(a) General body fat and weight

General Fat Index	Mean Body Weight (g)	n	Coefficient of Variation (%)	F statistic	p
0	435	222	27	19.51	0.000
1	486	312	17		
2	497	193	17		
3	510	256	18		
4	522	45	10		
5	527	20	16		
(b) General body fat and shin length					
0	77.6	212	8	6.54	0.000
1	77.5	294	6		
2	77.5	184	6		
3	78.0	236	5		
4	77.7	40	4		
5	76.7	14	8		
(c) General body fat and standardised body weight					
0	5.8	209	22	17.39	0.000
1	6.3	291	14		
2	6.4	182	15		
3	6.5	236	16		
4	6.7	38	9		
5	6.9	14	11		

Table 6 Mean body weight, shin length and standardised body weight for each fat index

7.1.3 Reproduction

7.1.3.1 Annual cycles

There were distinct annual cycles in reproduction in adult males and females based on external signs (Figure 10). Sixty per cent or more of all males were in breeding condition at all times, with peaks between January and June each year. The female annual cycles were more marked with a cessation of reproductive activity in Nov/Dec in 1992 and 1993, and a near cessation in 1994 (Figure 10). Two peaks in female reproductive activity can be seen each year in Mar/Apr and Jul/Aug; these correspond to the peaks in production of spring and summer litters respectively (see Gurnell, 1987).

7.1.3.2 Males

Clear annual cycles in testis size and stain are evident (Figure 11, Table 7) with stain tending to increase slightly after an increase in size. Testes increased in size in mid-winter (slightly earlier in 1994), were at a maximum in March/April, then declined to a low figure in September/ October (Figure 11). These cycles in testis size generally reflect those of the proportion of males in breeding condition.

7.1.3.3 Females

Pregnant females were captured between January and August each year, with marked peaks in January/February and July/August (Figure 12). Peaks in lactating females and females that had recently lactated generally followed at a lag of 1 to 2 bimonthly periods respectively (Figure 12). Little or no reproductive activity in females was seen in the period November/December each year.

Although the proportion of adult females that were pregnant reveals annuals cycles, it masks the intensity of breeding. Figure 13 shows that the number of females breeding declined from 1993 to 1995, even though the mean number of embryos per female fluctuated between two and five without obvious pattern. The overall number of embryos per pregnant female was 3.2 (n = 51, st. dev. = 1.17). This was significantly larger than the mean number of placental scars in lactating females (mean = 2.8, n = 91, st.dev. = 1.14; $t_{101} = 2.25$, p = 0.026), suggesting some losses of embryos before parturition. There was no difference in the mean number of placental scars in lactating females and those that had recently finished lactating (mean = 2.9, n = 176, st.dev. = 1.11; $t_{177} = 0.84$, p = 0.40). An index of productivity has been estimated from the addition of the total number of embryos and the total number of placental scars in lactating females for each bimonthly period (Figure 14). Productivity peaked between March and June each year, but there was a clear decline over the three years.

7.2 Cone feeding remains and tree seed crops

7.2.1 Feeding remains

Thirty-four transect lines for collecting cores from eaten cones (and whole cones, but these were very seldom found) were used over the three year period (Table 8, Figure 15). Some lines were moved during the study as a result of disturbance from forest operations such as felling and extra lines were added to sector C in the centre of the reserve during the study.

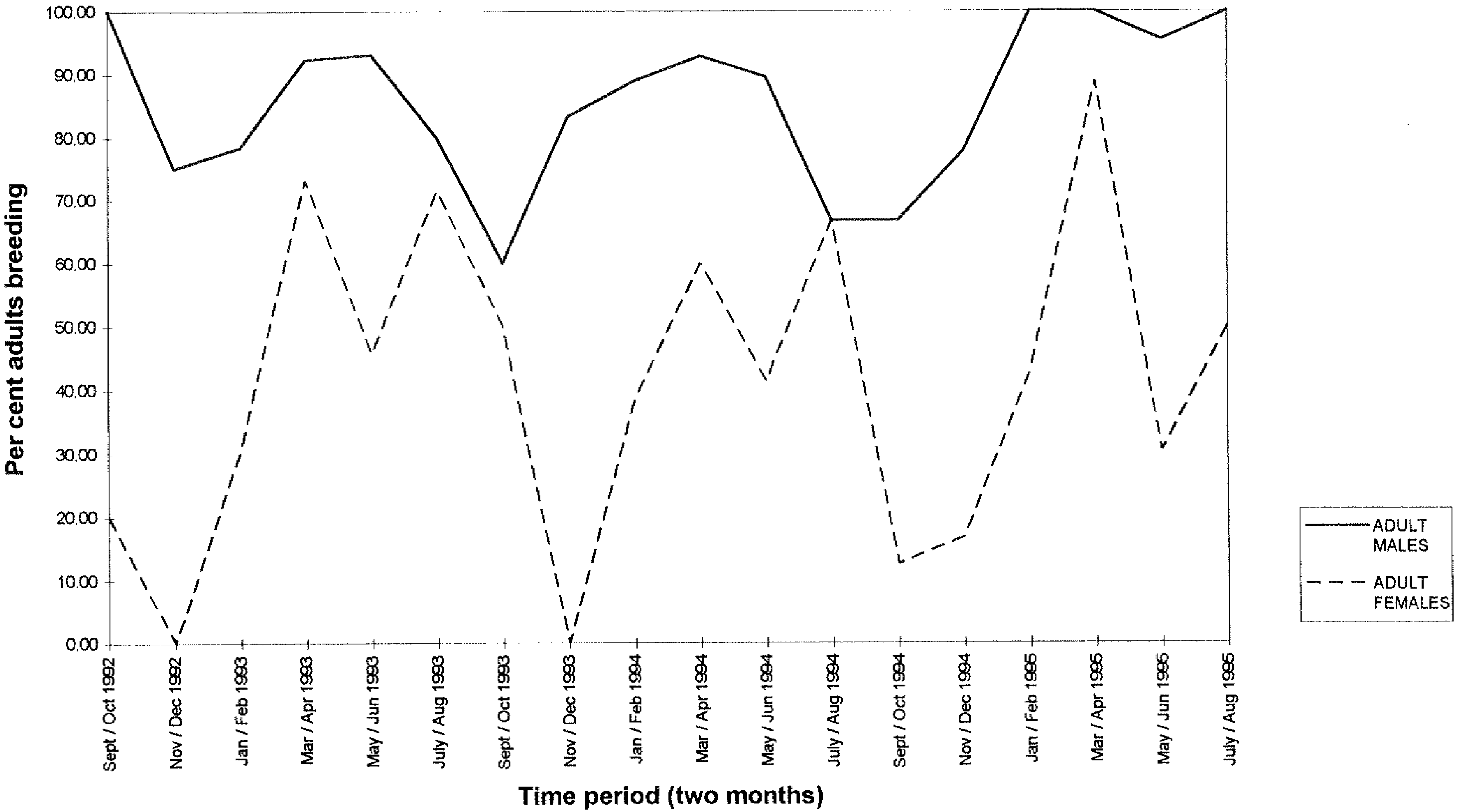


Figure 10 Per cent adult males and females breeding in each bimonthly period

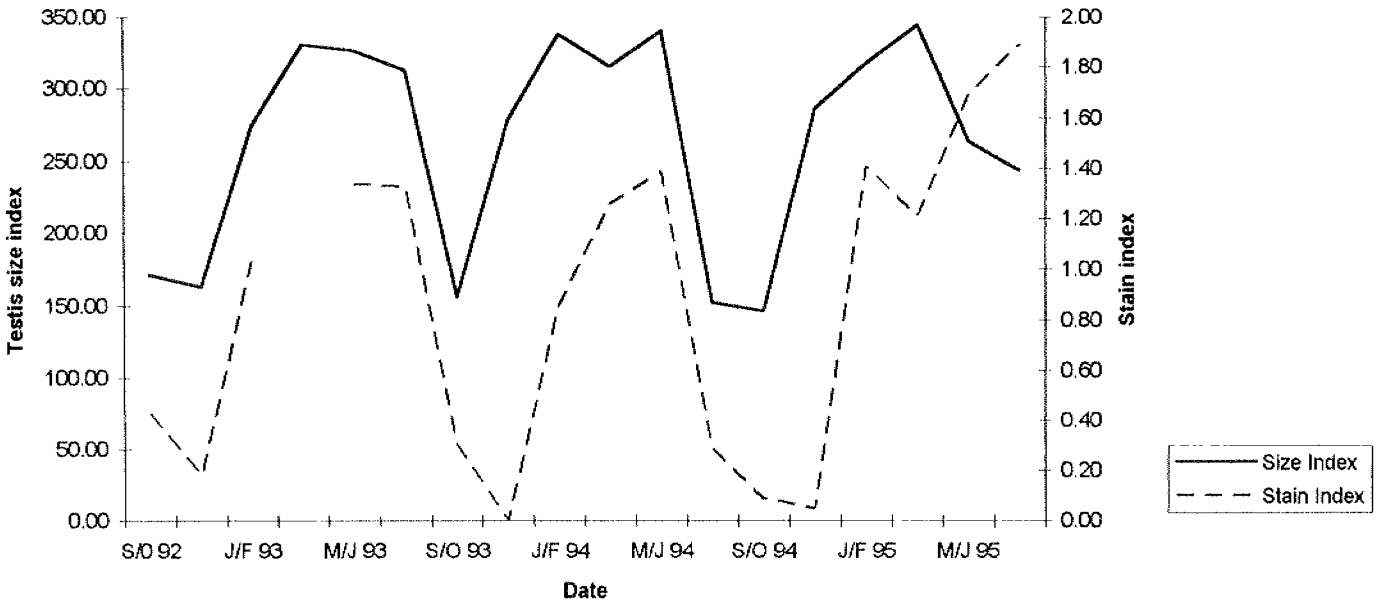


Figure 11 Mean indices of testes size and scrotal stain for each bimonthly period.

