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# Habitat use and population density of the red squirrel, *Sciurus vulgaris meridionalis*, in the Sila Grande mountain range (Calabria, South Italy)

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## ABSTRACT

Counts of squirrel nests (dreys) and vegetation surveys in 32 1-ha census stations were carried out to estimate densities in different forest types and determine habitat selection of the subspecies of red squirrel *Sciurus vulgaris meridionalis* in the Sila Grande forests, Calabria, South Italy. Dreys were not built randomly, but the majority was constructed at 60-70% of the total height of the nest-tree, pines and oaks being the preferred tree species. Mean drey densities, 2.75/ha, 2.78/ha, and 2.00/ha in, respectively, Calabrian black pine forest, beech dominated mixed forest, and chestnut woodlands, did not differ between forest types and extrapolated to estimated squirrel densities ranging from 0.44 to 0.61 squirrels/ha. Variation between stations in a tree species diversity index and in distance from the nearest plot of pine woodland significantly affected variation in drey density: squirrels preferred forest habitats dominated by beech, with also black pine and oak available, or chestnut woodlands that were within the range of one (male) squirrel home range diameter (310 m) of a plot of pine forest (mean drey density 5.4/ha). Fewer dreys were found in deciduous (beech or chestnut) woodland >310 m away from areas with pine forest (1.1 dreys/ha). Hence, the availability, at least in the vicinity of the census station, of pine seeds of the Calabrian black pine as main food resource strongly influenced habitat choice.

KEY WORDS: Mammal ecology - Ethology - Sciuridae - Rodentia.

## ACKNOWLEDGEMENTS

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## INTRODUCTION

In Italy, the current distribution of the red squirrel *Sciurus vulgaris* L., 1758, is closely linked to woodlands and continuous broadleaf and conifer mountainous forests of the Alps and Apennines at altitudes between 500 and 2000 m a.s.l. It is absent from Sicily and Sardinia (Cagnolaro, 1981). Isolated populations occur in woodland fragments of the upper Po plain of Piedmont and Lombardy, where its distribution is strongly affected by habitat destruction and woodland fragmentation and, in Piedmont, by the presence of the introduced American grey squirrel (Celada *et al.*, 1994; Currado *et al.*, 1997; Fornasari *et al.*, 1997; Wauters *et al.*, 1997a, b). Throughout the Italian peninsula, three different subspecies are recognized that differ in size and in coat colour. *S. vulgaris fuscoater* Altum, 1876, is found in northern Italy, and is characterized by small dimensions (condylobasal length from museum specimens from Liguria and Tuscany: range juveniles and adults pooled 43.2 - 47.7 mm, mean 45.6 mm,  $n = 82$  in Wiltsky, 1973), and a strong degree of coat-colour polymorphism both within and between populations (L. A. Wauters, unpubl. data). While this subspecies is also widely distributed in central and western Europe, the other two are endemic to Italy (Sidorowicz, 1971; Cagnolaro, 1981). The range of *S. vulgaris italicus* Bonaparte, 1838, is not well defined, but specimens have been collected in central and southern-Italy from Lazio and Abruzzo to Campania. It is a small subspecies (mean condylobasal length of adults 46.9 mm, after Sidorowicz, 1971) of which most populations show some degree of coat colour polymorphism, with the dark-brown morph dominant in mountainous forests at higher altitudes. Throughout Calabria, and probably also in parts of neighbouring regions of southern-Italy, the subspecies *S. vulgaris meridionalis* Lucifero, 1907, is monomorphic for fur colour, always having a uniform black dorsal fur with some greyish shades on the sides, a black tail and a strongly contrasting white belly. It is also the largest Italian subspecies (mean condylobasal length of adults 51.1 mm). Its current distribution in Calabria seems closely linked to that of extensive high-altitude mixed forests dominated by the native Calabrian black pine *Pinus laricio* Poirer, occurring principally in the mountainous areas of the Pollino, Sila Grande, and Sila Piccola massifs and Aspromonte, with probably a very small, isolated population in a pine woodland of the Catena Costiera mountain (Oriolo, 1998). There is, however, very little information on the current status, population size or densities, distribution and habitat use of the two latter subspecies in central and southern-Italy.

