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CONTRIBUTION TO THE KNOWLEDGE OF *APODEMUS* GENUS IN THE GRAN PARADISO NATIONAL PARK

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ABSTRACT **-** Between 1992 and 2001, small mammals were trapped in the Gran Paradiso National Park (NW Italy), using Capture-Mark-Recapture techniques. According to a sample of data collected in August, the following percentages were found for the genus *Apodemus*: 25.9% of the individuals caught in alder shrubwoods, 20.9% in hardwoods, 12.1% in open habitat-types and 3.1% in coniferous woods. Further trapping, carried out in winter in the villages inside the Park, demonstrated that *Apodemus* occurrence inside the buildings was quite common.

Fiftytwo specimens were sacrificed and identified by protein electrophoresis and/or molecular analyses as *A. alpicola* (N= 14), *A. flavicollis* (N= 21) and *A. sylvaticus* (N= 17). External morphology and biometric parameters were analysed on the above specimens, as were cranial features, and the effectiveness of the determination technique proposed by Reutter *et al.* on the study area material was verified. This technique enabled us to determine other specimens (mainly from discarded bottles) using skull analysis.

A. flavicollis (recorded from the lowest altitude of the area, 750 m, up to 2123 m a.s.l.) dominated in hardwoods. *A. alpicola* (recorded from 1580 m to 2423 m) is more abundant above 1750 m, in alder shrubwoods and in open habitat-types, characterized by patches of rocky elements, low ligneous and herbaceus vegetation. All the individuals caught inside buildings were *A. sylvaticus*, but this species (recorded from 750 m to 1960 m) was scarcely observed in natural habitats.

Strix aluco and *Aegolius funereus* prey remains, collected in the area during the breeding period of both owls, were examined. *Apodemus* accounted for 13.7% of prey and 9.4% of biomass eaten by *Strix aluco* and for 7.2% of prey and 7.3% of biomass consumed by *Aegolius funereus*.

Key words: Apodemus, determination criteria, distribution, prey species, Gran Paradiso National Park, Italy

RIASSUNTO - ***Contributo alla conoscenza del genere* Apodemus *nel Parco Nazionale Gran Paradiso.*** Fra il 1992 e il 2001, sono stati effettuati nel Parco Nazionale Gran Paradiso trappolaggi microteriologici, secondo tecniche di Cattura-Marcatura-Ricattura. Sulla base di un campione di dati raccolti in agosto, al genere *Apodemus* vanno ascritti 25,9% degli esemplari catturati negli alneti *(Alnus viridis)*, 20,9% nei boschi di latifoglie, 12,1% negli ambienti aperti e 3,1% nei boschi di conifere.

Da ulteriori trappolaggi, condotti in autunno e inverno nei villaggi del Parco, risulta comune la presenza di *Apodemus* negli edifici.

Cinquantadue esemplari sono stati sacrificati e attribuiti con analisi elettroforetica e/o bio-

molecolare ad *A. alpicola* (N=14), *A. flavicollis* (N=21) e *A. sylvaticus* (N=17). Gli stessi esemplari sono stati analizzati dal punto di vista morfologico-biometrico esterno e craniologico, accertando la validità per l'area di studio del metodo di determinazione proposto da Reutter *et al.* Ciò ha consentito di determinare ulteriori esemplari dell'area, prevalentemente rinvenuti all'interno di bottiglie abbandonate nell'ambiente.
A. flavicollis (rilevata dalla quota minore dell'area, m 750, fino a 2123 m) denota massimi di presenza nei boschi di latifoglie. *A. alpicola* (rilevata fra 1580 e 2423 m) è più abbondante sopra i 1750 m, in alneti e ambienti aperti caratterizzati da un mosaico di elementi rocciosi, vegetazione erbacea e legnoso-bassa. Tutti gli esemplari catturati all'interno di edifici sono risultati riferibili ad *A. sylvaticus*, ma la specie (complessivamente rilevata fra 750 e 1960 m) è stata rinvenuta negli ambienti naturali assai raramente.
L'analisi di resti alimentari di *Strix aluco* e *Aegolius funereus* raccolti nell'area durante il periodo riproduttivo dei due Strigidi evidenzia un contributo di *Apodemus* pari al 13,7% delle prede e al 9,4% della biomassa ingerita nel caso di *Strix aluco*, del 7,2% delle prede e del 7,3% della biomassa nel caso di *Aegolius funereus*.