	Index of testes size			Index of male stain		
Date	Mean	n	CV (%)	Mean	n	CV(%)
S/0 92	171.00	7	94	0.43	7	124
N/D 92	163.00	8	127	0.18	11	255
J/F 93	274.00	46	60	1.03	37	96
M/A 93	330.00	61	27			
M/J 93	326.00	68	29	1.34	77	89
J/A 93	312.00	17	21	1.33	21	87
S/O 93	156.00	5	54	0.30	11	225
N/D 93	278.00	14	41	0.00	18	0
J/F 94	338.00	26	24	0.86	36	118
M/A 94	315.00	43	28	1.26	43	92
M/J 94	340.00	70	21	1.39	104	91
J/A 94	152.00	17	62	0.29	28	230
S/O 94	146.00	6	70	0.09	11	33
N/D 94	286.00	15	27	0.05	21	454
J/F 95	317.00	25	23	1.41	27	77
M/A 95	344.00	14	21	1.21	14	80
M/J 95	264.00	35	53	1.69	35	77
J/A 95	244.00	6	39	1.89	9	15

Table 7 Mean indices of indices of testes size and scrotal stain for each bimonthly period. CV = coefficient of variation (%), n = sample size.

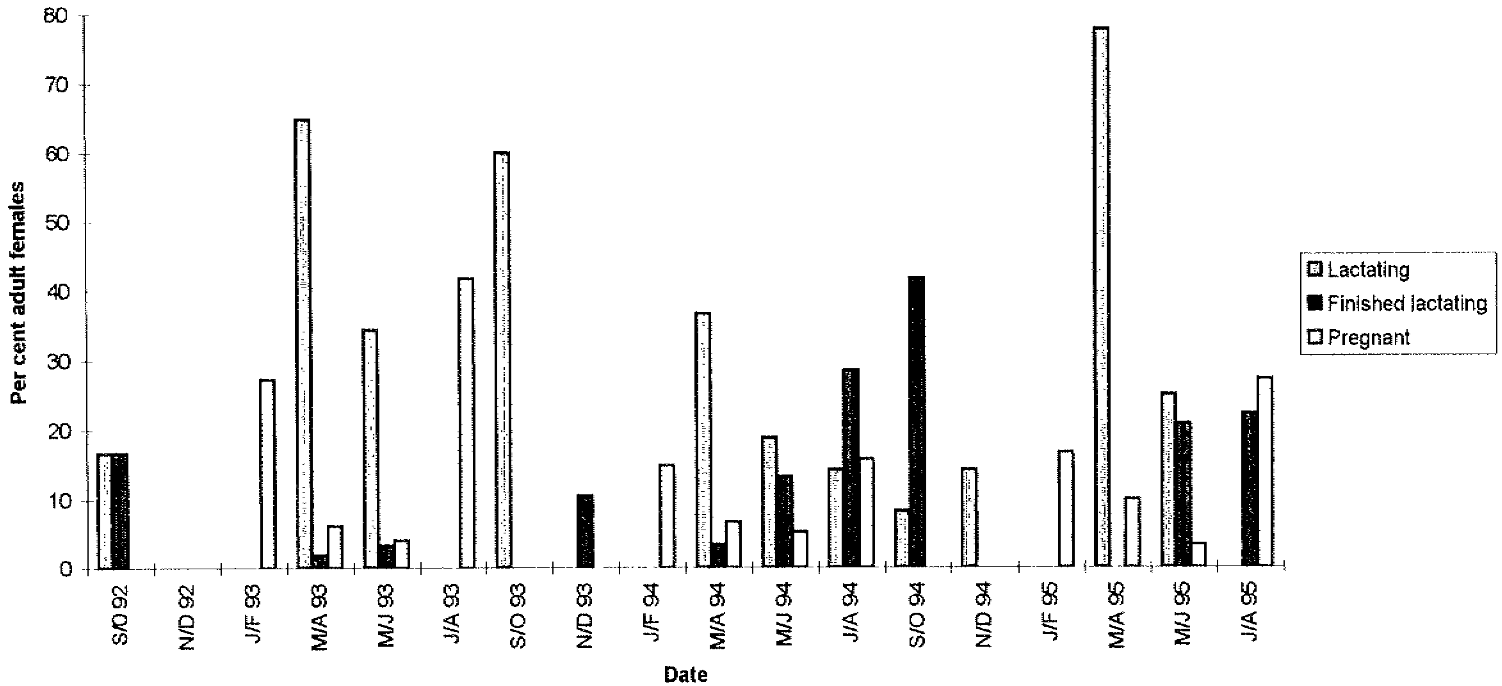


Figure 12 Per cent adult females pregnant, lactating or having recently finished lactating in each bimonthly period.

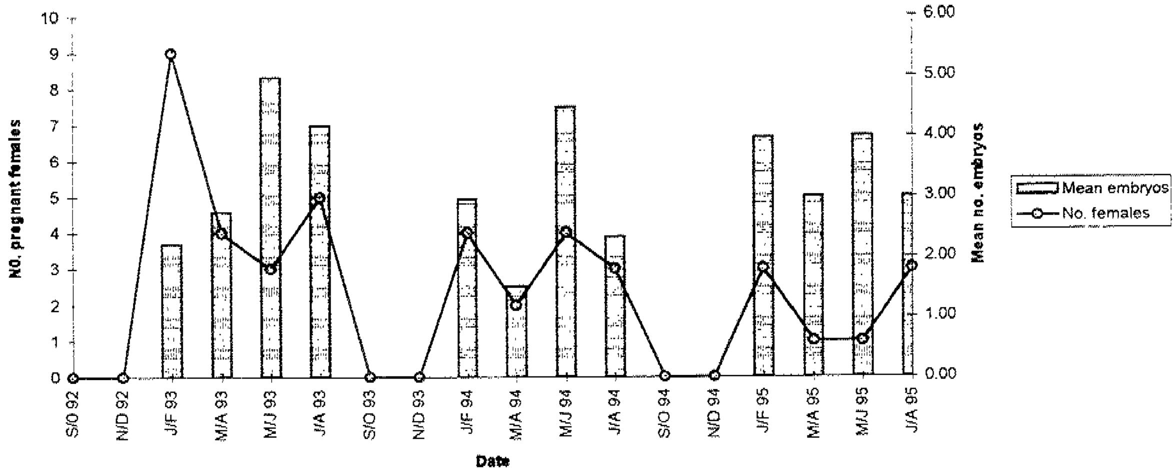


Figure 13 Mean number of embryos per pregnant female and number of pregnant females each bimonthly period.

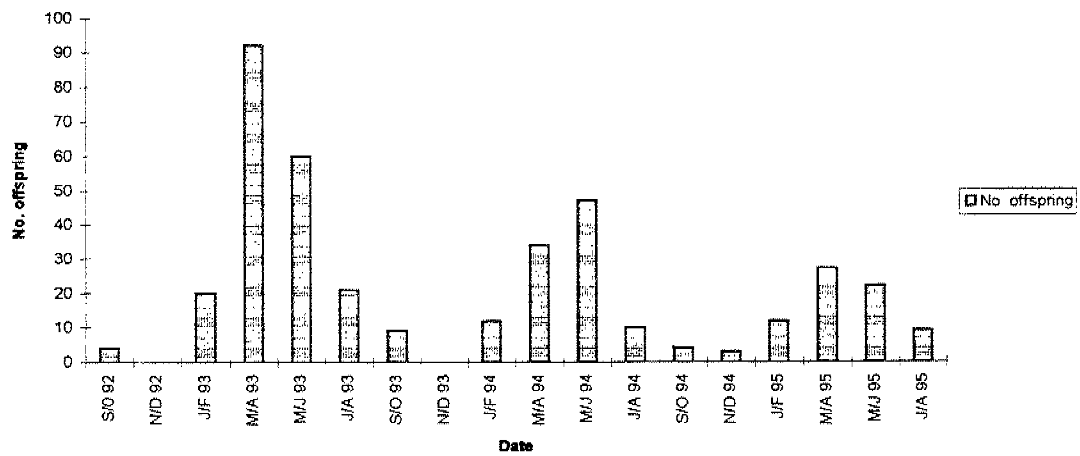


Figure 14 Total number of offspring produced each bimonthly period based on pregnant and recently pregnant females (from lactating females with uterine scars).