Here we present the first data on the distribution, habitat occupancy, and density of the Calabrian squirrel, in the Sila Grande mountain chain in Calabria. We searched for squirrel nests, called dreys, and typical feeding signs on pine cones to determine presence/absence of squirrels in different forest types (Wauters &

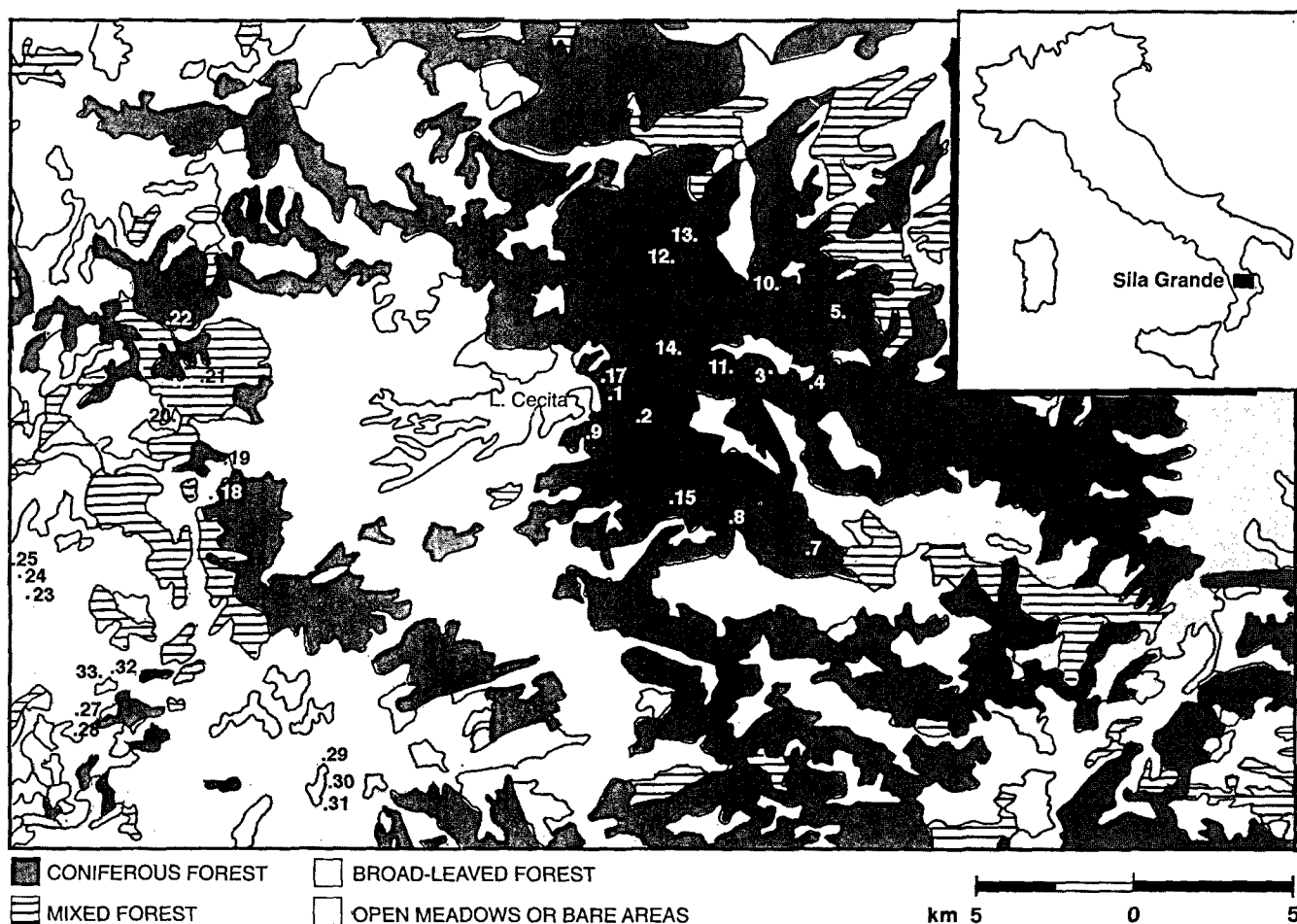


Fig. 1 - Habitat map of the study area in the Sila Grande and its location in Italy. The positions of the census stations are indicated with numbered dots.

Dhondt, 1988; Verboom & van Apeldoorn, 1990; Lurz & Garson, 1992; Andr n & Delin, 1994; Fornasari *et al.*, 1997), and performed drey counts to estimate a squirrel density index in different habitats (Wauters & Dhondt, 1988, 1990). Finally, we compared the suitability of two methods to evaluate habitat selection: drey counts and counts of consumed pine cones (e.g. Bryce *et al.*, 1997).