Parole chiave: Apodemus, criteri di classificazione, distribuzione, specie preda, Parco Nazionale del Gran Paradiso, Italia

INTRODUCTION

Identification of the species belonging to the *Apodemus* (*Sylvaemus*) taxon on the basis of external morphology and cranial features is particularly difficult in Southern Europe, due to the opposite clinal trend shown by the yellow-necked mouse (*Apodemus flavicollis*) and the wood mouse (*A. sylvaticus*) (Krapp, 1984). As for Central and Southern Italy, reliable methods have been developed to distinguish these two species according to morphological and morphometric characteristics (Filippucci *et al.*, 1984; Amori *et al.*, 1986; Panzironi *et al.*, 1993), but no analogous work was published for Northern Italy. In this part of the country, studies concerning *Apodemus* were based on determination criteria developed for other geographic areas, without verifying their local validity. In the Alps, the situation is even more difficult because of the occurrence of the alpine mouse (*Apodemus alpicola*) (Vogel *et al.*, 1991; Filippucci, 1992), which was considered as a subspecies of *A. flavicollis* for a long time (Heinrich, 1951 and 1952) and only recently has been recognized as a different species (Storch and Lütt, 1989; Vogel *et al.*, 1991). As a consequence, apart from a few recent recordings of local occurrence of the species, proved by biochemical evidence, previous information about the ecological and spatial distribution of the three species in the area must be verified.
More generally, the scarce knowledge about the ecology of *A. alpicola* and the relationships among the three species in their areas of sympatry, calls for research. The aim of the present work was to contribute to the cited topics, with reference to the Gran Paradiso National Park area.
In the period 1992-2001, various short

term field surveys were conducted in the area, aimed at drawing up a small mammal inventory and collecting preliminary ecological information about the species. Some results were published (Patriarca and Debernardi, 1997, 1999), but, due to the problems of specific determination, the *taxon Apodemus* was considered only at the genus level.

All the data and material concerning *Apodemus*, collected in the whole period, are considered here, in order to verify the local validity of morphological and morphometric determination criteria developed for other geographical areas, and to furnish a preliminary ecological characterization concerning the presence and the distribution of the *Apodemus* species in the study area and their role as prey of tawny owl (*Strix aluco*) and Tengmalm's owl (*Aegolius funereus*). The choice of these two owl species was made for two reasons, their prompt use of artificial nests (where pellets and other food remains can be collected) and the complementary habitat preferences they show in the study area during the nesting period, the first species being typically bound to hardwoods, while the second preferring coniferous woods.

STUDY AREA

The Gran Paradiso National Park, situated in the Western Italian Alps (Fig. 1), has an area of about 72000 ha, varying in altitude from about 750 to 4061 m a.s.l. About 49% of the territory, including 6600 ha of glaciers, is characterized by ground without vegetational cover, 39% by low bushes and grassland of natural or artificial origin (pastures and hay meadows on land that once was forest) and 12% by forest, mainly

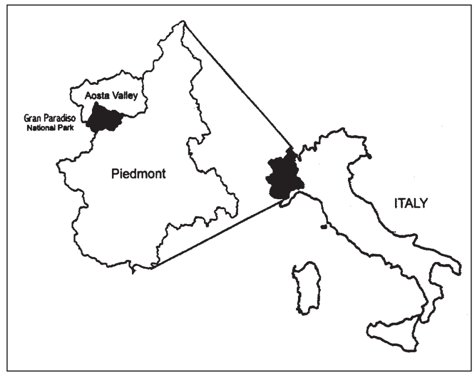

Figure1 - Study area.

represented by coniferous woods, marginally by hardwoods.

The area features sublitoral rainfall (Mennella, 1967). Harsh winters with abundant snowfalls are frequent (Perosino and Scarpinato, 1981).

METHODS

OCCURRING SPECIES

A total of 52 specimens belonging to the genus *Apodemus* were captured at 17 different trapping sites in the Park (see below). The animals were sacrificed and classified at the species level by protein electrophoresis (Reutter *et al.*, 1999a; Reutter *et al.*, 2001) or by a PCR-based RFLP analysis (Reutter *et al.*, 2002).

EXTERNAL MORPHOLOGY

Of the 52 sacrificed specimens, 49 were examined for morphological features; three individuals were excluded because one's head was damaged and two showed juvenile fur coloration. External measurements (length of head and body, length of tail, length of ear, length of hind food) were taken, using a digital caliper accurate to 0.1 mm. Mean values, observed for each species, were compared using Student t-test.

Fur traits were recorded following the classification categories defined by Filippucci *et al.* (1984).

SKULL MORPHOLOGY

Morphological and morphometric analyses were performed on the skulls of sacrificed specimens, in order to test the local validity of methods to determine the *Apodemus* species suggested for other geographical areas (Tab. 1).