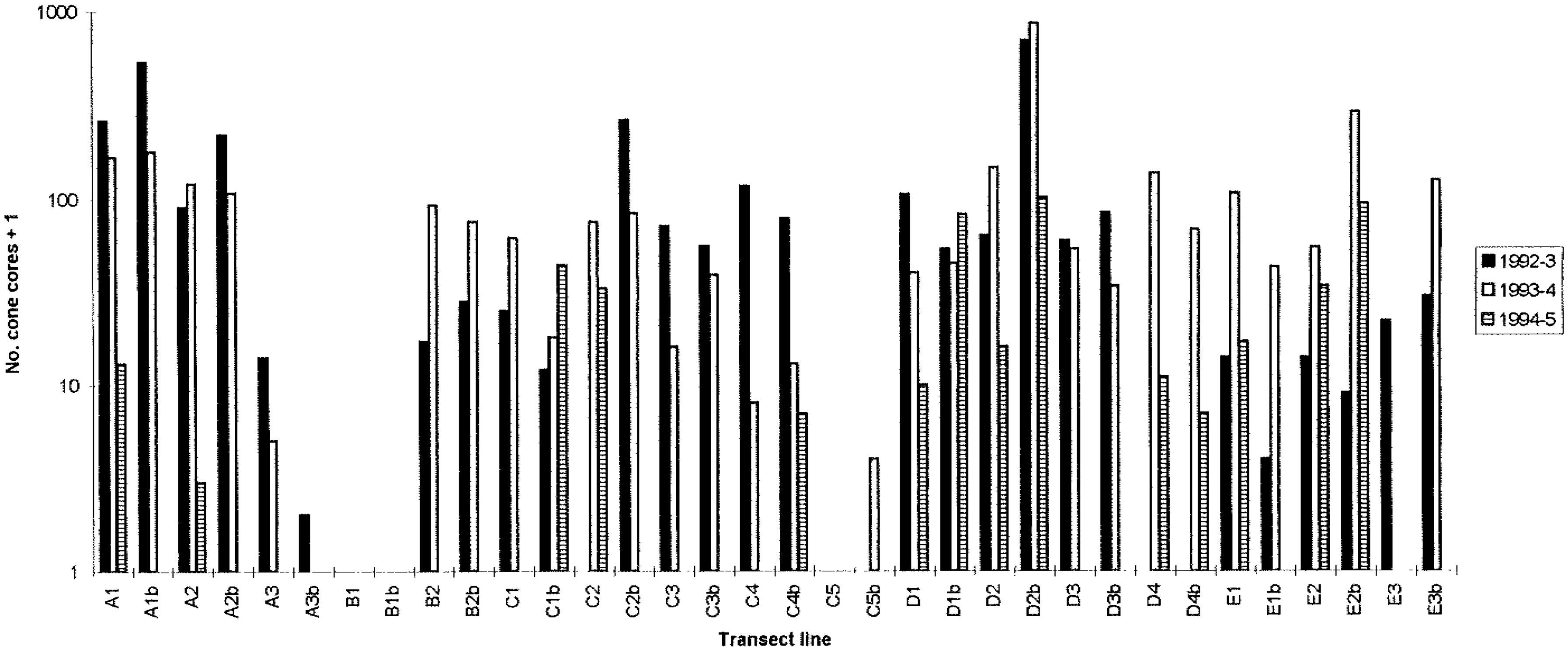


Figure 15 Total number of cores from eaten cones on the transect lines in each of 3 years. The cone year is taken from July to the following June (incl.)

There was a great deal of variation in the number of cone cores collected among and between the three 'cone years'. A cone year has been defined as the period from the beginning of July, just after the first cores of the new crop were collected, to the end of June in the following year. Approximately 3000 cones were taken in the first two years, but <500, i.e. a sixth, in the third year (Table 8). This is associated with lower numbers of grey squirrel entering the Reserve in the third year, but, in addition, it probably reflects a smaller number of cones available at this time.

The lines within the Reserve were worked in two groups; those in sectors A, B and C were examined together, and those in C and D were examined some 3 weeks later. An index of feeding remains has been derived from the mean number of cores collected per line per day since the date of the last collection, for these two parts of the Reserve (Figure 16). There was a general decline in the feeding index throughout cone year 1992-3. There was a peak in feeding, especially in sectors D and E, in winter in the year 1993-4. This partly reflects the presence of immigrating grey squirrels, but also feeding by red squirrels which were known to be present in sectors C, D and E. It is not possible to distinguish the cone feeding remains from the two species.

Cumulative numbers of cone cores collected in each of the three cone years for each of the transect lines are shown in Appendix 3 (note the different scales on the y axis of each graph). Most of the cumulative curves tend to increase in steps lasting from one to three months, rather than as continuous, moderate increases through time. For example, the forest around line A1b was used between December and January in 1992/3, and 1993/4 but was not used at any other times. Consequently, feeding occurred in a patchy manner through time and space. These patterns may have resulted from cone availability and the temporary presence of immigrant grey squirrels which tended to be removed in pulses. Many transect lines show increases during the winter to spring period in the first two years which coincided with increases in grey squirrel numbers (see Figure 2). There was little feeding throughout much of the forest in 1994/5, although we attribute feeding remains at lines C1b, C2, D1b, E2 and E2b to come from red squirrels.

Cone size (length) has been measured for each cone core. From trees over 50 years old, there was an overall significant difference in cone length between the species ($F_{2,1020} = 166.3$, $p<0.001$; mean length Scots pine was 37 mm (n = 99, stand.dev.= 7.4), Corsican pine 57 mm (57, 9.6) and mixed conifer, i.e. and mixture of Corsican and Scots pines, 43 mm (867, 6.5). There was also a difference in cone length according to species and year (Table 9), with Corsican pine cones being particularly small in 1994 (Figure 17). Further analyses on cone size, and seed and energy content will be presented elsewhere.

7.2.2 Broadleaf tree seed crops

Some horse chestnuts and sycamore seeds were found in 1992, but no beech nuts, and overall the broadleaf seed crops were poor to moderate (Table 10). In 1993 and 1994 the crops were very poor; grey squirrels were seen feeding on sweet chestnuts on the trees in 1994 but they were quickly depleted and none were found on the forest floor. In contrast, broadleaf seeds, and especially beech nuts, were abundant. This affected trappability of grey squirrels, and few were captured during the autumn and winter.

Table 8 Cone feeding transects. First letter of number denotes sector.

Line No.	Sub-cmpt	x coord	y coord	Species	Age (yrs)	Total No. cones per year 1992-3	1993-4	1994-5
A1a	3059A	579500	284500	MC (CP, SP)	46	262	168	12
A1b	3059A	579700	284600	MC (CP, SP)	46	538	179	0
A2a	3062C	580100	284800	MC (CP, SP)	64	89	120	2
A2b	3062B	580300	284900	SP	89	221	107	0
A3a	3068A	580300	283900	SP	65	13	4	0
A3b	3068A	580500	283900	SP	65	1	0	0
B2a	3174C	581500	282200	MC (CP)	24	16	92	0
B2b	3173A	581500	281900	MC (CP)	24	27	75	0
C1a	3126A	581200	283400	MC (CP)	27	24	61	0
C1b	3126A	581400	283400	MC (CP, SP)	27	11	17	43
C2a	3106D	581800	283900	MC (CP, SP)	69	-	75	32
C2b	3106A	581600	283700	MC (CP, SP)	30	265	83	0
C3a	3128B	581700	283200	CP	27	71	15	0
C3b	3128B	581800	283100	CP	27	55	38	0
C4a	3107B	581700	283400	CP	30	117	7	0
C4b	3107A	582000	283500	MC (CP, SP)	69	78	12	6
C5a	3129C	582000	283350	MC (CP, SP)	32	-	-	-
D1a	3111A	582700	283250	CP	25	106	39	9
D1b	3111A	583000	283200	CP	25	53	44	82
D2a	3053A	583500	283600	MC (CP, SP)	70	63	147	15
D2b	3053A	583600	283500	MC (CP, SP)	70	698	863	101
D3a	3088F	583700	283300	CD (SP,BE)	70	59	53	-
D3b	3088B	583500	283100	CP	70	84	33	-
D4a	3086A	583260	283600	MC (CP, SP)	70	-	137	10
D4b	3086A	583380	283550	MC (CP, SP)	70	-	68	6
E1a	3135A	582700	283000	MC (CP)	26	13	107	16
E1b	3135A	582900	282700	MC (CP)	26	3	42	0
E2a	3138A	582890	282470	CP	31	13	54	33
E2b	3138A	583070	282510	CP	31	8	292	94
E3a	3113A	583800	282800	CP	23	21	0	0
E3b	3113A	583900	282800	CP	23	29	125	0
					Total	2938	3057	461

For species see Table 1.

