# Ecological relationships between small mammals and age of coppice in an oak-mixed forest in central Italy

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# ECOLOGICAL RELATIONSHIPS BETWEEN SMALL MAMMALS AND AGE OF COPPICE IN AN OAK-MIXED FOREST IN CENTRAL ITALY

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## INTRODUCTION

Environmental factors and animal species are strictly related, and plants in a given ecosystem form structures that are important to animals (for reviews see Diamond, 1975 ; Bersier & Meyer, 1995 and Danielson, 1992). For instance, forestry greatly influences the bird assemblages even on a small scale (Harris, 1984 ; Blondel, 1986 ; Fuller & Moreton, 1987 ; Virkkala, 1987 ; Saxon, 1990 ; Thiollay, 1992 ; Bersier & Meyer, 1995).

Coppice is an ancient and traditional type of forest management in Mediterranean sylviculture. Forest regeneration is constituted almost entirely by shoots produced from the cut stumps, and the rotation is usually very short (10-15 years). In central Italy, the deciduous oaks (*Quercus cerris* and *Q. pubescens*), which are in turn dominant in the coppice forests, are among the most important tree species subjected to such management. *Q. cerris* is widespread mainly on acid and subacid moist soils, while *Q. pubescens* is widespread especially on dry and poor soils. Both these oak species are usually subjected to a rotation of about 10-12 years, and occasionally of about 15-18 years.

Coppice forests are inhabited by a rich variety of animals. This animal variety is thus strongly influenced by the human use of the forested territory. The ecological distribution and relationships between animals inhabiting coppice forests have been thoroughly studied in several European countries (for a review see Buckley, 1992). For instance, importance of coppicing and forest management to insects and other invertebrates is quite evident (Warren, 1987 ; Hill *et al.*, 1990) and general opinion suggests that coppicing especially benefits those species that prefer early growth stages. On the contrary, species strictly linked to dead wood and mature trees tend to be confined in older areas of coppice forests (Greatorex-Davies & Marrs, 1992).

The relationships between small mammals and coppices have received attention in the northern latitudes (e.g. see Gurnell, 1985), but not in the Mediterranean Europe where practically nothing is known on both the ecological distribution and the seasonal variations in the abundance of the small mammal

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fauna in relation to the rotation cycle. However, this topic is especially interesting for the studies on the influence of forest management on free-ranging animal populations, as the human activities produce a mosaic of patches different both in space and in time in their attractiveness to rodents (e.g. see Diaz, 1992).

Aims of the present paper are to examine, for the first time to our knowledge as far as the Italian peninsula is concerned, (i) the composition and diversity of the small mammal community in the different successional stages of coppice regrowth in a managed forest with relatively long coppice rotation (once every 18 years), and (ii) the conservation implications coming from the study of the relationships between small mammals and age of coppice.

# MATERIALS AND METHODS

### STUDY AREA AND SAMPLING PERIODS

The research was carried out between March and December 1994 in a woody area situated about 15 km northeast of Rome, on the left bank of the river Tiber (about 30-70 m a.s.l.). The study area, previously sampled for field studies on the ecological relationships between owls, small mammals, lizards and snakes (Capizzi & Luiselli, 1995 ; Capizzi *et al.,* 1995), consists of a 150 ha forested area surrounded by cultivated fields. The whole area is part of an hunting reserve (« La Marcigliana »).

The wood is divided into several patches, which are in turn coppiced once every 18 years. In every clear-cut plot 60-80 standards per ha are retained. The wood is composed by deciduous oaks (mainly *Q. cerris,* but also *Q. robur, Q. frainetto* and *Q. pubescens*). Other common trees are *Ulmus minor, Acer campestris, Fraxinus ornus* and *Robinia pseudoacacia.* The undergrowth is constituted by *Rubus fruticosa, Ligustrum vulgare, Crataegus monogyna, Rosa canina, Prunus spinosa, Sambucus nigra, Euonymus europaeus, Ruscus aculeatus* and *Smilax aspera.*

Four trapping sessions were performed during the study period : one in spring (1-5 april 1994), one in summer (1-5 july), one in autumn (1-5 october) and one in winter (1-5 december).

### SELECTION OF THE SITES AND TRAPPING PROCEDURES

Study sites were selected as effective samples of different wood age classes. Small mammal traps were placed in four different environmental types : (1) clear-cut area (1 year old) ; (2) young wood (6 years old) ; (3) mature wood (12 years old) ; (4) old wood (18 years old). In each environmental type, five different plots were sampled in every season. The various plots were spaced at least 300 m apart each the others. Thus, we assumed each plot as an independent unit for all analyses. In confirmation of this, no animal marked in a given plot was recaptured in another plot.