Some skulls were partially damaged during preparation; as the determination methods require different measurements (part of which obtainable also from incomplete skulls) the number of considered specimens varied for each technique: 49 specimens were considered using criteria by Storch and Lütt (1989), 43 specimens using criteria defined by Spitzenberger and Englisch (1996) and 42 specimens using the method developed by Reutter *et al.* (1999b).

Together with the cited works, referred to geographical areas where *A. alpicola*, *A. flavicollis* and *A. sylvaticus* are sympatric, the method used by Filippucci *et al.* (1984) to determine *A. flavicollis* and *A. sylvaticus* from Central and Southern Italy was also considered, because of its interest in pellet analysis (the method can be applied also to partially broken skulls). In this case a sample of 65 specimens was examined, including 17 further specimens found dead in the study area (mainly inside discarded bottles) and classified by craniometric analysis after having verified the local validity of adopted taxonomic criteria.

The craniometric measurements were taken by using a Nikon profile projector accurate to 0.01 mm, equipped with an optical system (Jammot, 1973). In cases of paired characteristics the left side was measured.

All the considered skulls, according to tooth wear criteria (Steiner, 1968), belonged to adult individuals (age classes 2-6).

RELATIVE ABUNDANCE OF *APODEMUS* GENUS IN DIFFERENT HABITAT TYPES

Small mammals were trapped using Capture-Mark-Recapture techniques, with live traps (Longworth, Sherman SFAL cm 5.2x6.5x23.4, Sherman LNA cm 7.8x7.8x23.4) arranged in lines (traps spaced 3 m apart; lines and trapping sessions of various length) or grids (100 traps, set in 10-by-10 arrays, with a 10 m spacing between them, operated for sessions of 6 consecutive days, for a trapping effort of 600 trap-nights per session).

Trapping sites were located in the following habitat types:

- Hardwoods: characterized by common beech (*Fagus sylvatica*), dominant or mixed with other broadleaf species, such as common ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*), aspen (*Populus tremula*) and hazel (*Corylus avellana*).
- Coniferous woods: mainly characterized by the dominance of larch (*Larix decidua*) or by the co-dominance of larch and Norway spruce (*Picea abies*).
- Green alder shrubwoods: dominated by green alder (*Alnus viridis*) and often representing the landscape transition component between woods and open habitat-types.
- Open habitats 1: characterized by patches of herbaceous and low (<2 m) ligneous vegetation, rock debris and a limited presence (1-10% cover) of high (>2 m) ligneous vegetation or (if high ligneous vegetation cover <1%) localized within 300 m from woods or shrubwoods.
- Open habitats 2: characterized by patches of herbaceous and low (<2 m) ligneous vegetation, rock debris, high (>2 m) ligneous vegetation cover below 1% and localized more than 300 m from woods or shrubwoods.

Due to the lack of precise standardization and in order to reduce the bias due to seasonal and annual demographic fluctuations, only the data collected in a homogeneous

Table 1 - Criteria suggested in literature to identify *Apodemus* species using skull features.

References	Aim	Criteria
Storch and Lütt (1989)	Discrimination of *A. alpicola*, *A. flavicollis* and *A. sylvaticus*	Correlation between upper incisor thickness plus upper molar row length and diastema length. Morphology of M^2.
Spitzenberger and Englisch (1996)	Discrimination of *A. alpicola* from *A. flavicollis* and *A. sylvaticus*	Correlation between upper incisor thickness plus upper molar row length and diastema length/condylobasal length percent ratio.
Reutter *et al.* (1999a)	Discrimination of *A. alpicola*, *A. flavicollis* and *A. sylvaticus*	Correlation between two discriminant factors based on six characters (condylobasal length, diastema length, foramina incisiva length, braincase length, upper molar row (alveoli) length, bullae length) or use of three Fisher's linear discriminant functions including the same variables.
Filippucci *et al.* (1984)	Discrimination of *A. flavicollis* and *A. sylvaticus* (in central and southern Italy)	Index based on morphometric (foramina incisiva length, upper molar row (alveoli) length, palatal bridge length, interorbital width) and morphologic (morphology of M^1 and M^2, position of the incisor orifices as compared to the roots of M^1) characters.

period of the year, the month of August, were considered and the results of 3-4 different years of recordings were pooled (Tab. 2). Abundance of *Apodemus* in different habitat types was compared using G-test of independence.

To verify a peculiar result registered in coniferous woods, data collected throughout the whole summer, were also considered for this habitat type.

It is known that *Apodemus* often occurs in human settlements and buildings, particularly in winter, therefore some trapping samplings were also conducted inside Park village buildings, during the winter months.