(a) Analysis of Variance Table for species and years 1993 and 1994

Source	DF	F	p
species	2	61.6	<0.001
year	1	46.9	<0.001
species*year	2	27.9	<0.001
Error	1594		
Total	1599		

(b) Means and standard deviations

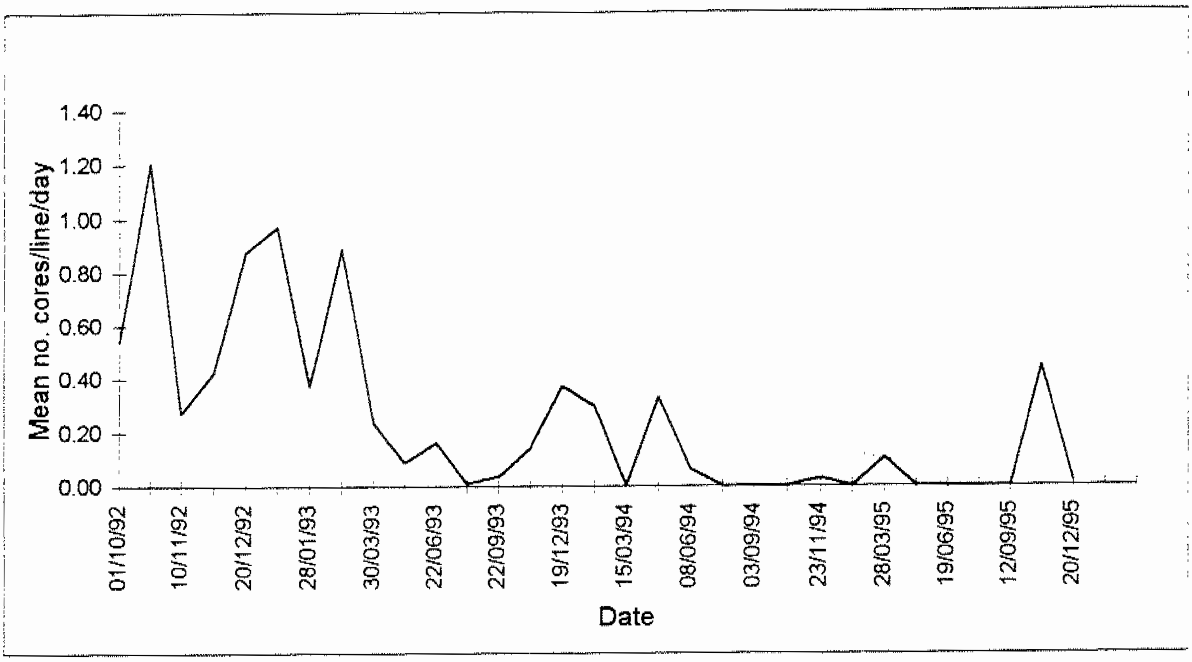
		1993	1994	1995	All
Scots pine	n	30	69	0	99
	mean	37	37		37
	stand.dev.	5.9	8.0		7.4
Corsican pine	n	87	169	138	394
	mean	55	43	56	50
	stand.dev.	8.8	10.6	11.3	11.3
Mixed conifer	n	345	900	593	1700
	mean	45	42	44	44
	stand.dev.	11.4	7.6	9.5	8.5
ALL	n	462	1138	593	2193
	mean	47	42	47	44
	stand.dev.	11.6	8.2	8.8	9.5

Table 9 Cone size (length mm) according to species and year

Year	Seed Crop Index
1992	Poor/moderate
1993	None/poor
1994	None/poor
1995	Abundant

Table 10 Index of size of broadleaf tree seed crops. Assessed by ground quadrats in selected compartments in the first week of November each year.

(a) Sectors A, B and C



(b) Sectors D and E

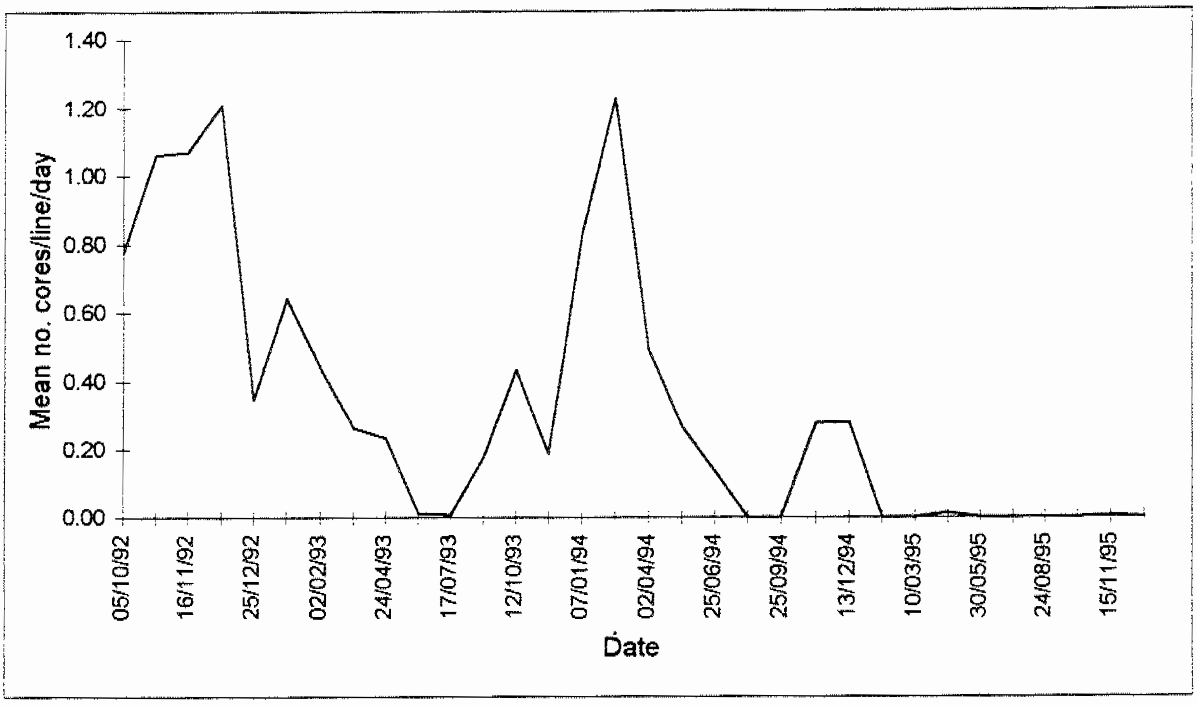


Figure 16 Index of cone feeding remains (mean number of cores collecetd per line per day since date of the last collection).

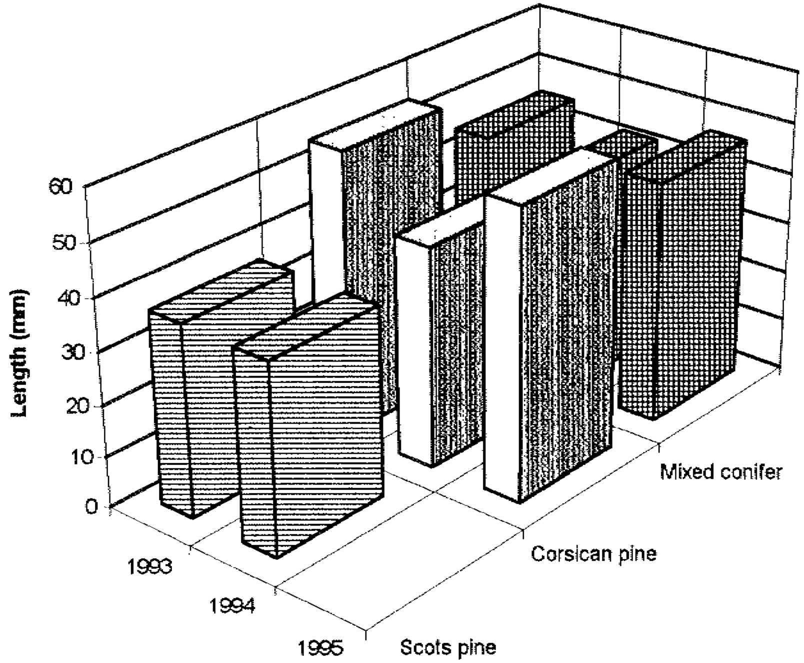


Figure 17 Mean cone length according to year and species.