In each plot, 10 trap-stations were aligned and spaced 10 m apart. Each trap-station consisted of two self-made WEB traps (Le Boulengé & Le Boulengé-Nguyen, 1987), baited with oats and fillet of mackerel. Thus, twenty traps per

trapline were used. This method provides a reliable index of presence for studies of population dynamics in small mammals (Hansson, 1967 ; Linn & Downton, 1975 ; van Apeldoorn et al., 1992). Each trapping-trip lasted five nights and the traps were visited every morning. Thus, a total of 8000 trap-nights was conducted.

We used a capture-mark-recapture method (see Flowerdew, 1976 ; Montgomery, 1987). Every captured individual was classified to species, weighed, sexed and marked by toe-clipping. No animal was killed or intentionally damaged during the process of this study. To discriminate as correctly as possible between *Apodemus sylvaticus* and *A. flavicollis,* a discriminant function (on living material previously captured at the study area) was calculated before the beginning of the present study (Capizzi, in prep.). Due to the difficulty in the correct identification of the shrew species (*Crocidura leucodon* and *C. suaveolens*), we avoided further classification, and thus refer to them in the following text simply as *Crocidura* sp.

STATISTICAL ANALYSES

All the statistical analyses were done with a SAS computer package (version 6.0), all tests being two-tailed, and $\alpha$ set at 5 %. Diversity of small mammal community composition in the various plots was assessed by using a Simpson's diversity index (1949). One-way ANOVA was employed to compare the seasonal fluctuations in the numerical abundance of the various small mammal species (Student-Newman-Keuls *post hoc* test). Since recaptures between seasons were very few, we used a straightforward ANOVA rather than a repeated measure ANOVA, that would be the better procedure in the eventuality of multiple recaptures throughout seasons. Spearman rank correlation coefficient and multiple regression analysis were computed to correlate abundance of species with the age of wood. In these correlation analyses we pooled the numbers of animals captured during the four seasons in each plot, so that a total of twenty cases is processed. Principal Component Analysis (PCA) was performed in order to detect which small mammal species are the most important to explain differences between wood age classes. Canonical Discriminant Analyses (CDA) were used to classify the plots by means of the small mammal occurrence. For the use of multivariate statistics we followed recommendations in Capen (1981). All data were tested for homoscedasticity before using any statistical application and, in the case, normalised.

Nonparametric tests were used when we failed in obtaining a normal distribution of data.

# RESULTS

GENERAL FEATURES OF SMALL MAMMAL OCCURRENCE

A total of 753 individuals belonging to eight small mammal species was captured (Table I). The commonest species in the whole area was the Woodmouse (*A. sylvaticus,* 43.4 % of the total amount of caught animals), followed by the Bank Vole (*Clethrionomys glareolus,* 22.8 %) and the Yellow-necked Woodmouse (*A. flavicollis,* 12.2 %). The House Mouse (*Mus domesticus,* 2.4 %), the Ship Rat (*Rattus rattus,* 4.2 %) and the Brown Rat (*Rattus norvegicus,* 0.7 %) were occasionally caught. Shrews of the genus *Crocidura* were also frequently trapped (9.3 %).

Table I

*Total number of small mammal specimens captured in every season in relation to age of wood.*