DISTRIBUTION OF *APODEMUS* SPECIES ACCORDING TO ALTITUDE AND HABITAT TYPE

A sample of 69 specimens, from 17 different sites within the study area, was considered, comprising the 52 specimens which were trapped, sacrificed and determined by biochemical or molecular analyses and the 17 specimens found dead and determined by skull analysis. Their distribution in relation to species and altitude was compared by χ^2 test for indipendent samples.

Habitat variables of natural sites where the species were collected were compared using Mann Whitney U test and correla-

Table 2 - Trapping effort in August for each habitat type.
(*) Lowest and highest altitudes of trapping sites expressed in m a.s.l.

Habitat type	Hardwoods 750-1380*	Coniferous woods 1550-1820*	Green alder shrubwoods 1560-1990*	Open habitats 1 1705-2138*	Open habitats 2 1942-2730*
Sites (no.)	3	5	3	8	6
Years (no.)	4	4	3	3	3
Trapping array	grid, line	grid, line	line	line	grid, line
Trap-nights	1614	1827	1115	2065	1504

tions between them (Pearson correlation coefficients) were examined.

ROLE OF *APODEMUS* GENUS IN THE DIET OF TAWNY OWL AND TENGMALM'S OWL

Pellets and other prey remains were collected for three consecutive years (1996-98 in the case of Tengmalm's owl; 1998-2000 for tawny owl), from artificial (Debernardi and Patriarca, 1999) or natural owl nests and, marginally, from the ground. Predation occurred during the owl breeding period or soon afterwards, in April-June for the Tawny owl, from the end of May to early September (mainly in June-July), for Tengmalm's owl.

Prey items were determined according to literature criteria (mainly referring to: Chaline *et al.*, 1974; Niethammer and Krapp, 1978, 1982, 1990; Cuisin, 1981, 1982; Moreno, 1985, 1986; Brown *et al.*, 1987) or by comparing remains with reference material.

The numbers of specimens were counted considering the highest number of hemimandibles or other skeletal parts of the same body side. Biomasses were evaluated on the basis of mean weight values recorded on individuals captured on Western Italian Alps or reported in literature.

Part of the remains, corresponding to 5.2% of the total number of prey eaten by Tengmalm's owl, could be classified only at the order level. In order to evaluate the contribution to the diet of the different prey items (classified at the level of species or genus), we divided this group into the different items (of that order) present, using the same percentage values for each item as found in the determined material.

RESULTS

OCCURRING SPECIES

By means of biochemical and molecular analyses, 14 of the sacrificed specimens were classified as *A. alpicola* (7 males and 7 females), 21 as *A. flavicollis* (14 males and 7 females) and 17 as *A. sylvaticus* (11 males and 6 females).

EXTERNAL MORPHOLOGY

Although a statistical comparison of biometric parameters pointed out differences between means recorded for different species (Tab. 3), ranges largely overlapped.

Likewise, the species resulted very similar as regards fur characteristics. In the sample considered, "complete collar" and "neck spot lacking" characters were observed in only one of the three species, but the other characters resulted to be shared by at least two of the species (Tab. 4).

SKULL MORPHOLOGY

Discrimination among the three species by correlating the sum of upper incisor thickness and upper molar row length with the diastema length, as suggested by Storch and Lütt (1989), was not clear (Fig. 2). Moreover, as regards to the criteria applied by these Authors on Austrian *Apodemus*, it must be observed that the absence of t9 cusp on the second upper molar, cited for *A. alpicola*, was not appliable to the material from the study area. As already observed for other localities of the western Alps (Vogel *et al.*, 1991), t9 cusp also occurs in specimens of *A. alpicola* and, in this species, an ambiguous tooth

Table 3 - Standard statistics for external characteristics of the three *Apodemus* species (specimens collected in the Park and determined by biochemical or molecular analysis) and comparison between mean values by t-test (HB = length of head and body; T = length of tail; E = length of ear; HF = length of hind foot. NS = not significant).

