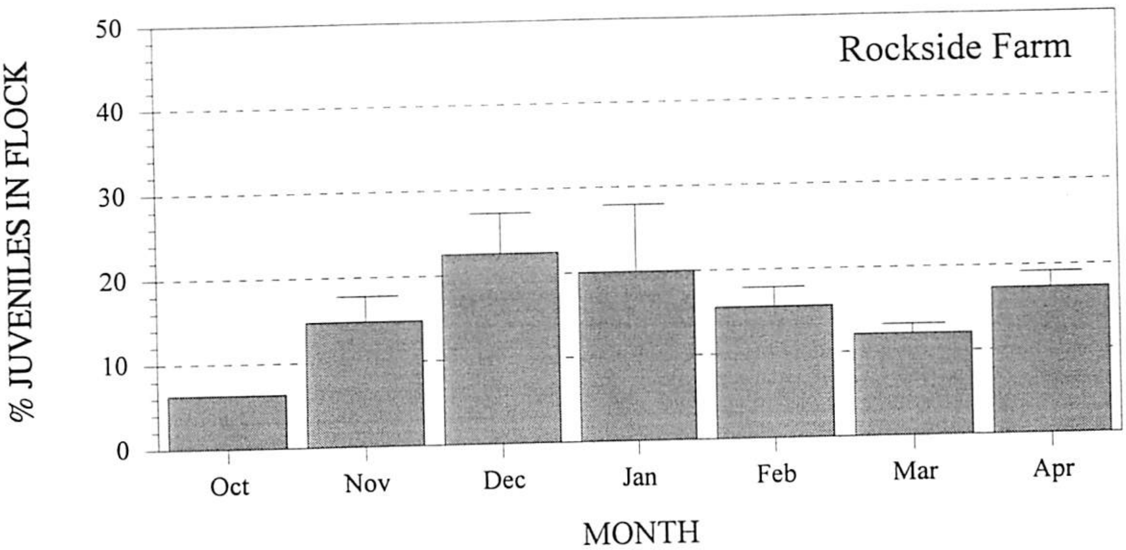


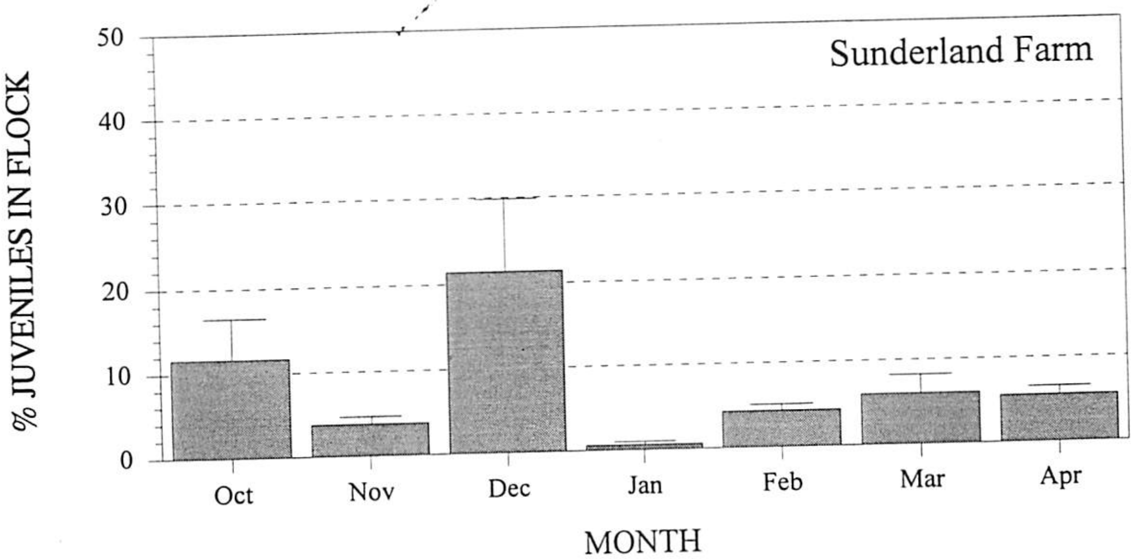




3.1.5i (cont)

Fig Percentage of juvenile Greenland Whitefronts per month - Winter 1992-1993 (histogram and S.E. bar)





3.1.5j

Fig. Percentage of juvenile Greenland Whitefronts in flock plotted against sward length (mean and S.E. bar)