| Species | Spring | | | | | Summer | | | | | Autumn | | | | | Winter | | | | | Total | | | | | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 6 | 12 | 18 | t | 1 | 6 | 12 | 18 | t | 1 | 6 | 12 | 18 | t | 1 | 6 | 12 | 18 | t | 1 | 6 | 12 | 18 | t | |
| *Apodemus sylvaticus* | 35 | 50 | 24 | 9 | 118 | 16 | 24 | 9 | 4 | 53 | 28 | 30 | 11 | 6 | 75 | 41 | 21 | 12 | 7 | 81 | 120 | 125 | 56 | 26 | 327 | 43.4 |
| *Apodemus flavicollis* | 4 | 3 | 8 | 15 | 30 | 2 | 5 | 2 | 9 | 18 | 3 | 1 | 6 | 12 | 22 | 1 | 2 | 9 | 10 | 22 | 10 | 11 | 25 | 46 | 92 | 12.2 |
| *Apodemus* sp. | 5 | 2 | 5 | 2 | 14 | 1 | 3 | 0 | 0 | 4 | 4 | 4 | 4 | 3 | 15 | 1 | 2 | 0 | 1 | 4 | 11 | 11 | 9 | 6 | 37 | 4.91 |
| *Clethrionomys glareolus* | 6 | 22 | 20 | 33 | 81 | 4 | 10 | 11 | 11 | 36 | 2 | 8 | 7 | 9 | 26 | 9 | 6 | 8 | 6 | 29 | 21 | 46 | 46 | 59 | 172 | 22.8 |
| *Mus domesticus* | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 2 | 1 | 4 | 1 | 4 | 1 | 2 | 8 | 1 | 2 | 1 | 0 | 4 | 4 | 6 | 5 | 3 | 18 | 2.39 |
| *Rattus rattus* | 1 | 3 | 1 | 1 | 6 | 0 | 1 | 2 | 3 | 6 | 0 | 2 | 4 | 4 | 10 | 0 | 4 | 4 | 2 | 10 | 1 | 10 | 11 | 10 | 32 | 4.25 |
| *Rattus norvegicus* | 3 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 5 | 0.66 |
| *Crocidura* sp. | 5 | 4 | 2 | 0 | 11 | 6 | 5 | 5 | 1 | 17 | 13 | 7 | 6 | 3 | 29 | 6 | 1 | 4 | 2 | 13 | 30 | 17 | 17 | 6 | 70 | 9.3 |
| Total | 60 | 85 | 61 | 60 | 266 | 30 | 48 | 31 | 29 | 138 | 52 | 56 | 39 | 39 | 186 | 59 | 38 | 38 | 28 | 163 | 201 | 227 | 169 | 156 | 753 | 100 |

SEASONAL VARIATIONS

Pooling together all the small mammal species, the highest peak of captured animals was recorded in spring, when a total of 266 specimens was caught. A lower number of specimens was recorded in autumn ( n  =  186 ) and winter ( n  =  163 ), but the lowest number of captures was recorded in summer ( n  =  138 ). These seasonal fluctuations were statistically significant (one-way ANOVA : $F_{3,76}$  =  15.46, p  <  0.000001 ). One-way ANOVA was performed to test whether the abundance of the different species significantly differed during the sampling period (Table II). The species that showed significant abundance differences between seasons were C. glareolus ($F_{3,76}$  =  15.73, p  <  0.000001 ), A. sylvaticus ($F_{3,76}$  =  3.84, p  <  0.02 ), and Crocidura sp. ($F_{3,76}$  =  4.66, p  <  0.005 ). C. glareolus were captured significantly more often in spring than in the other seasons, while A. sylvaticus were captured significantly less often in the summer months and Crocidura were captured significantly more often in autumn than in the other seasons (in all cases, Student-Newman-Keuls post hoc test).

TABLE II

One-way ANOVA (3,76 degrees of freedom) on the number of small mammal individuals caught in the different seasons of this study.

| Species | mean | F ratio | p value |
|---|---|---|---|
| Apodemus flavicollis | 1.15 | 1.14 | n.s. |
| Apodemus sylvaticus | 4.09 | 3.84 | * |
| Clethrionomys glareolus | 2.15 | 15.72 | *** |
| Crocidura sp. | 0.87 | 4.66 | ** |
| Mus domesticus | 0.225 | 1.60 | n.s. |
| Rattus rattus | 0.40 | 0.904 | n.s. |
| Total | 9.41 | 15.46 | *** |

(n.s. : not significant ; * : p < 0.05 ; ** : p < 0.005 ; *** : p < 0.000001).

SMALL MAMMAL OCCURRENCE IN DIFFERENT WOOD AGE PLOTS

The relationships between small mammal occurrence and wood age are given in table III. The numbers of captured A. sylvaticus (Spearman r  =  − 0.84, n  =  20, p  <  0.000003 ) and Crocidura sp. (Spearman r  =  − 0.74, n  =  20, p  =  0.0002 ) were inversely correlated with wood age. Conversely, the numbers of captured A. flavicollis (Spearman r  =  0.87, n  =  20, p  =  0.000001 ), C. glareolus (Spearman r  =  0.69, n  =  20, p  <  0.0008 ), and Rattus rattus (Spearman r  =  0.52, n  =  20, p  <  0.02 ) were positively correlated with wood age. Multiple regression analysis, performed by considering together the interactions of the various small mammal species (as independent variables) versus the wood age (dependent variable), attained a very high statistical significance (multiple  r = 0.975,  adjusted  $r^2$  =  0.929, ANOVA : $F_{6,13}$  =  42.575, p  <  0.000001 ).