## MATERIALS AND METHODS

The Sila Grande (Fig. 1) is an extensive undulating plateau of 1170 km<sup>2</sup> extending from 800 m a.s.l. to a maximum of 1930 m a.s.l., in the southern Apennines, Calabria, southern Italy (39°24'N, 16°20'E). The climate changes markedly with altitude. Along the lower slopes, both on the Tyrrhenian and the Adriatic sides, the climate is typically Mediterranean with mild winters and hot dry summers. With increasing altitude and distance from the sea, the climate can be described as mountainous-Mediterranean characterized by wet relatively cool winters (mean temperature of coldest month 2° C, minimum -11° C) and warm relatively dry summers (mean temperature of warmest month 18° C, maximum 35° C). Rain or snowfall is concentrated from November to April (annual mean 1423 mm), and snowfall is most abundant in January with an average snow-cover of 26 days and an average snow-depth of 55 cm at an altitude of 1360 m a.s.l. (Fiore, 1999). Linked

to this climatic gradient, forest composition and structure change with altitude (Fig. 1). Between 600 and 1100 m a.s.l. broadleaf woodlands are dominated by chestnut *Castanea sativa*, once managed for the harvest of chestnuts but more recently mainly kept as coppices, most of which are single-species chestnut woodlands. In some areas, mixed deciduous woodland consists of different oak species, *Quercus cerris*, *Q. frainetto*, *Q. dalechampii*, and *Q. petraea*, and maple, *Acer obtusatum* and *Acer campestre*. Above an altitude of 1100 m a.s.l., the forest is dominated by the Calabrian black pine *Pinus laricio*, forming extensive, mature pine forest interspersed with beechwoods, *Fagus sylvatica*, that occur between 1200 and 1600 m a.s.l., especially on richer soils (Fig. 1). On some of the north-facing slopes beech woodlands are mixed with white fir *Abies alba*. The highest mountain tops are covered by pure beechwoods and, in more exposed places, by shrubland, dominated by hazel *Corylus avellana* and poplar *Populus tremula*. Finally, riparian woodland belts are characterized by alder *Alnus glutinosa*, *Salix* sp. and *Populus tremula* (Brandmayr *et al.*, 1991).

Squirrel winter density and habitat preference were studied by looking for and counting typical squirrel dreys in 32 census stations of 1 ha each from November 1997 to January 1999. Three main forest types were defined: black pine dominated forest ( $n = 16$  stations, > 80% conifers, pure or mixed with some beech or with other conifers); beech dominated forest ( $n = 9$  stations, < 20% conifers, pure beechwood or mixed with pine, white fir or oak); and pure chestnut woodlands ( $n = 7$  stations). Drey counts were made walking through every station on straight lines, about 20 m apart (Wauters & Dhondt, 1988; Fornasari *et al.*, 1997). Old

and dilapidated dreys were disregarded. When a drey was found, the following information was recorded: tree species; diameter at breast height (DBH, cm); height of the tree (m); height of the drey (m). Since there was no ivy *Hedera helix*, covering tree trunks in the study area, drey visibility was similar in all forest types.

Forest composition and structure in each census station was described by monitoring several vegetation characteristics in a 20 by 20 m subplot: canopy cover, ground cover, and understorey, classified in one of five categories (< 20% cover, 21-40%, 41-60%, 61-80%, > 80%); species composition of the understorey and the number of fruit-bearing (berries) understorey species; the number of trees of each tree species; the mean DBH (cm) and mean height (m) of each tree species (Table I). Five different understorey species producing berries were present: *Rubus* sp., *Rosa canina*, *Crataegus monogyna*, *Malus sylvestris*, and *Prunus avium*. We determined the proportion of Calabrian black pine, and calculated the Shannon-Wiener index of tree species diversity:

$$H = -(\sum p_i \times \ln p_i)$$

with  $p_i$  = proportion of species  $i$ .

To determine whether a squirrel having its drey in a certain station had a pine forest within a range of one home range diameter (< 310 m, based on a mean home range size of male red squirrels in mixed pine-deciduous forest in northern Italy of 7.5 ha, Lorusso, 1999), the distance to the nearest pine woodland was calculated. In a second step, each station received a score, hereinafter abbreviated as HRD, based on distance from the nearest pine forest. HRD = 1 for all stations in pine dominated forest, HRD = 2 for stations in beech dominated and chestnut forest with pine woodland at < 310 m, HRD = 3 for stations in beech dominated and chestnut forest with the nearest pine woodland at > 310 m.