		Parameters				
Species		HB (mm)	T (mm)	T/HB (%)	E (mm)	HF (mm)
A. sylvaticus	N	17	16	16	17	17
	Mean	90.65	87.11	96.25	15.12	22.07
	SD	6.38	7.86	9.84	1.55	1.32
	Min	79.2	71.6	75.8	12.2	20.0
	Max	105.5	99.5	108.0	17.5	24.5
A. alpicola	N	13	13	13	13	13
	Mean	91.35	109.68	120.36	17.23	23.29
	SD	7.95	9.02	7.76	0.65	1.04
	Min	82.1	99.8	105.3	16.2	21
	Max	108	135	132.8	18.5	24.5
A. flavicollis	N	19	17	17	19	19
	Mean	96.4	105.02	109.1	16.48	23.24
	SD	5.93	5.42	7.94	1.33	0.82
	Min	85.5	98	90.6	14.4	21.5
	Max	108.1	113.7	124.2	18.3	25
A. sylvaticus vs. A. alpicola	t-test	NS	P <0.01	P <0.01	P <0.01	P <0.01
A. alpicola vs. A. flavicollis	t-test	P <0.05	NS	P <0.01	NS	NS
A. sylvaticus vs. A. flavicollis	t-test	P <0.01	P <0.01	NS	P <0.05	P <0.001

Table 4 - Percent frequency of different fur characters, classified according to Filippucci *et al.* (1984) categories, in the three *Apodemus* species (specimens collected in the Park and determined by biochemical or molecular analysis).

		A. sylvaticus N = 17	*A. alpicola* N = 13	*A. flavicollis* N = 19
Dorsal coloration	dark agouti	47.1	0.0	26.3
	agouti	47.1	100.0	52.6
	agouti with reddish tones	5.8	0.0	21.1
Ventral coloration	white	76.5	53.8	68.4
	yellowish white	23.5	46.2	31.6
Neck spot	complet collar	0.0	0.0	73.7
	large and well delineated	5.9	53.9	15.8
	present but not well delineated	35.3	30.7	10.5
	almost lacking	35.3	15.4	0.0
	lacking	23.5	0.0	0.0
Demarcation between dorsal and ventral parts (body)	clear	52.9	69.2	84.2
	sufficiently clear	47.1	30.8	15.8
	scarcely clear	0.0	0.0	0.0
	unclear	0.0	0.0	0.0
Demarcation between dorsal and ventral parts (tail)	clear	76.5	53.8	52.6
	sufficiently clear	17.6	38.5	15.8
	scarcely clear	5.9	0.0	26.3
	unclear	0.0	7.7	5.3

shape is frequent (Tab. 5).

The method suggested by Spitzenberger and Englisch (1996), based on four skull measurements, allowed a correct and clear separation of the specimens belonging to *A. alpicola* from those of the other two species (Fig. 3).

Using six morphometric characters, the method developed by Reutter *et al.* (1999b), resulted appropriate for the examined material. Only 2 out of 42 specimens were misidentified, i.e. more than 95% of the sample was correctly determined. The result was obtained using the three Fisher's linear discriminant functions furnished by the same Authors, but it can be demonstrated by means of a graph referring to two discriminant factors (Fig. 4).

It must be stressed that the last two methods require entire skulls. Unfortunately, the method by Filippucci *et al.* (1984) resulted of little use in the study area. The *A. alpicola* specimens were confused with both the other two species and the only information that could be obtained was the exclusion of *A. sylvaticus* when the morphometric index assumed values above 8.0 and the exclusion of *A. flavicollis* when it was lower than 6.9 (Fig. 5).

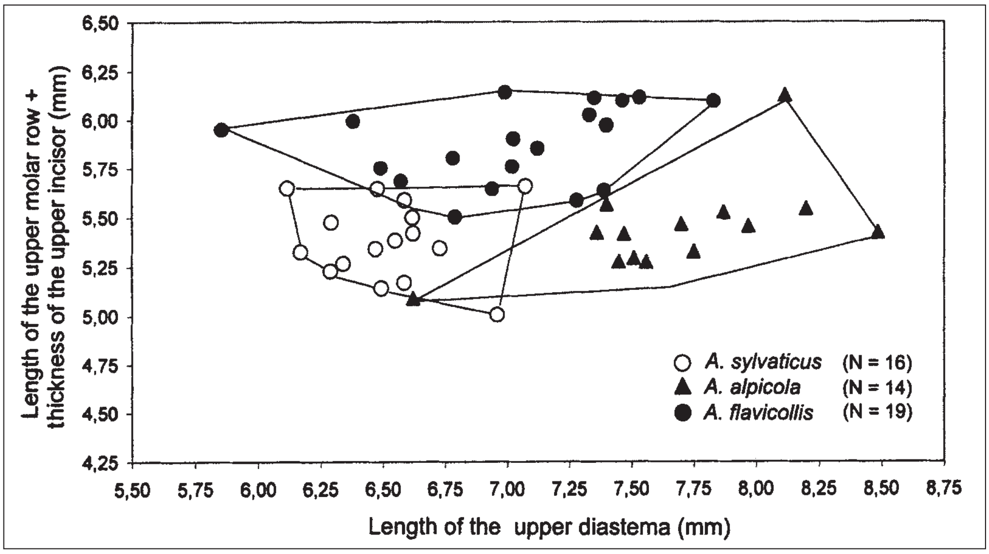

Figure 2 - Scattergram of the Park specimens (determined by biochemical or molecular analysis) for the variables used by Storch & Lütt (1989) in determining *Apodemus* collected in Austria.