TABLE III

Values of Spearman correlation coefficient (r) between wood age and species occurrence. In this analysis we pooled the numbers of animals captured during the four seasons in each plot, thus 20 cases are considered for the regression.

| Species | r value | sign. |
|---|---|---|
| Apodemus flavicollis | 0.872 | *** |
| Apodemus sylvaticus | − 0.844 | *** |
| Clethrionomys glareolus | 0.690 | ** |
| Crocidura sp. | − 0.737 | ** |
| Mus domesticus | − 0.092 | n.s. |
| Rattus rattus | 0.521 | * |

(n.s. : not significant ; * : $p < 0.05$ ; *** : $p < 0.001$ ; **** : $p < 0.00001$).

Figure 1 shows the loadings of the first two factors extracted from PCA. Factor 1 (eigenvalue = 2.940 ; % explained variance = 48.997) ordered the species within the multivariate space better than factor 2 (eigenvalue = 1.514 ; % explained variance = 25.240 ; cumulative % of explained variance = 74.237) : it represents the canopy structure, and the highest scores on the x axis are associated with the typically forest taxa (e.g. A. flavicollis and C. glareolus).

A first CDA was performed to classify plots situated in all wood age classes. It provided three different functions, but only the two with the highest eigenvalues are plotted in figure 2. The resulting model (with 6 variables, Wilks' $\lambda = 0.00531$, $F_{18,31} = 9.43$, $p < 0.0001$, see tables IV and V) correctly classified 100 % of cases. The differently aged wooded areas resulted clearly separated by the occurrence of small mammals, their centroids being quite distant (see figure 2). Significance of the first two discriminant functions was very high ( $p < 0.000001$ for the first one and $p < 0.005$ for the second one), while the third one was not statistically significant ( $p = 0.4$ ). Factor structure indicates that A. flavicollis and A. sylvaticus are highly correlated with root 1 (table IV), that was the most significant in the given model (table V). However, it should be noted that the correlation with root 1 is of opposite sign in the two Apodemus species, that indicates a clear habitat separation between these congeneric rodents.

A further discriminant analysis was performed between plots belonging to environmental types (3) and (4) (i.e. 12 and 18 years of age) to check whether they were also discriminated by the occurrence of small mammal species (table VI). In this analysis (Wilks' $\lambda = 0.01$, $F_{6,3} = 46.7$, $p < 0.005$ ) 100 % of cases are correctly classified ( $\chi^2 = 22.74$, df = 6, $p < 0.0009$ ). Coefficients and factor structure indicate that the greatest contribution to discrimination was given by A. flavicollis, which was highly correlated with the obtained function.

Values of Simpson's diversity measure calculated on the small mammal community composition of the twenty studied plots (with data from four seasons cumulated) are shown in figure 3. The various plots differed significantly as far as the diversity values is concerned (one-way ANOVA : $F_{3,16} = 14.597$, $p < 0.0008$ ), and a Tukey honest significance post-hoc test revealed that (i) plots in environmental type (1) differed significantly from those in (3)
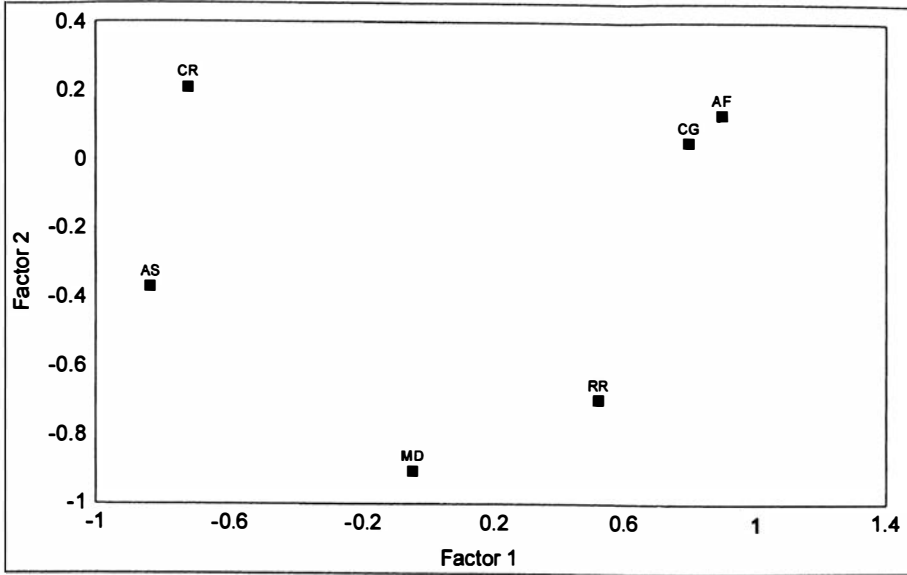
Figure 1. — Factor loadings of variables (species) included in the PCA. Symbols : AF = *Apodemus flavicollis*, AS = *A. sylvaticus*, CG = *Clethrionomys glareolus*, CR = *Crocidura* sp., MD = *Mus domesticus*, RR = *Rattus rattus*.