For statistical analysis, a cover category was represented by its median value, and all data expressed as proportions ( $a$ ) were transformed using the arcsin  $\sqrt{a}$  transformation (Wauters *et al.*, 1995). The Pearson correlation coefficient was calculated to look for significant correlations between the different vegetation parameters in each census station ( $n = 32$ ) using the PROC CORR procedure in SAS (SAS, 1989). Tree density, the number of trees in 400 m<sup>2</sup>, was positively correlated with canopy cover ( $r = 0.459$ ;  $P = 0.0082$ ) and negatively correlated with DBH ( $r = -0.567$ ;  $P = 0.0007$ ), indicating that younger, denser forest consisted of smaller trees than more open (lower tree density) mature (larger DBH) forest. Therefore, tree density was used as an independent variable describing forest structure in multivariate models developed to

explain variation in drey density between census stations. Tree density and altitude were log-transformed to normalize data for multivariate analyses and the number of fruit bearing shrub species was transformed from a continuous variable into a class, having three possible values: no fruit bearing species = 0, one to two species = 1, more than two species = 2. One-way ANOVA and multiple ANOVA models using a stepwise backward procedure to select a model containing only significant variables or classes ( $P < 0.05$ ) were calculated with the PROC GLM procedure in SAS (SAS, 1989), regression models with the PROC REG procedure (SAS, 1989).

In 11 census stations dominated by Calabrian pine, we counted and removed all fallen cones and the remains of consumed cones on 22 cone-sampling plots of 2 by 2 m, from September to November 1997. The number of uneaten and consumed 'old' (brown coloured) cones removed on our first visit was used to determine spatial variation in cone productivity and pine seed predation rate by seed predators of the 1996 cone crop. We also determined the relative importance of different seed predators (% of cones consumed by squirrels, other rodents, and birds, in particular great spotted woodpecker *Picoides major* and crossbill *Loxia curvirostris*). For each census station, total cone consumption between September and November was used as an index of habitat use by squirrels.

Mean squirrel density was estimated from drey density using an average of 4.5 dreys per squirrel (after Wauters & Dhondt, 1988). The 95% confidence intervals were calculated using their regression equation: squirrel density =  $0.212 (\pm 0.175) + 0.221 (\pm 0.045) \times$  drey density (Wauters & Dhondt, 1988). We felt confident about extrapolating their regression equation to our data for the following reasons: (i) the number of dreys used per radiotagged squirrel in mixed conifer-broadleaf forests in northern Italy (4.5 - 5.1 dreys/squirrel, Lorusso, 1999) was similar to that in Belgium (4.85 - 5.03 dreys/squirrel, Wauters & Dhondt, 1990); (ii) overall forest structure and drey visibility in our study area were similar to those encountered in the study areas of Wauters & Dhondt (1988); and (iii) drey visibility was comparable over all forest types encountered in our sampling plots.

## RESULTS

Census stations in chestnut woods were different from those in the other two forest types, having always a single tree species ( $H = 0$  in Table I) and a poorly de-

TABLE I - Forest structure characteristics for the different woodland types.

| Parameter           | Conifer forest     | Beech dominated mixed forest | Chestnut forest    |
|---------------------|--------------------|------------------------------|--------------------|
| Altitude (m a.s.l.) | 1345 $\pm$ 175     | 1546 $\pm$ 229*              | 1034 $\pm$ 74      |
| Trees/plot          | 38 $\pm$ 22        | 81 $\pm$ 60*                 | 56 $\pm$ 57        |
| DBH (cm)            | 34.0 $\pm$ 12.0    | 28.0 $\pm$ 8.6               | 43.4 $\pm$ 23.1    |
| Tree height (m)     | 23 $\pm$ 6         | 16 $\pm$ 3*                  | 16 $\pm$ 4         |
| Canopy cover (%)    | 61 $\pm$ 18        | 88 $\pm$ 7**                 | 67 $\pm$ 21        |
| Understorey (%)     | 19 $\pm$ 20        | 19 $\pm$ 14                  | 21 $\pm$ 11        |
| Und. div.           | 2.0 $\pm$ 1.5      | 1.2 $\pm$ 1.0                | 0.3 $\pm$ 0.5      |
| H                   | 0.15 $\pm$ 0.28    | 0.8 $\pm$ 0.29               | 0                  |
| Dreys/ha            | 2.75 $\pm$ 2.35    | 2.78 $\pm$ 2.82              | 2.00 $\pm$ 2.64    |
| Squirrels/ha        | 0.61 (0.52 - 1.12) | 0.61 (0.53 - 1.13)           | 0.44 (0.39 - 0.92) |