RELATIVE ABUNDANCE OF *APODEMUS* GENUS IN DIFFERENT HABITAT TYPES

The genus *Apodemus* occurred in all the considered habitat types. According to data collected in August, its contribution to the theriocoenosis differs among habitat types (G=37.88, d.f.= 4, P<0.001, data referred to species other than *Apodemus* were pooled). Higher values of abundance were recorded in green alder shrubwoods and hardwoods (*Apodemus* accounted for more than 20% of the individuals captured), intermediate values in open habitats and the lowest value in coniferous woods, where *Apodemus* represented only 3.1% of captured individuals (Tab. 6). The latter value significantly differed from all the other values (vs. hardwoods: G=28.60, d.f.= 1, P<0.001; vs. green alder shrubwoods: G=22.84, d.f.=1, P<0.001; vs. open habitats 1: G=7.299, d.f.=1, P<0.01) but the one recorded for open habitats 2. Other significant differences resulted comparing green alder shrubwoods with open habitats 1 (G=3.847, d.f.= 1, P<0.05) and open habitats 2 (G=5.645, d.f.=1, P<0.05) and comparing hardwoods with open habitats 2 (G=4.077, d.f.=1, P<0.05).

The rarity of *Apodemus* in coniferous woods was confirmed by trapping results recorded in other summer months. At two sites, which were chosen because of the good level of naturality (presence of old trees, large amount of coarse woody debris), grid trapping was carried out, for a total of six trapping sessions (3600 trap-nights) and this led to capture only one individual of *Apodemus* (Tab. 7). Similarly, low abundance indices were recorded by line trapping at the other six sites considered in coniferous woods (Tab. 8).

On the other hand, trapping inside buildings showed a high occurrence of the *Apodemus* (accounting for 54% of small mammals captured) in villages

Table 5 - Percent frequency of occurrence of t9 cusp on the second upper molar in the Park specimens (determined by biochemical or molecular analysis).

	well developed	intermediate	not present
A. alpicola (N=14)	30.8	46.1	23.1
A. flavicollis (N=21)	9.1	72.7	18.2
A. sylvaticus (N=17)	91.7	8.3	0

surrounded by different habitat types (pastures, hay meadows, hardwoods and coniferous woods) (Tab. 9).

DISTRIBUTION OF THE *APODEMUS* SPECIES ACCORDING TO ALTITUDE AND HABITAT TYPE

A. alpicola was recorded from 1580 m to 2423 m a.s.l. The limited size of the considered sample does not permit an evaluation on occurrence, or absence, of this species at the lowest altitudes of the study area. Nevertheless, the collected data (pooled for ranges 750-1250, 1250-1750, 1750-2500 in order to enable statistical analysis) attest a different altimetric distribution for *Apodemus* species (χ^2 = 34.48, d.f.= 4, P<0.001), suggesting a greater abundance of *A. alpicola* at high altitudes, in comparison to *A. flavicollis* (χ^2 = 22.82, d.f.=2, P<0.001) and *A. sylvaticus* (χ^2 = 10.97, d.f.=2, P<0.01). Among different habitat types, *A. alpicola* was more frequently collected in green alder shrubwoods and open habitats (Fig. 6).

A. flavicollis was recorded from the lowest altitudes of the study area, 750 m, up to a height of 2123 m a.s.l. In comparison to *A. alpicola*, *A. flavicollis* showed an opposite altimetric trend, being more abundant at lower altitudes and particularly in hardwoods (Fig. 6). Comparing habitat variables of the sites where the two species were observed, significant differences emerge for altitude (higher values for *A. alpicola*) and arboreal cover (higher values for *A. flavicollis*) (Tab. 10). It should be underlined that arboreal cover, as other recorded variables, are correlated with altitude too (Tab. 11).

Occurrence of *A. sylvaticus* was observed in the range 750-1960 m. All the specimens collected inside buildings belonged to this species and, as a consequence, the species is probably well represented in human-transformed spaces surrounding villages. On the contrary, *A. sylvaticus* was scarcely observed in natural habitat types (Fig. 6). Although limited by the low sample of data, such observations suggest that *A. sylvaticus* shows synantropic habits and, among the species of its genus, it never dominates or prevails in natural habitats of the study area.