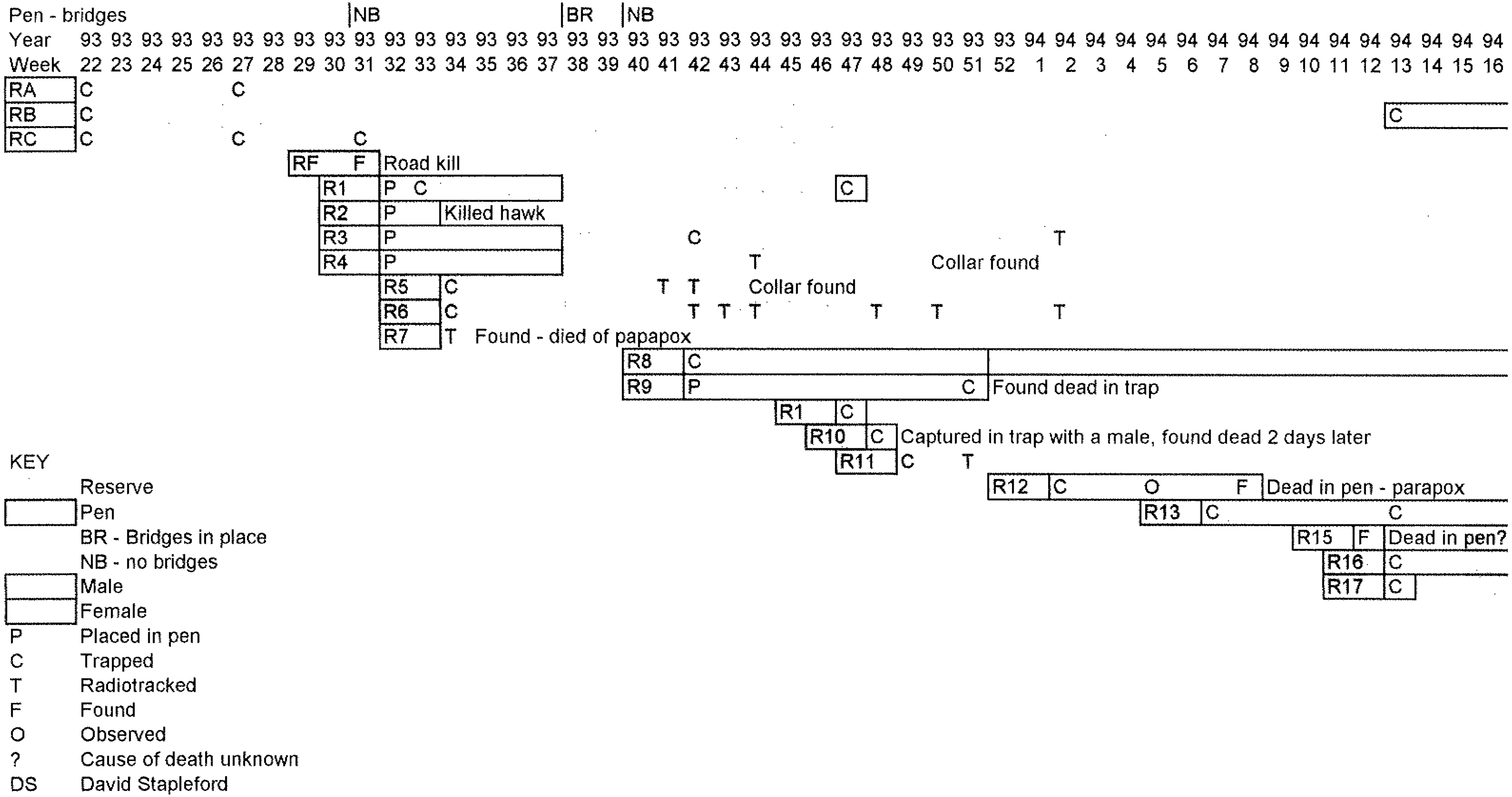


Figure 18 History of individual red squirrels

																								BR																								
	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	95	95	95	95	95	95	95	95	95	95	95	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	
RB		C																																														Dead in nest box - parapox
RC											C																																					
R6																																																
R8			C																																													
R13			C								C						C			T	T																									Found dead - septicaemia
R16			C								C														T															T					C			
R17																																																
R20			C				C									C																																Taken to DS
				F																																												Road kill
R22							C				C					C																																Taken to DS
R23							C				C					C																																Taken to DS
R25							C				C						C				F																									Found dead oustide pen - colisepticaemia
R26											C					C																																Taken to DS
R27																									C				C		T						F											Dead in reserve - lymphoma
R24																														C									C									
R28																																							C									
R30																																													C			

																											NB			BR														NB			
	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	96	96	96	96	96	96
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6
R6										C																																					
R16			C							C					C																													? entered			
R17										C					C																													? entered			
																					Replaced in pen																										
																					Replaced in pen																						C	Lost collar			
R30			C							C					C															F	Found dead in Reserve - ?																
										R29		F	Found dead - raptor																																		
													R31		C																															
													R32		C																															

	96 7	96 8	96 9	96 10	96 11	96 12	96 13	96 14	96 15	96 16	96 17	
R16				C							T	
R17				C							T	
R22				C							T	Killed - goshawk

7.3 Red squirrels within the reserve

7.3.1 Numbers, trappability, survival and breeding

A complete history of all the known red squirrels in the Reserve is shown in Figure 18. Thirtyseven individuals (19 males, 18 females) have been identified in the Reserve since the summer of 1993, but the maximum number known to be alive at any one time was nine (Figure 18). Squirrel R1 (from Kielder Forest), R2, R3 and R4 (from David Stapleford's collection), R8 and R9 (from Kielder Forest) were involved with the pilot reintroduction programme in 1993 (Gurnell, 1994; Gurnell & Venning, in press) and R24, R27 and R28 (all resident Thetford animals) were also released from the pen in the autumn of 1994 (Gurnell 1995). These releases will be considered further in a later report. Four animals (R20, R22, R23 and R26) were taken to David Stapleford in Fakenham; two (R22, R23) were returned to the pen in September 1995. These animals became ill during their time in David Stapleford's collection, possibly from a selenium and Vitamin E deficiency (see Gurnell 1995). They recovered after their food was supplemented with these nutrients. Typical body weights for the animals are shown later in Tables 15 and 16.

Twelve red squirrels were captured for the first time in the pen between November 1993 and July 1994; they entered the pen at times when there were no bridges over the pen fences (Figure 18). Grey squirrels also entered the pen and were trapped and removed from time to time. No squirrels were seen getting into the pen, but they must have done so by climbing up the fence posts and jumping in; once in, they were unable to get out until bridges over the fences were set up. In practice, therefore, the pen operated as a large, live-capture trap. From October 1994 to early 1996, and except for a short period in September 1995, the bridges were left in place over the fences thus removing the possibility of catching new squirrels in the pen. Probably as a direct consequence of this, only seven new animals were captured in the Reserve after October 1994 (Figure 18).

Only twelve red squirrels were first captured outside the pen, and recaptures within the Reserve have been few (Figure 18). Thus red squirrels in Thetford have proved to be very difficult to capture, and this was also found in studies carried out during the 1980's (Gurnell, 1996; Gurnell and Taylor 1989). A minimum estimate of red squirrel trappability (i.e. the probability of catching an animal in a trap at any one time) was calculated by dividing the number of captures of red squirrels by the number of trap-days of trapping in those areas where radiocollared red squirrels were known to be living. Between September 1993 and September 1994 there were 10 captures in 775 trap-days, i.e. a probability of capture in any trap on any day of 0.013. Comparable figures from September 1994 to September 1995 were 22 captures in 1180 trap-days giving a probability of capture of 0.019. The mean of these two figures is 0.016. Poor trappability is believed to be because red squirrels had sufficient food supplies in the forest canopy and were not attracted down to the bait at the traps. In contrast, grey squirrel trappability was high, except for the autumn and winter of 1995/6 when there was a very abundant crop of broadleaf seeds (Gurnell and Venning, 1995; also see Gurnell, 1996).

At the time of writing (April 1996), two females (R16, R17) are known to be present in the Reserve and have the longest known persistence times of 110 weeks. Other red squirrel persistence times were: 92 weeks (female R6), 58 weeks (male RC), 34 weeks (male R30) and

30 weeks (male R8). All other persistence times were <30 weeks. Persistence times do not reflect survival but the length of time animals were known to be alive within the Reserve.

Fourteen red squirrels are recorded to have died during the studies: 3 were killed by raptors (21%), 2 were road kills (14%), 1 accidentally died in a trap (7%; see Gurnell 1994), 8 died from some form of illness (57%; 3 parapoxvirus, 2 enteritis, 1 septicaemia, 1 lymphoma and 1 from unknown causes). Section 8 provides further details.

There is evidence that at least some female red squirrels bred in 1994 and 1995. R20 and R22 were born in the pen in spring 1994. The mother was either R13 who was pregnant and weighed 410g in February of that year, and/or R16 who was lactating in May and weighed 355g. In sector E of the Reserve, female R17 was lactating, and pregnant again, in May 1995 (weight 400g). On the basis of radiotracking studies, this female was believed to be suckling young at a drey in June and July 1995. Two juveniles were captured in sector E in July 1995, weighing 160g. These animals have not been seen since that time.

7.3.2 Home range size

Two estimators of home range size have been used. The first, the Minimum Convex Polygon (MCP) is based on the smallest polygon that can be drawn around a group of locations or fixes. MCP areas presented have made use of all locations (i.e. 100% MCP's). The second method is a parametric kernal (K) estimator based on estimating fix density over a matrix of intersections of a grid arbitrarily placed over the study area and interpolating contours (isolines) between the intersections. Thus, there may be more than one nucleus to a range using the k estimator, and the shape of the range gives a better representation of habitat use (see White and Garrott, 1990). Two estimates of K range size have been used: one using 95% of fixes furthest from the range centre (i.e. leaving out the outermost 5% of fixes), and one using 70% of fixes furthest from the range centre as an indication of the core area used by an animal. 70% ranges have been taken as the core areas for comparison with similar estimates in the literature. Utilisation plots to estimate the size of core areas will be presented elsewhere (see Ranges V manual, 1996).

Maps showing the positions of selected ranges are presented in Appendix 4. Ninety-five per cent kernal estimates varied from 6 ha to 36 ha for females (mean 17 ha, n = 18, st. dev. = 20.8) and from 15 ha to 35 ha for the one male from which good data have been obtained (R30; mean 24 ha, n = 6, st.dev. = 8.7) (Table 11). 70% core areas were 6 ha for both sets of data representing 35% of the 95% estimate of range size in females and 24% in the male. Together these figures suggest that 6 ha is the minimum area of pine forest required by red squirrels.

All the radiotracking fixes come from just two, obviously key, parts of the Reserve: in sector C around the pen and at the interface between sectors D and E (Maps 1, 3 and 4, and Appendix 4). Individuals have moved between the two areas, and female R6 spent a considerable amount of time in each area and this accounts for her very large total area of forest used by that animal, i.e. 95 ha (Table 11).