( $\bar{x} \pm$  SD). Und. div., the number of understorey shrub species with consumable fruits; H, Shannon-Wiener index of tree species diversity. For calculation of squirrel density see methods (95% confidence interval between brackets). Student t-test comparing means between conifer and beech dominated forest: \*,  $P < 0.05$ ; \*\*,  $P < 0.01$ .

veloped understorey (only *Rubus* sp.). In general, beech forest differed from black pine dominated forest in having a higher tree density of smaller trees and a denser canopy cover (Table I). Chestnut woodland tended to have fewer stations with squirrel dreys (3 out of 7, 43%) than beech forest (6 out of 9, 67%), or pine forest (13 out of 16, 81%), but these differences were not statistically significant ( $\chi^2 = 3.366$ ;  $df = 2$ ;  $P = 0.18$ ). Mean drey density (Table I) did not differ between the three forest types (one-way ANOVA  $F = 0.24$ ;  $df = 2, 29$ ;  $P = 0.79$ ). Overall drey density was  $2.59 \pm 2.48$  dreys/ha which extrapolated to a mean density of 0.57 squirrels/ha. Density estimates for the different forest types were 0.61, 0.61, and 0.44 squirrels/ha in, respectively, black pine forest, beech dominated forest and chestnut woodlands (Table I).

In a multiple ANCOVA model, the partial effects of forest type, tree density, altitude and the number of shrub species with consumable fruits were not significant (Table II). In the selected model, variation in tree species diversity and HRD accounted for 33% of variation in drey density between census stations (Table II). Drey density increased significantly with tree species diversity ( $r = 0.413$ ;  $n = 32$ ;  $P = 0.019$ ), and was higher in stations that had pine forests nearby. Stations in mixed beech dominated forest or in chestnut woodland that had pine forest within a distance less than the diameter of a male squirrel's home range ( $< 310$  m, factor HRD = 2,  $n = 5$ ;  $5.40 \pm 1.95$  dreys/ha) had a higher drey density than stations in pine dominated forest (HRD = 1,  $n = 16$ ;  $2.75 \pm 2.35$  dreys/ha) and than stations with no pine forest within that distance (HRD = 3,  $n = 11$ ;  $1.09 \pm 1.70$  dreys/ha; Tukey test for differences between two means gave HRD 2 with 1,  $P = 0.02$ ; HRD 2 with 3,  $P = 0.0007$ ; HRD 1 with 3,  $P = 0.052$ ).

The selection of trees for drey building was not random (observed frequency of occurrence compared to expected frequency of occurrence based on the abundance of

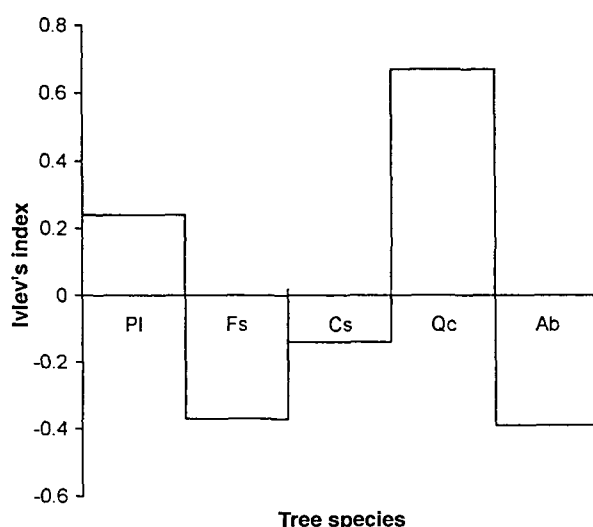


Fig. 2 - Ivlev's electivity index of tree species used for nest building (PI, Calabrian black pine; Fs, beech; Cs, chestnut; Qc, oaks; Ab, white fir).