Syntopy for the three *Apodemus* species was not directly observed, but it probably occurs in different localities of the Park. Syntopy between *A. alpicola* and *A. flavicollis* was observed at two sites, corresponding to the habitat types of green alder shrubwoods and open habitats 1. In another site, classified as open habitats 1, syntopy between *A. alpicola* and *A. sylvaticus* was observed.

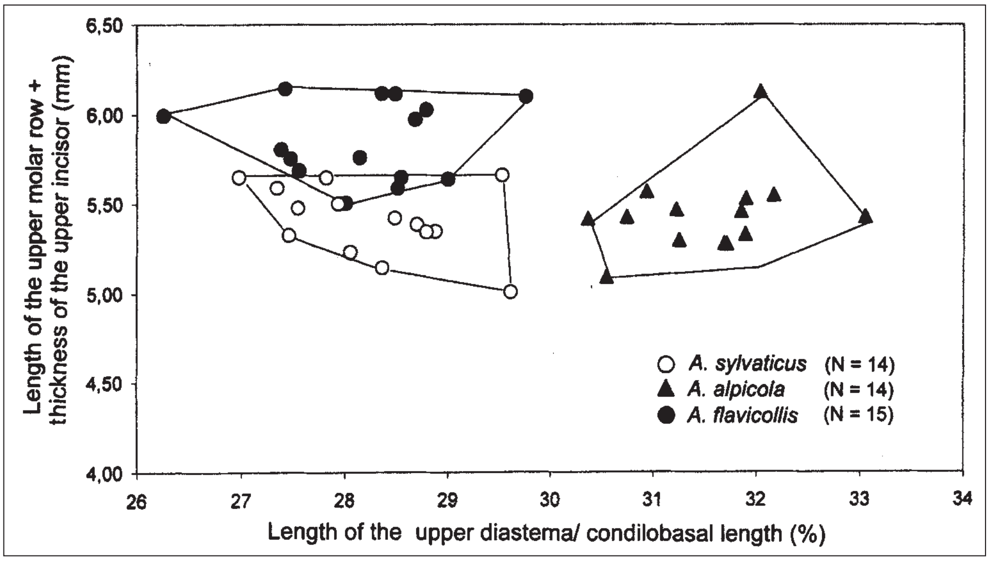

Figure 3 - Scattergram of the Park specimens (determined by biochemical or molecular analysis) for the variables used by Spitzenberger & Englisch (1986) in determining *Apodemus* collected in Austria.

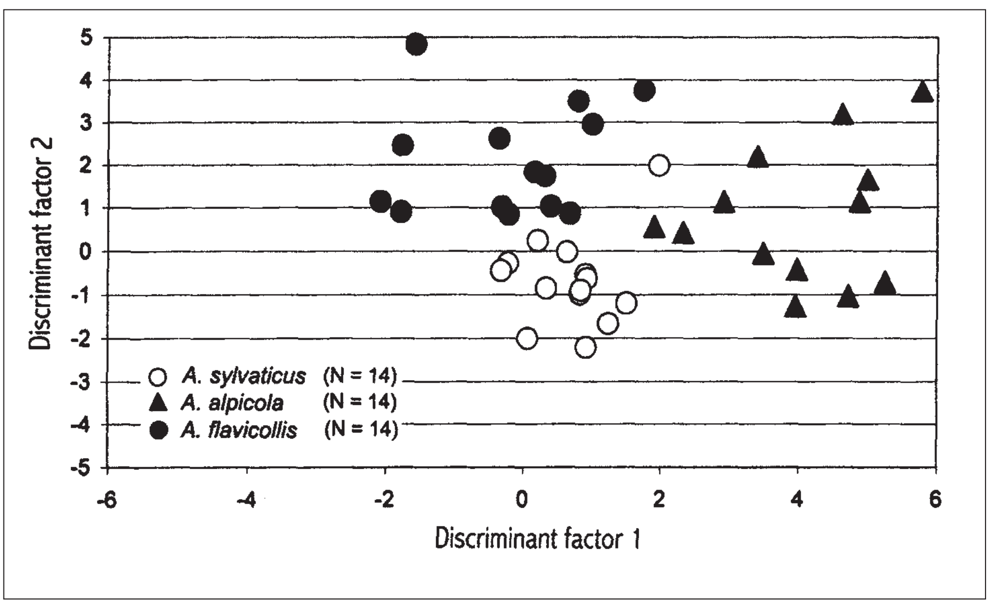

Figure 4 - Discrimination of the Park specimens (determined by biochemical or molecular analysis) according to the method used by Reutter *et al.* (1999b) to determine *Apodemus* collected in different areas of Alps.