## TABLE IV

*Standardized canonical discriminant function coefficients and factors structure (only for significant functions) of variables included in first discriminant analysis performed between sites belonging to four different wood age classes (100 % of cases correctly classified).*

| Species | ROOT 1 | | ROOT 2 | | ROOT 3 |
| --- | --- | --- | --- | --- | --- |
| | Coeff. | Factors | Coeff. | Factors | Coeff. |
| *Apodemus flavicollis* | − 1.155 | − 0.416 | − 0.528 | − 0.087 | − 0.701 |
| *Apodemus sylvaticus* | 0.970 | 0.488 | 0.477 | − 0.017 | 0.528 |
| *Clethrionomys glareolus* | − 0.123 | 0.209 | − 1.302 | − 0.481 | 0.004 |
| *Crocidura* sp. | − 0.588 | − 0.167 | 0.740 | 0.303 | − 0.165 |
| *Mus domesticus* | 0.311 | − 0.033 | 0.495 | − 0.091 | − 0.633 |
| *Rattus rattus* | − 0.252 | 0.065 | − 0.614 | − 0.255 | − 0.253 |

( p = 0.0003 ) and in (4) ( p = 0.006 ), (ii) plots in environmental type (2) differed significantly from those in (3) ( p = 0.0009 ) and in (4) ( p = 0.035 ), (iii) plots in environmental type (1) did not differ significantly from those in (2) ( p = 0.81 ), and (iv) plots in environmental type (3) did not differ significantly from those in (4) ( p = 0.27 ).
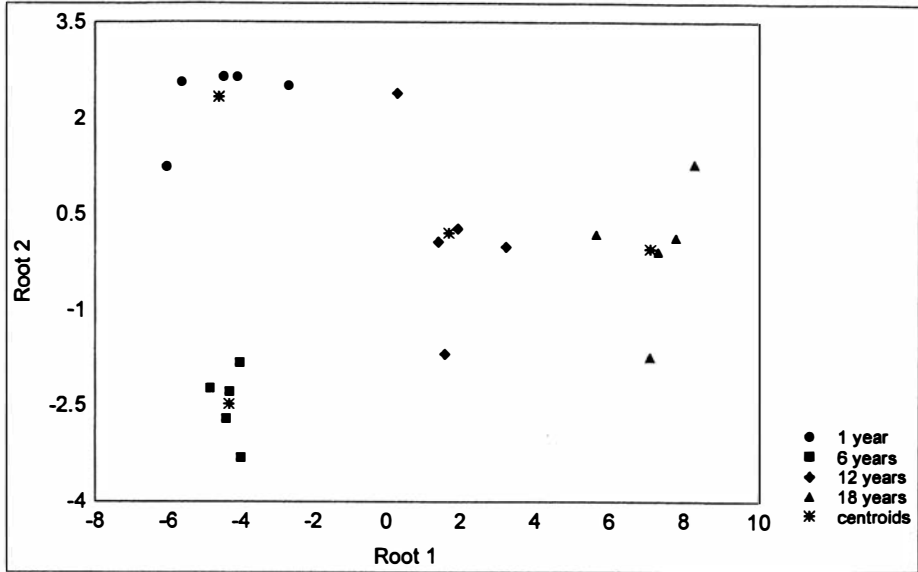
Figure 2. — Scatterplot of different wood age plots in discriminant space of first two roots in Canonical Discriminant Analysis (CDA). Asterisks represent the group means (centroids). In this analysis we pooled the numbers of animals captured during the four seasons in each plot, thus 20 cases are considered.

TABLE V

*Chi-square test with successive roots removed in canonical disciminant analysis performed between sites belonging to four different wood age classes.*

| Roots removed | Eigenvalues | Canonical correlation | Wilks' $\lambda$ | $\chi^2$ | d.f. | $\chi^2$ signif. |
|---|---|---|---|---|---|---|
| 0 | 29.617 | 0.983 | 0.005 | 73.333 | 18 | ** |
| 1 | 3.616 | 0.885 | 0.163 | 25.431 | 10 | * |
| 2 | 0.332 | 0.500 | 0.750 | 4.018 | 4 | n.s. |

(n.s. : not significant ; * : $p < 0.005$ ; ** : $p < 0.00001$).