different tree species:  $\chi^2 = 39.2$ ;  $df = 4$ ;  $P < 0.001$ ). Out of 83 dreys monitored, 59% were found in black pine, 16.9% in beech, 16.9% in chestnut, 6% in oak, and 1.2% in white fir. An Ivlev electivity index (Krebs, 1989) showed that squirrels selected black pine and oak for drey building, while beech, chestnut, and white fir were used less than expected from their relative availability (Fig. 2). Squirrels preferred large trees for constructing dreys (paired t-test of mean height of drey trees versus mean height of all trees per census station:  $n = 22$ ;  $t = 2.197$ ;  $P = 0.039$ ). Dreys were built between 7 and 38 m high ( $\bar{x} \pm SD = 15.8 \pm 7.0$  m) in black pine, 7 and 21 m ( $13.1 \pm 3.6$  m) in chestnut, 7 and 13 m ( $12.1 \pm 2.5$  m) in beech, and 9 and 18 m ( $12.0 \pm 3.7$  m) in oak (Fig. 3). On average, dreys were found at 60% of the total height of the tree in black pine, and at 70% in all other tree species. We tested whether drey height was affected by height of the drey tree, tree species, and forest type with a multiple ANCOVA model. The effect of tree species ( $F = 1.89$ ;  $df = 3, 76$ ;  $P = 0.14$ ), and of forest type ( $F = 1.19$ ;  $df = 2, 79$ ;  $P = 0.31$ ) were not significant. Variation in tree height alone accounted for 50% of the observed variation in drey height (linear regression:  $F = 79.7$ ;  $df = 1, 81$ ;  $P < 0.0001$ ; Fig. 3).

Pine cone productivity (old cones removed in September 1997) varied greatly between stations ( $\bar{x} \pm SD = 36 \pm 24/m^2$ , range 6 - 87), but was not correlated with drey density ( $r = -0.073$ ;  $n = 10$ ; NS). Only 24 % ( $SD = 17\%$ , range 7-60%) of cones was consumed, with squirrels being the main seed predator (% of eaten cones consumed by squirrels  $76.7 \pm 15.2\%$ ), followed by birds ( $15.0 \pm 18.1\%$ ), and other forest rodents ( $8.3 \pm 6.7\%$ ). Of the 10 stations where consumption of fresh cones was monitored during autumn (mean duration of monitoring  $30 \pm 13$  days), squirrels consumed an average of  $4.9 \pm 5.1$  cones (range 0 - 15.6) over a 30-day period. Pine

TABLE II - Multiple ANCOVA model testing the effects of forest type, tree density, altitude, the number of understorey species with consumable fruits (shrubs), tree species diversity (Shannon-Wiener index,  $H$ ) and HRD (see Material and Methods), on variation in drey density between census stations (dependent variable).

|                     | F    | df   | P      | R <sup>2</sup> |
|---------------------|------|------|--------|----------------|
| Full model          | 2.85 | 7.24 | 0.026  | 0.45           |
| Factors removed     |      |      |        |                |
| Tree density        | 0.10 | 1.24 | 0.75   |                |
| Forest type         | 0.38 | 2.25 | 0.69   |                |
| Altitude            | 2.40 | 1.26 | 0.13   |                |
| Shrubs              | 1.02 | 1.27 | 0.32   |                |
| Selected model      | 5.97 | 3.28 | 0.0028 | 0.39           |
| Significant factors |      |      |        |                |
| H                   | 7.84 | 1.28 | 0.0092 |                |
| HRD                 | 5.04 | 2.28 | 0.014  |                |

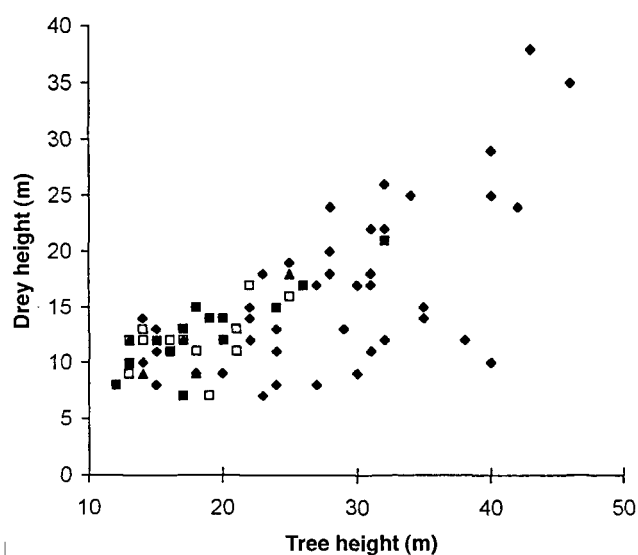


Fig. 3 - Linear regression of drey height over tree height in the Sila Grande study area (diamond, pine forest; square, mixed beech dominated forest; triangle, chestnut woodland).