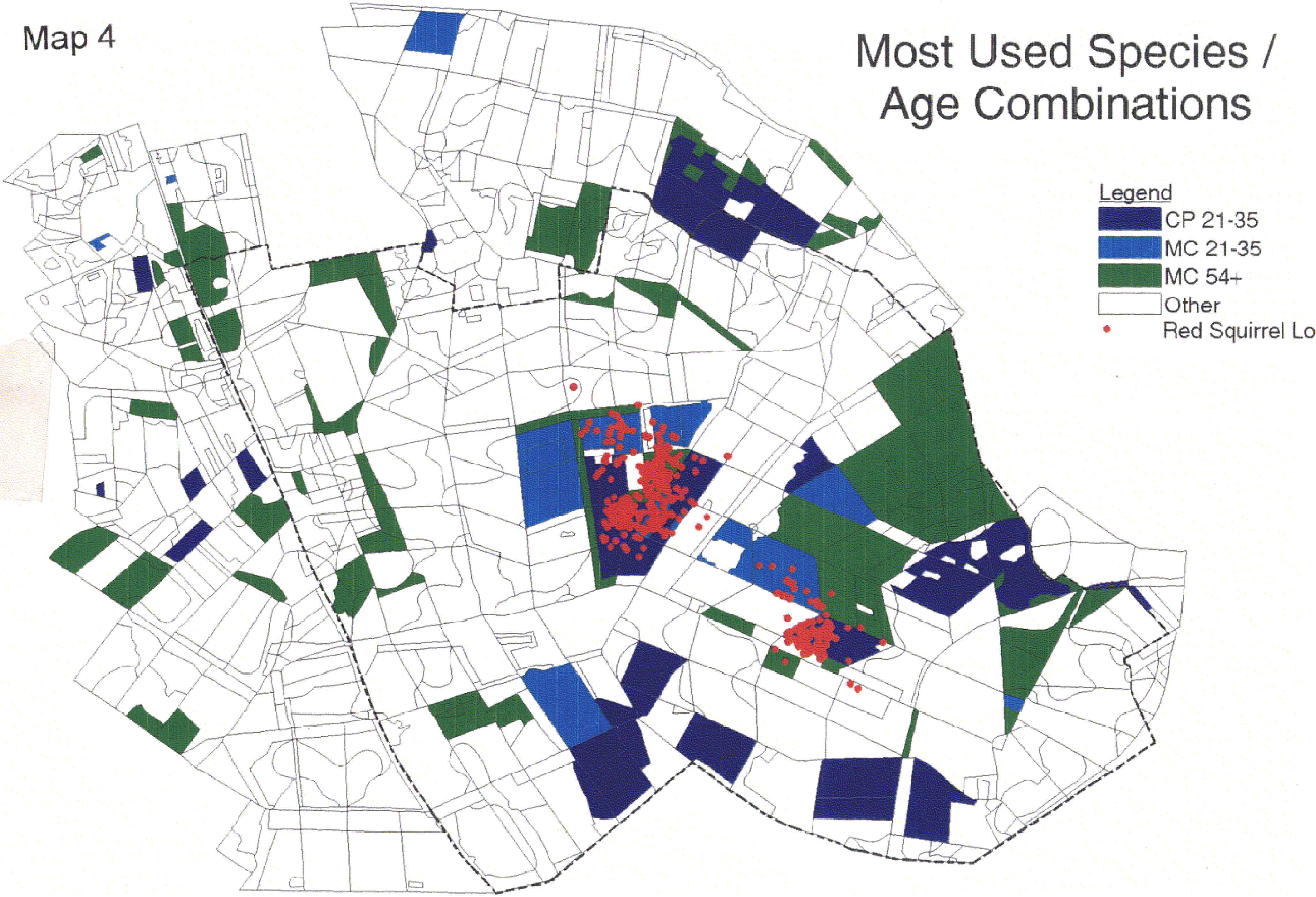
Animal No.	Sex	Month	No. fixes	MCP (%)	K (%)	
				100	95.0	70.0
R5	M	Sep-93	55	31.1	12.3	4.4
R6	F	Sep-93	63	16.1	15.3	7.9
R6	F	Jan-95	6	2.1	-	-
R6	F	Feb-95	9	15.4	-	-
R6	F	Mar-95	14	6.9	10.1	3.6
R6	F	Apr-95	19	19.8	35.7	10.1
R6	F	May-95	11	7.4	-	-
R6	F	Jun-95	13	11.9	10.1	3.6
R6	F	Jul-95	22	10.3	15.1	3.4
R6	F	All	94	98.5	94.3	32.6
R13	F	Sep-94	8	1.2	-	-
R16	F	Sep-94	45	15.6	19.5	4.3
R16	F	Oct-94	8	2.2	-	-
R16	F	Nov-94	11	1.1	-	-
R16	F	Jan-95	11	8.2	-	-
R16	F	Feb-95	8	4.5	-	-
R16	F	Mar-95	15	5.3	7.2	3.6
R16	F	Apr-95	12	12.6	16.6	7.5
R16	F	May-95	10	7.8	-	-
R16	F	Jun-95	12	7.0	-	-
R16	F	Jul-95	26	10.3	12.4	4.4
R16	F	Aug-95	26	6.8	9.2	2.5
R16	F	All	147	25.9	23.4	8.6
R17	F	Mar-95	9	4.1	-	-
R17	F	Apr-95	16	4.4	4.0	2.7
R17	F	May-95	9	1.6	-	-
R17	F	Jun-95	16	6.7	4.5	2.0
R17	F	Jul-95	26	7.4	6.6	2.5
R17	F	All	76	17.9	13.0	3.6
R25	F	Sep-94	6	0.4	-	-
R27	F	Oct-94	6	0.9	-	-
R27	F	Nov-94	14	2.1	2.9	0.9
R27	F	Jan-95	6	0.4	-	-
R27	F	Feb-95	6	0.5	-	-
R27	F	All	32	35.0	-	-
R30	M	Mar-95	35	24.2	30.5	12.0
R30	M	Apr-95	36	19.8	25.8	3.1
R30	M	May-95	10	5.5	13.2	3.7
R30	M	Jun-95	17	12.3	23.1	4.4
R30	M	Jul-95	27	22.4	35.1	6.7
R30	M	Aug-95	25	7.0	14.5	4.1
R30	M	Sep-95	8	3.6	-	-
R30	M	Oct-95	11	8.9	-	-
R30	M	All	177	49.3	41.5	17.7

Table 11 Home range sizes. Range area estimated by two methods: MCP = minimum convex polygon, K = kernal. Per cent figures refer to proportion of fixes furthest from range centre. Analysis carried out using Ranges V (ITE).
All - refers to the total range for all months of that animal. Kernal ranges only estimated where the number of fixes >12.

Map 3
Selected Species / Age Mixes
Legend
CP 0-10
CP 11-20
Other
SP 55+
Red Squirrel Locations

Map 4

Most Used Species / Age Combinations



Animal Number	Sex	No. crossings Side Ride	Main Ride	No. dreys used	Trees species used for dreys
R30	Male	32	12	6	Scots pine (4), Corsican pine (2)
R16	Female	12	6	2	Corsican pine (2)
R17	Female	25	4	6	Larch, Beech (2), Corsican pine (3)
R6	Female	11	12	2	Corsican Pine (2)

Table 12 Ride crossings and dreys used by four radiotagged squirrels in July and August 1995. Main rides , including tracks, are 12 m to 17 m wide, side rides are <4 m wide with canopies often meeting over the ride.

Tree species	Age (yr)	Area (km^2)	Relative Avail.	Red Squirrel Usage	Relative Red Sq. Use (o)	se(o)	Lower Conf. Int. (o)	Upper Conf. Int. (o)	Ivlev's Index	Selection Ratio (w)	se(w)	Bonferroni Conf. Int. Lower (w)	Upper (w)	Standard Ratio (B)
Lodgepole pine	21-34	0.03	0.002	6	0.012	0.005	0.000	0.026	1.00	6.410	1.033	5.378	7.443	0.286
Corsican pine	21-34	1.69	0.111	232	0.446	0.022	0.381	0.512	0.57	4.162	0.127	4.035	4.288	0.186
Mixed conifer	21-34	0.87	0.058	117	0.225	0.018	0.170	0.280	0.64	4.054	0.181	3.873	4.235	0.181
Mixed broadleaves	>54	0.13	0.008	16	0.031	0.008	0.008	0.053	1.00	3.799	0.485	3.313	4.284	0.169
Scots pine	21-34	0.05	0.003	3	0.006	0.003	0.000	0.016	0.07	1.861	0.786	1.075	2.647	0.083
Mixed conifer	>54	2.23	0.147	127	0.244	0.019	0.188	0.301	0.31	1.724	0.108	1.616	1.832	0.077
Mixed conifer	35-54	0.23	0.015	2	0.004	0.003	0.000	0.012	-0.72	0.267	0.363	0.000	0.630	0.012
Scots pine	>54	3.52	0.232	10	0.019	0.006	0.001	0.037	-0.85	0.086	0.082	0.004	0.167	0.004
Corsican pine	0-10	3.72	0.246	7	0.013	0.005	0.000	0.029	-0.90	0.057	0.079	0.000	0.136	0.003
Corsican pine	11-20	0.93	0.061	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.175	0.000	0.175	0.000
Corsican pine	35-54	0.27	0.018	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.331	0.000	0.331	0.000
Corsican pine	>54	0.35	0.023	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.290	0.000	0.290	0.000
Scots pine	11-20	0.14	0.009	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.463	0.000	0.463	0.000
Scots pine	35-54	0.25	0.016	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.347	0.000	0.347	0.000
Mixed conifer	0-10	0.24	0.016	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.352	0.000	0.352	0.000
Mixed conifer	11-20	0.11	0.007	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.522	0.000	0.522	0.000
Broadleaves	>54	0.10	0.007	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.546	0.000	0.546	0.000
Conifer dominant	>54	0.39	0.026	0	0.000	0.000	0.000	0.000	-1.00	0.000	0.274	0.000	0.274	0.000
Broadleaves	11-20	0.03	0.002	0	0.000	0.000	0.000	0.000	-1.00	0.000	1.095	0.000	1.095	0.000

Note: Negative lower confidence intervals have been set at zero

Table 13 Red squirrel habitat selection indices for the Red Squirrel Reserve. Ivlev's Index ranges from -1 (complete avoidance) through 0 (no selection) to +1 (complete preference), The selection ratio, w, is Relative Use/Relative Availability. The standardised ratio, B, is such that the selection ratios sum to 1 (see Manly et al., 1993). The selection ratio, w, is significantly different from 1 ($p<0.05$) if its confidence interval does not contain the value 1.