## DISCUSSION

*A. sylvaticus* was the most abundant small mammal species in the study area during all the four seasons of research. This is consistent with previous studies showing that this species (i) is very common in most of the agro-forested and bushy Mediterranean landscapes (Moreno & Kufner, 1989 ; Canova & Fasola, 1991, 1993), and (ii) is one of the main food resource for a variety of predators, including e.g. birds of prey (Capizzi & Luiselli, 1995), carnivorous mammals (e.g. see Papageorgiu *et al.,* 1988) and snakes (Luiselli & Agrimi, 1991 ; Luiselli &

TABLE VI

*Standardized canonical discriminant function coefficients and factors structure of discriminant function calculated on plots 12 and 18 years old (d.f. = 6, $\chi^2$ = 22.74, p < 0.0009 : 100 % of cases correctly classified).*

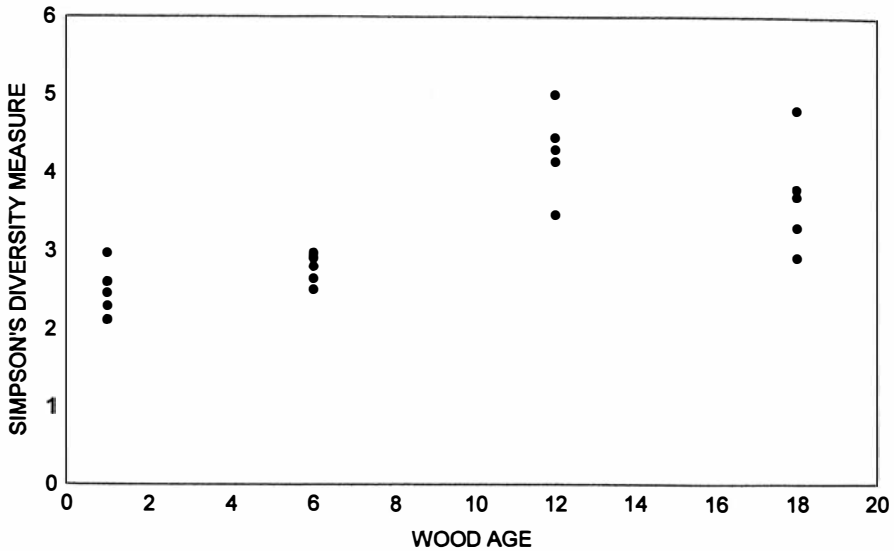| Species (variables) | Coeff. | Factors |
|---|---|---|
| *Apodemus flavicollis* | 1.564 | 0.169 |
| *Apodemus sylvaticus* | – 4.191 | – 0.179 |
| *Clethrionomys glareolus* | 3.280 | – 0.071 |
| *Crocidura* sp. | 2.396 | 0.029 |
| *Mus domesticus* | 1.108 | 0.009 |
| *Rattus rattus* | – 0.474 | 0.080 |



Figure 3. — Values of Simpson's diversity measure (calculated on the small mammal community composition) for the twenty studied plots at the study area. Note that 12-years-old wood has the higher mean diversity value. For statistical details, see text.

Anibaldi, 1991 ; Luiselli *et al.,* 1994 ; Capizzi *et al.,* 1995 ; Rugiero & Luiselli, 1995 ; Luiselli, 1996). The great moisture of the environment (due mainly to the neighbouring river Tiber) seems to be not a favourable condition for *M. domesticus,* a species that was occasionally caught here and that is in fact usually bounded to relatively arid environments. *C. glareolus* were commonly captured, while *A. flavicollis* were captured frequently only in the old wood plots. Shrews were also frequently caught. Curiously the Brown Rats (*R. norvegicus*), despite (i) their

generalist and opportunist habits (e.g. see Calhoun, 1963 ; Fenn, 1989 ; Berdoy & MacDonald, 1991), and (ii) their abundance in the cultivated areas surrounding the studied forest, were uncommon in the studied plots.

Our study demonstrates that there were also remarkable seasonal fluctuations in the numbers of captured animals in most of the abundant and widespread species, namely *A. sylvaticus, C. glareolus* and *Crocidura* sp. These seasonal fluctuations are not surprising if we consider that (i) they have frequently been observed in earlier studies on small mammals from western Europe (e.g. see Gurnell, 1979, 1981), and that (ii) they are often dependent upon differential between-seasons predation risks (e.g. see Kotler, 1984 ; Simonetti, 1989) and need for high-quality refuges (Doncaster & Micol, 1990 ; Diaz, 1992).