cone consumption rate was positively correlated with drey density ( $r = 0.748$ ;  $n = 10$ ;  $P = 0.013$ ), indicating that it can be used as a relative density index. Of a total of 178 collected fresh pine cones, 97 were consumed (54%), with squirrels, again, being the most important pine seed predators (86.6% of eaten cones), followed by great spotted woodpecker (6.2%), crossbill (5.1 %), and small forest rodents (2.1%).

## DISCUSSION

Red squirrels feed on a wide variety of different types of food, changing their diet with seasonal availability. Their primary food resource, however, is tree seeds which form the bulk of the squirrel's diet from late June to the end of March (e.g. Moller, 1983; Gurnell, 1987; Wauters *et al.*, 1992). Consequently, annual fluctuations in tree seed crops and spatial variation in tree seed abundance are the main determinants of red squirrel population dynamics, in particular reproductive rate and dispersal behaviour (Wauters & Dhondt, 1990; Wauters & Lens 1995; Lurz *et al.*, 1997), spacing behaviour and habitat use (Wauters & Dhondt, 1992; Piqué, 1997; Lurz *et al.*, 1999). Red squirrel densities vary widely throughout their European range (reviewed in Lurz *et al.*, 1995): they are lowest in young boreal forests and man-made conifer plantations in northern England, intermediate in mixed broadleaf-pine forests in southern Europe and in oak-hazel woodlands in England, and highest in Scots pine dominated woodlands and mixed oak-beech-Scots pine woodlands in western-Europe (Lurz *et al.*, 1995; Wauters & Lens, 1995; Piqué, 1997; Kenward *et al.*, 1998; Wauters & Gurnell, 1999).

Our density estimates, based on drey counts, for the three different woodland types in the Sila Grande (0.44 - 0.61 squirrels/ha) were similar to those reported in a mixed Scots pine-chestnut-oak forest at the edge of the upper Po plain, northern Italy, that were based on capture-mark-recapture and radiotracking (winter density 0.54 squirrels/ha, Wauters & Gurnell, 1999). In a high-quality, oak-hornbeam-maple woodland, in the upper Po plain of Piedmont, containing also walnut (*Juglans regia*) and black walnut (*J. nigra*) of which the seeds were the main food resource throughout autumn, winter, and early spring, winter densities of red squirrels were considerably higher (ca. 1.6/ha, Wauters & Gurnell, 1999). Also in northern Spain, Piqué (1997) estimated higher densities (mean winter density of 0.97 marked squirrels/ha, with a strongly biased male sex-ratio), in a Mediterranean forest dominated by *Pinus halepensis* and several oak species, *Quercus ilex*, *Q. suber*, and *Q. cerrioides*. In a suburban park with a temporally predictable and rich food supply, and few predators, squirrels were very abundant and densities (1.7/ha) were similar to those found in the mixed deciduous woodland in northern Italy (Piqué, 1997).

In the Sila Grande, red squirrel drey densities did not differ significantly between woodland types. Pure chestnut woodlands offer a rich food supply of highly preferred chestnuts (Lorusso, 1999) from September (immature seeds in trees) to February-March (fallen and scatter-hoarded nuts), but have little or no alternative food available during the rest of the year. Most years (rich seed crops) of beech resulted in a strong increase in squirrel numbers in Belgium, through increased reproduction, recruitment of young and immigration, but they occur irregularly with very poor seed crops in the intermediate years (Wauters & Lens, 1995). Therefore, beech dominated forest can be an extremely good habitat in some years, but a very poor one in others, probably resulting in strong annual fluctuations of local density and flexible dispersal behaviour of both young and adult squirrels (see also Andrén & Lemnell, 1992; Lurz *et al.*, 1997 in mixed conifer forests with extreme temporal variation in the size of tree seed crops). We did not estimate the production of beech seeds in our study area and have no data on long-term fluctuations of seed crops. Therefore, we are unable to evaluate whether the current density estimate in beech forest was related to a situation of good, medium, or poor food availability. The Calabrian black pine forest had drey densities similar to beech dominated forest. Counts of fallen and consumed pine cones indicated that only 24% of cones available from July 1996 to June 1997 had been eaten, with red squirrels being the main seed predator (77% of consumed cones). Hence, squirrel densities seemed to be well below the carrying capacity defined by pine seed availability in the pine forests of the Sila Grande. Also in northern Italy, density in mixed Scots pine-chestnut-oak forest was lower than expected based on food abundance (Lorusso, 1999). It was suggested that