7.3.3 Dreys and the effects of rides on squirrel movement

The best information on drey use comes from four animals radiotracked in June and July 1995 (Table 11). Two females (R6, R16) each used two dreys in Corsican pine whereas the male, R30, and the female R17 each used six dreys in different species of trees. R17 was believed to have been suckling a litter of young in a drey in a beech tree at the interface between beech and pine crops during this period.

Main rides or forest tracks within the home ranges of these squirrels were not crossed as frequently as the small rides between compartments, except in the case of female R6 (Table 12). However, there is no evidence that forest tracks inhibited the movement of animals within their ranges.

7.4 Red squirrel habitat selection

Pooled together, the radiotracking data enables us to gain an objective estimate of the habitats selected by the red squirrels. Map 3 shows all the known locations (trap and radiotrack) of red squirrels and three of the most abundant tree-species age combinations within the Reserve: Corsican pine 0-10 years old, CP 11-20 years old and Scots pine >55 years old. Map 4 shows the known locations and the distribution of the three most heavily used habitats: CP 21-35 years old, Mixed Conifer 21-35 years old and MC >55 years. Figure 19 shows the sample proportion of used habitats and the proportion of habitats available, and Figure 20 presents the same data as a scattergram.

Habitat selection and standardised ratios have been calculated according to the methods presented in Manly *et al.* (1993). These ratios are based on the areas of different habitats available (Table 13; for classification of tree species and ages see Table 1). Overall, the sample proportion of habitats used is highly significantly different from the proportion of habitats available ($X^2_L = 1057$, df = 15, $p<0.001$) giving clear evidence of selection. (A similar exercise comparing the habitat at 500 observed locations with 500 random locations came to similar conclusions, $X^2_L = 878$, df = 15, $p<0.001$, and will not be presented here.) All the selection indices are also significant (Table 13).

In addition to the three most abundant habitats used shown in Map 4, red squirrels used small patches of Lodgepole pine, mixed broadleaves and Scots pine between 21 and 35 years old. In all, only 500 ha or 32% of the Reserve consists of habitat types that were used by red squirrels and most of these habitats were distributed in sectors C and E; approximately 50 ha were distributed in small patches which were probably too small to hold red squirrels (see Map 1). We expected that Corsican pine plantations <20 years old would not be used by red squirrels. The Corsican pine at Thetford do not start to produce good cone crops until about 30 years of age. (Scots pine produces good cone crops at between 15 and 20 years old and also provides good cover at these young ages.) As these young plantations grow older they will be used by red squirrels and the overall suitability of the Reserve will change (see below). We were, however, surprised that no Scots pine plantations >55 years old were used at all, even those plantations that were very close to the main centres of activity of the squirrels.

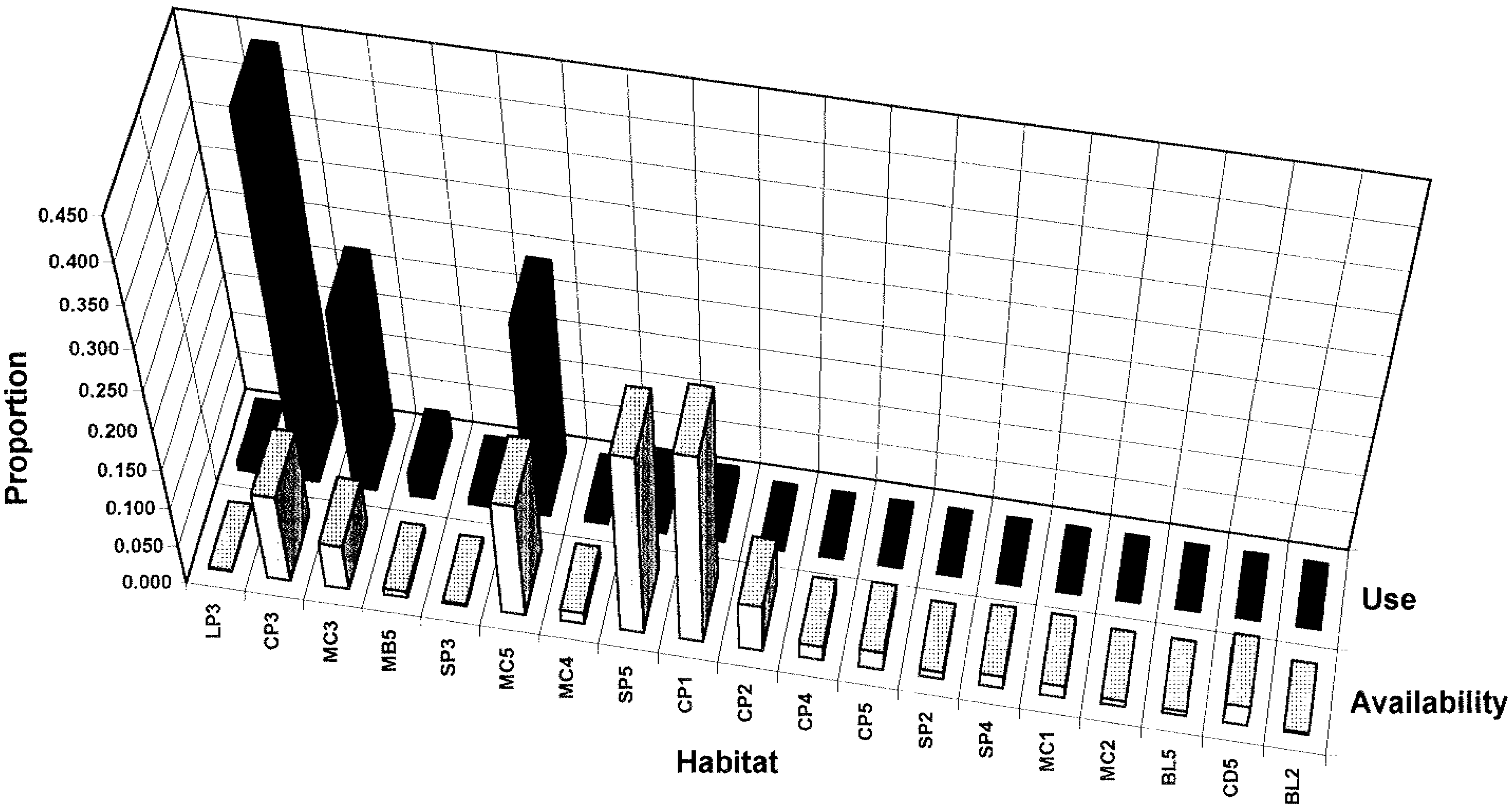


Figure 19 Proportion of habitats available and the proportion used by red squirrels. Notation as in Table 1.