However, in our study area the relative frequency of the various small mammal species inhabiting a given environmental type remained consistent amongst seasons, thus suggesting (i) that the various communities of coppiced forests are well separated during the whole year, (ii) that the age of wood (i.e. ultimately the canopy structure) is the most relevant factor in determining the species composition of these communities, and (iii) that the human activities (responsible for the rotation cycle and thus for the existence of given forest landscapes) can vigorously act in favour or against the evolution of a given community. Other studies from different geographic regions mirror our data : for instance, a strong effect of human landscape modification on rodent microhabitat use has been demonstrated in the shrublands of central Chile (Simonetti, 1989).

The strong relationship existing between small mammal community composition and wood age is easily demonstrated by the fact that some species (chiefly *A. flavicollis* and *C. glareolus,* but also *R. rattus*) are more common in mature wood plots. Looking in more detail at the results of factor loadings of variables (species) included in PCA (Fig. 1), it appears evident the strong similarity in environmental type requirements between *A. flavicollis* and *C. glareolus,* while *M. domesticus* and *R. rattus* form a second « ecological group », and *Crocidura* sp. together with *A. sylvaticus* form a third « ecological group ». The similarity between species forming the first « ecological group » is consistent with the fact that some ancient and successionally stable oak high-forests of peninsular Italy are inhabited almost exclusively by sympatric *A. flavicollis* and *C. glareolus* populations (Amori *et al.,* 1986). The second « ecological group » is constituted by species that elsewhere are frequently found in close contact to human environments (Clark, 1982 ; Santini, 1983), and that in this area probably partition vertically the spatial niche, the one species being semi-arboreal and nesting on trees (*R. rattus*) and the other species being strictly terrestrial (*M. domesticus*) (Santini, 1983 ; Capizzi & Luiselli, unpubl. obs.). Finally, the third group is constituted by etho-ecologically and phylogenetically diverging organisms such as *Crocidura* and *A. sylvaticus,* that much probably have only minor ecological interrelations each the other. Thus, whereas within the second and the third « ecological groups » it seems that interspecific competition could be low, the same may not be true for the first group, that includes species which are known to be in competition elsewhere (Andrzejewski & Olszewski, 1963 ; Kalinowska, 1971 ; Obrtel & Holisova, 1974 ; Wojcik & Wolk, 1985).

The peculiar ecological distribution of the various species given in this study may be possibly due not only to different requirements in habitat structure but also to proximate environmental factors such as e.g. food availability (Diaz, 1988), a factor that greatly affects population dynamics of mice (Bomford, 1987a, 1987b ;

Tann *et al.,* 1991). For instance, with regard to shrews, it is possible that their increased density in clear-cut wood plots depends on the higher invertebrate abundance that is found in the areas of first year regrowth stage (Greatorex-Davies & Marrs, 1992).

Moreover, the discriminant analysis performed on plots of every wood age class has clearly demonstrated that the various plots are well divided in the multivariate space, and that their centroids are significantly distant (Fig. 2). This conclusion is especially noteworthy because all the examined plots, though distant at least 300 m each from the others, were situated in the same oak-forest, so that no apparent barriers (other than individual preferences for a given microhabitat) act against dispersal of individuals.

Curiously, the higher taxonomical diversity has been observed in the communities inhabiting environmental types (3) and (4) (Fig. 3), that suggests that mature and old wood plots should deserve special attention by forest managers. We are lead to think that the highest diversity value (found in environmental type (3)) could be explained by a kind of « edge effect » attributable to this environmental type, in which both the typically old-forest taxa (e.g. *A. flavicollis*) and the typically young-forest taxa (e.g. *A. sylvaticus*) find acceptable ecological conditions to survive.

The small mammal species that were the most important ones to discriminate the various plots were *A. sylvaticus* and *A. flavicollis*. The ecological distribution of these two species appeared in fact complementary : *A. sylvaticus* was found primarily in the clear-cut and young wood plots, while *A. flavicollis* was strictly confined to the old wood plots. Considering that *A. sylvaticus* and *A. flavicollis* are morphologically similar throughout the Italian peninsula (e.g. Filippucci *et al.,* 1989) and very similar also in several ecological aspects (such as e.g. food habits, see Obrtel & Holisova, 1983), we suggest that their complementary ecological distribution reflects the needs of reducing interspecific competition. In this respect it should be noted that these two species seem to partition the available habitat resource also in other geographic regions, including for instance Sweden (e.g. see Hoffmeyer, 1973), Germany (e.g. see Felten, 1952), Britain (Montgomery, 1980 ; Gurnell, 1985) and Italy (Recco *et al.,* 1978). Moreover, it has been demonstrated that evidence of competition between *A. sylvaticus* and *A. flavicollis* is seldom apparent in their population dynamics and densities in sympatry and allopatry (e.g. see Mermod, 1969 ; Montgomery, 1980, 1981).