the lower squirrel densities relative to those found in habitats similar in food abundance and food quality, in Belgium, might be caused by a more complete community of woodland predators (Lorusso, 1999). In fact, pine marten (*Martes martes*) in the Sila Grande, beech marten (*Martes foina*) in northern Italy, and goshawk (*Accipiter gentilis*) in both areas can be important squirrel predators (e.g. Marquiss & Newton, 1982; Marchesi *et al.*, 1989; De Marinis & Masseti, 1995; Halliwell, 1997) that were not present in the study sites in Belgium (but see Wauters & Lens, 1995 for goshawk). Alternatively, habitat quality might be poorer in the Sila Mountains black pine forest compared to Belgian pine dominated woodlands. This seems unlikely, however, since the mean number of cones/m<sup>2</sup> of black pine produced in 1996 was similar to that produced by Scots and Corsican pine in good seed years in Belgium, but the energy content per cone is higher for black pine (24.2 kJ/cone against 3.54 kJ/cone for Scots pine, Wauters *et al.*, 1992; Fiore, 1999). Hence, Calabrian black pine forest seems to have a higher pine seed production than Belgian pine forests. Whether, based on drey counts, we underestimated squirrel density at the Sila Grande can only be checked using capture-mark-recapture.

Habitat selection by red squirrels, measured by drey density within 1-ha sampling stations, was mainly determined by tree species diversity within a sampling station and by its distance from the nearest pine woodland. Drey densities were highest in mixed beech dominated plots with some pine trees that were within a (male's) home range diameter distance from areas of pine woodland. It was lowest in beech and chestnut woodland stations further away from pine woodland, and intermediate in pure Calabrian black pine forest. Clearly, the first situation presents the richest habitat in terms of food availability. Beechnuts or chestnuts are readily available in autumn-winter, while in spring pine buds, shoots, and male flowers can be consumed in the nearby plots of pine forest. From June onwards, the squirrels start feeding heavily on the immature seeds of fresh pine cones, which continue to be their main food resource until late August-early September, when deciduous seeds progressively become more important (see also Moller, 1983; Wauters & Dhondt, 1987; Wauters *et al.*, 1992). Pure chestnut woodland in our study site has no or little understorey and therefore contains food (chestnuts) for only a limited period of the year (September-February). It was avoided by the squirrels, when not sufficiently close to a pine forest, to allow daily movements for visiting pine trees (> 310 m), which would be particularly important in spring and early summer (April-July) for feeding on berries of shrub species and on pine buds, shoots, flowers, and immature seeds (Wauters & Dhondt, 1987).

Squirrels selected Calabrian black pines and oaks for nest building, while other tree species, especially beech, were avoided. Selection of certain tree species is typically found in all studies on drey site selection

throughout the squirrel range (Tittensor, 1970; Pulliainen, 1973; Wauters & Dhondt, 1988, 1990; Fornasari *et al.*, 1997; Piqué, 1997). Also drey height was clearly non-random, but the majority of dreys were built at about 60% of total height of the nest-tree in pines, and at 70% in other tree species. This relative height is slightly lower than values reported for northern Italy (Fornasari *et al.*, 1997).

Consumption rate of Calabrian black pine cones in autumn was positively correlated with drey density over several census plots, suggesting that both indices of squirrel abundance are consistent. A similar consistency of different sampling techniques was also found in a Scots pine plantation with extremely high red squirrel densities in Scotland (Bryce *et al.*, 1997). We did not use hair-tubes to monitor squirrel presence or to estimate squirrel abundance, although this method has proved very useful in conifer plantations in northern England and Scotland (e.g. Garson & Lurz, 1996) and tube occupancy has a good potential for being calibrated, allowing calculation of absolute squirrel densities (Lurz & Garson, unpubl. data). In the future, we are planning to repeat our drey censusing in combination with hair-tube monitoring, and to carry out hair-tube surveys throughout Calabria to determine the distribution of the Calabrian red squirrel and to study how it is affected by habitat composition and habitat fragmentation.

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