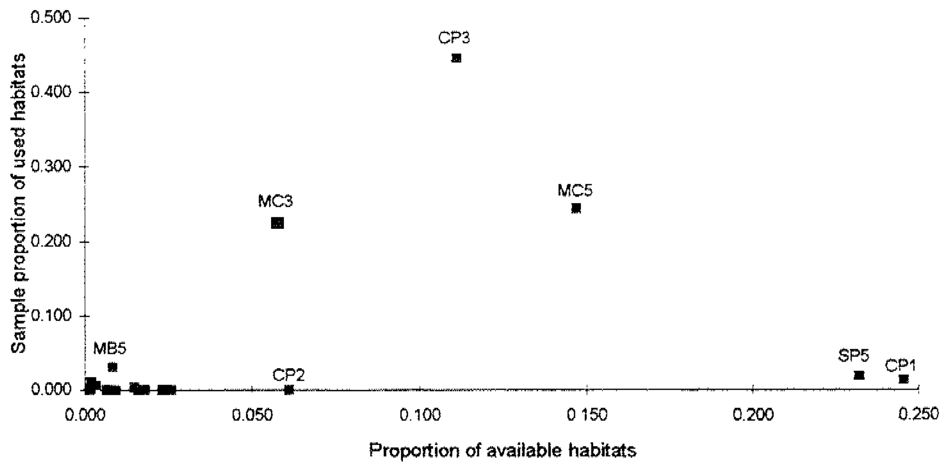
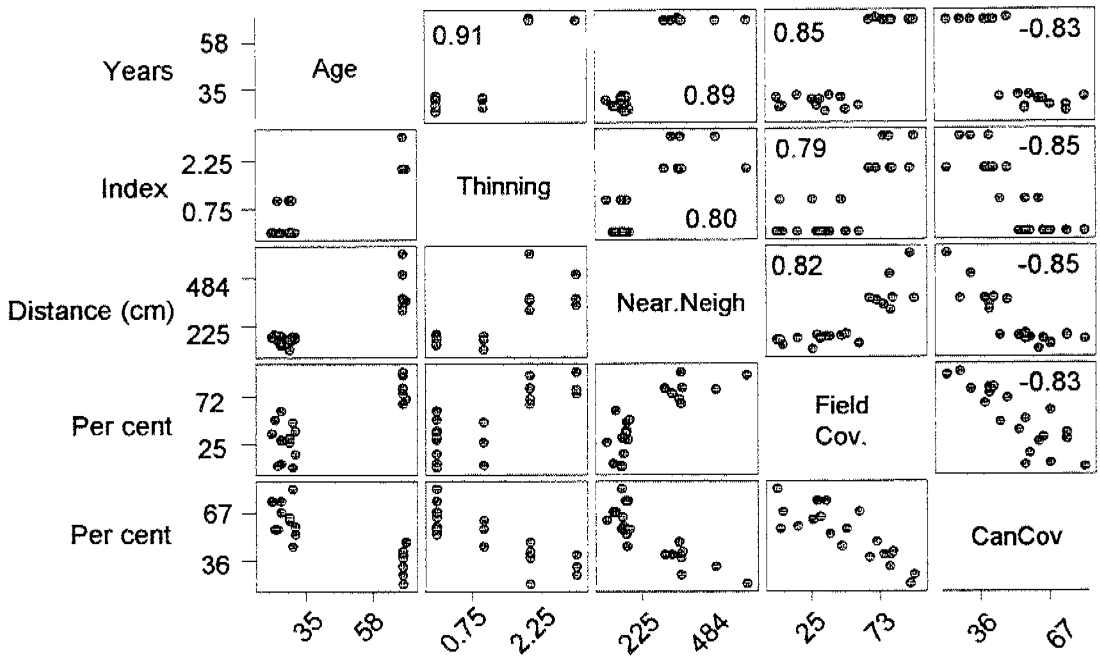


Figure 20 Scattergram between sample proportion of used habitats available and proportion of available habitats. The most prominent points are marked with a species and age code - see Table 1.

Cmpt No.	Tree species	Tree Age (yr)	Thinning	Stocking Density (no/ha)	Mean DBH (cm)	DBH n	DBH stdev	Basal Area (m^2/ha)	Mean NN (cm)	NN n	NN stdev	Drey Index	Field Cover (%)	Field Cover n	Field Cover stdev	Cone Feeding Index	Mean Cone Rank	Cone Rank n	Cone Rank stdev	Canopy Cover (%)	Can Cov n	Can Cov stdev
C1041	Scots pine	68	Late	44	36	28	5.3	4.6	373	28	92.7	0	81	15	26.8	11	2.4	10	1.07	42	10	24.0
C3077	Scots pine	68	Final	33	39	17	6.2	4.0	500	17	111.4	0	79	15	25.0	0	2.5	10	0.97	32	10	37.6
C3080	Scots pine	68	Late	40	37	25	6.0	4.2	370	26	95.5	2	65	15	28.6	0	0	10	0.00	38	10	31.7
C3083	Scots pine	68	Late	50	32	30	5.4	4.1	308	30	86.8	0	80	15	28.5	0	1.3	10	0.95	40	10	31.1
C3179	Scots pine	68	Final	44	33	23	4.5	3.7	369	26	98.6	0	96	15	10.8	0	0.5	10	0.97	27	10	24.7
C3181	Scots pine	68	Final	39	33	25	5.4	3.3	335	25	84.2	0	75	15	37.4	0	0.4	10	0.70	40	10	28.3
C3040	Corsican pine	68	Late	23	47	13	7.4	4.0	614	13	145.1	0	93	15	16.7	6	0.3	10	0.48	21	10	26.5
C3128	Corsican pine	26	None	178	19	30	6.9	5.2	128	30	46.1	1	58	15	17.9	3	1.6	10	0.97	67	10	31.3
C1307	Corsican pine	29	None	139	22	30	6.9	5.3	152	30	53.4	1	31	15	37.5	8	1.4	10	0.84	64	10	31.2
C3108	Corsican pine	23	None	173	21	30	10.8	6.1	165	30	47.6	2	35	15	33.9	5	1	10	0.82	74	10	20.8
C3111	Corsican pine	24	None	126	23	30	6.3	5.4	178	30	76.0	0	49	15	41.1	3	0.9	10	0.99	56	10	27.7
C3126	Corsican pine	26	None	111	24	30	6.1	5.2	171	30	65.0	1	29	15	25.9	7	0.7	10	0.67	74	10	29.8
C3135	Corsican pine	25	First	111	22	30	5.1	4.2	149	30	56.5	1	3	15	3.7	8	0.6	10	0.70	56	10	35.4
C3087	Mixed conifer	30	First	1613	25	30	4.6	79.6	170	30	58.3	2	46	15	35.7	0	0.9	10	0.74	45	10	29.7
C3106	Mixed conifer	29	First	2139	16	29	6.1	41.2	95	29	48.1	2	26	15	30.4	19	1.6	10	0.97	62	10	34.5
C3129	Mixed conifer	31	None	1687	20	30	6.0	55.4	166	30	42.2	2	38	15	36.1	25	1.1	10	0.88	53	10	34.8
C3130	Mixed conifer	31	None	2078	20	30	5.6	68.6	156	30	55.8	3	15	15	26.4	6	1.1	10	0.74	58	10	27.8
C3138	Mixed conifer	30	None	2200	25	30	9.6	104.4	149	30	26.0	2	1	15	2.1	25	0.6	10	0.52	82	10	13.2
C3086	Conifer/broadleaf	26	None	251	19	30	5.3	7.0	119	30	54.3	0	5	15	13.0	28	0.8	10	0.79	67	10	27.1
C3137	Conifer/broadleaf	69	Late	458	38	30	5.7	52.2	361	30	60.4	1	70	15	29.1	6	2.6	10	0.97	48	10	29.3

Table 14 Characteristics of selected habitats. DBH = diameter at breast height, NN = nearest neighbour.

Figure 21 Matrix plot for characteristics of selected compartments - see Table 13.



Figures in the upper diagonal boxes are correlation coefficients. All are significant at p<0.01 (two sided).

To examine the characteristics of the most abundant habitat types, we carried out detailed habitat inventories 20 selected compartments in the summer of 1995 (Table 14). There was a very high correlation between DBH and NN (r_{18} = 0.97, p<0.01), and only NN has been used in the matrix plot concerning THINNING, AGE, NN, FC and CC (Figure 21). The amount of field cover is inversely related to the amount of canopy cover which is in turn inversely related to the NN distance between trees and the amount of thinning that has been carried out (Figure 21). There was a significant difference between the mean NN distance between trees for compartments that had not been thinned or had undergone their first thin (1.5 m, stand. dev. = 24.5, n = 12) and those that had undergone a late or a final thin (4.0 m, stand. dev. = 101.8, n = 8) ($F_{1,18}$ = 70.4, p<0.001). Therefore, it seems that compartments that have undergone late or final thinning were not used by red squirrels either because it is difficult for them to move through the canopy, or because they are open and offer little protection from the weather. Red squirrels are known to be arboreal for most of the year (Kenward and Tonkin, 1986), especially when cones are present in the canopy, and they probably avoid moving between trees on the ground when there is a large amount of field cover present (see Kenward *et al.*, 1992).

In general it is not possible to distinguish the dreys of red and grey squirrels but since the habitat inventories were taken after 3 years of constantly removing grey squirrels, it is likely that most of the dreys originally built by grey squirrels had disappeared or were in a state of disrepair. Thus we assume that the majority of dreys seen in sectors C and E were built by red squirrels. Dreys were only seen in one of the conifer compartments with trees >68 years old (Table 13). Most dreys were in the younger Corsican Pine and Mixed Conifer compartments which reinforces the results from the habitat selection analysis. There was no correlation between the two indices of squirrel activity, DREY and FEED (r_{18} = 0.23, not sig.), or between FEED and CONE (r_{18} = 0.001, not sig.). The lack of association between these variables possibly results from the low density of red squirrels in the area.

8. Health and welfare of red squirrels

8.1 Background

Three diseases were of concern when the Thetford red squirrel research programme was initiated: parapoxvirus infection, metabolic bone disease and coccidiosis. Investigations of the health of red squirrels were carried out before and after release, and those animals found dead were subjected to post-mortem examination (Sainsbury and Gurnell 1995). In particular, parapoxvirus infection was monitored by electronmicroscopy of suspected tissues, metabolic bone disease by radiological and blood biochemical examination and coccidiosis by faecal examination. Other measures of health were assessed when appropriate including haematology, faecal bacteriology and examination of ectoparasites.

There was also a need to study the welfare significance of the conservation programme to the released and resident population. Welfare problems which can occur when mammals are reintroduced include, an inability to find sufficient food due to inexperience, excessive competition with the resident population for resources or aggression with conspecifics. Furthermore, reintroduced animals may contract infectious disease from the resident population. Similarly, the resident population may be at risk from competition, aggressive interactions and disease from those introduced.