In conclusion, considering that (i) human activities have produced the mosaic of different patches available in the studied forest, and based (ii) on the conceptual framework given by Diaz (1992), we are lead to conclude that both the ecological distribution observed and the seasonal fluctuations in numerical abundances can be discussed with respect to the expected survival values to the rodents of the habitats considered. Further studies would be very useful for definitely solving this issue.

The given study has also some implications for conservation. In the central Italian oak forests the coppicing is usually practised once every twelve years. This means that most of the central Italian forested territories is constituted by relatively young woods, that are represented in our study by the first two wood age plots. Thus, the first two wood age plots of our study area could be taken as effective and reliable sample cases of the taxonomical small mammal community composition in the normally-treated coppice oak forests of central Italy. But, the present study is especially interesting because it permits to compare, within the same forested area, the taxonomical small mammal community composition of these normally-

treated coppice oak forests with that of woods with older plant successions, that are rather uncommon in central Italy. The main emerging difference between the composition of small mammal communities of normally-treated and older-than-usual oak forests is the differential abundance of *A. flavicollis,* a typically old forest species that, contrary to other rodents (e.g. *C. glareolus* and *A. sylvaticus*), seems to be unequivocally damaged by the normally-practised forest management.

In our study area the type of practised forest management implies the maintenance of a relatively high number of standards (60-80 per ha), whereas this number is usually much lower in other coppices of central Italy (on average about 40 per ha). However, despite the higher number of standards maintained, the ecological distribution of such an old forest species as *A. flavicollis* was not positively influenced at all. This evidence permits us to stress that, to manage and preserve the small fauna typically linked to old wood areas, the maintenance of many standards may not be useful at all. Thus, the retaining of patches with very old wood, in a well planned rotation cycle, should be a necessary measure to preserve free-ranging populations of several forest animals. This conclusion is in general agreement with the preservation measures suggested for other small mammal species, such as Glirids (see Morris & Bright, 1992), which are present in our study area (Capizzi, unpubl. obs.) but have not been studied by us. Conversely, this sylvicultural practice may be in conflict with the forest management based on short rotation cycle that is intended to advantage other mammal (e.g. deer, see Ratcliffe, 1992) and bird species (e.g. nightingales, Bayes & Anderson, 1988 ; Fuller, 1992), even in many forests of the Italian peninsula.

### SUMMARY

The small mammal community composition was studied in relation to the length of rotation cycle in a oak-mixed coppice woodland in central Italy. *Apodemus sylvaticus* was the far commonest species in the area, followed by *Clethrionomys glareolus* and *A. flavicollis.* This latter species occurred almost exclusively in mature and old wood plots (age > 12 years), and its ecological distribution appeared rather complementary to that of *A. sylvaticus,* a potential competitor. Shrews were found mainly in young wood plots (age < 6 years). There were significant seasonal variations in the abundance of the various small mammal species. The abundance of the various species was positively (*A. flavicollis, C. glareolus, Rattus rattus*) or inversely (*A. sylvaticus* and *Crocidura* sp.) correlated to wood age. Multivariate analyses divided quite well the various wood age plots by means of small mammal species occurrence, and *A. flavicollis* was the

species giving the greatest relative contribution to discrimination. The conservation implications of our data for the types of forest management normally practised in the Italian peninsula are also briefly discussed.

## RÉSUMÉ

La composition du peuplement micromammalien a été étudiée dans le centre de l'Italie dans un taillis sous futaie mixte de chênes. *Apodemus sylvaticus* est de loin l'espèce la plus commune, suivi de *Clethrionomys glareolus* et d'*A. flavicollis*. Cette dernière espèce se montre exclusivement dans les parcelles matures et âgées (> 12 ans) et sa distribution écologique apparaît complémentaire de celle d'*A. sylvaticus*, qui s'avère être un compétiteur potentiel. Les musaraignes ont essentiellement été trouvées dans les jeunes parcelles (< 6 ans). Des variations d'abondance saisonnières significatives ont été observées chez les diverses espèces de petits mammifères étudiées. L'abondance des diverses espèces et l'âge du boisement montraient une corrélation positive (*A. flavicollis, C. glareolus, Rattus rattus*) ou inverse (*A. sylvaticus* et *Crocidura* sp.). Des analyses multivariées séparent bien les parcelles d'âge différent en fonction de l'occurrence des espèces micromammaliennes. *A. flavicollis* est l'espèce qui fournit la plus forte contribution relative à la discrimination. Les implications de ces résultats en matière de conservation et de gestion des divers types de forêts dans la péninsule italienne sont évoquées.

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