Discriminant factors: Z_1 = Cbl x -2.1 + Bull x -2.55 + Dia x 4.88 + Fori x 0.44 + Hkl x 1.38 + Ozra x 0.71 + 1.45; Z_2 = Cbl x -0.55 + Bull x -2.48 + Dia x 2 + Fori x -1.71 + Hkl x 0.73 + Ozra x 3.41 - 28.77

Cbl = condylobasal length, Dia = diastema length, Fori = foramina incisiva length, Hkl = braincase length, Ozra = upper molar row (alveoli) length, Bull = bullae length.

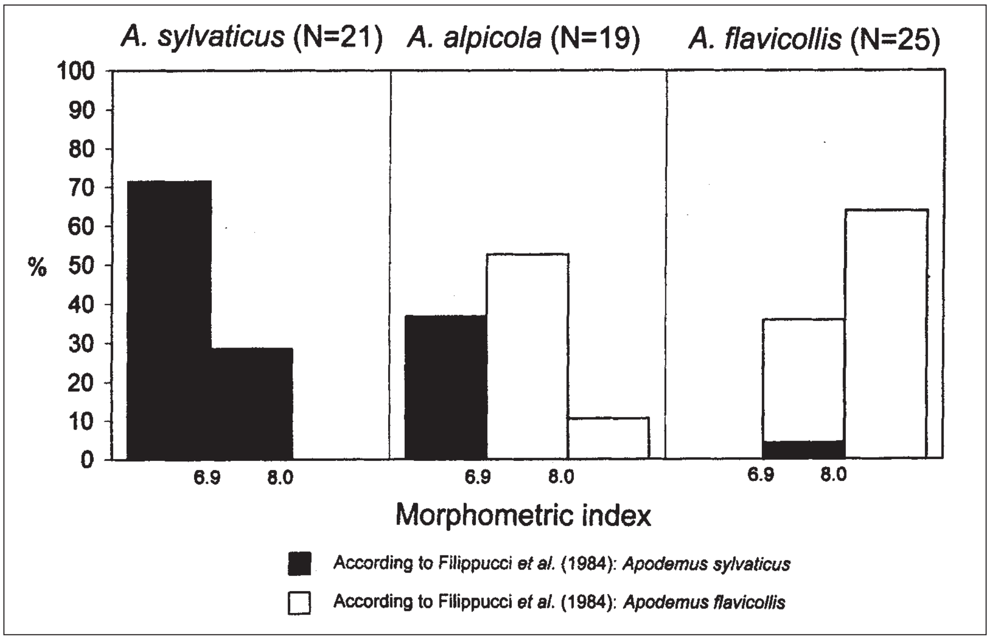

Figure 5 - Classification of the Park specimens (determined, as above specified, by biochemical, molecular or skull morphometric analysis) according to the method developed to determine *Apodemus sylvaticus* and *Apodemus flavicollis* of central and southern Italy by Filippucci *et al.* (1984). For morphometric index < 6.9 specimens should be classified as *A. sylvaticus*, for values > 8.0 as *A. flavicollis* . For values ranging between the two extremes, species is attributed using a morphological index.

Table. 6 - Small mammals (percentage values) captured in each natural habitat type in August (N= number of individuals).

Species	Hardwoods (N=191)	Coniferous woods (N=163)	Green alder shrubwoods (N=77)	Open habitats 1 (N=69)	Open habitats 2 (N=30)
Sorex alpinus	1.1	0.0	0.0	0.0	0.0
Sorex araneus	28.3	1.2	2.6	10.1	6.7
Sorex minutus	0.0	0.0	1.3	0.0	3.3
Eliomys quercinus	0.0	15.3	0.0	11.6	26.7
Glis glis	0.5	0.0	0.0	0.0	0.0
Muscardinus avellanarius	0.0	0.0	1.3	0.0	0.0
Clethrionomys glareolus	49.2	79.2	68.8	46.4	0.0
Microtus arvalis	0.0	0.0	0.0	0.0	3.3
Microtus multiplex	0.0	0.6	0.0	1.5	0.0
Chionomys nivalis	0.0	0.6	0.0	17.4	53.3
Apodemus spp.	20.9	3.1	26.0	13.0	6.7

Table 7 - Small mammals captured by grid trapping in coniferous woods in summer.
* Dominant tree species and, in parentheses, following species in order of abundance: P.a. = *Picea abies*, L.d. = *Larix decidua*, P.c. = *Pinus cembra*.Trap-night number = 600; MNA = minimum number of individuals alive on the grid (enclosed area = 0.81ha).

Site	Altitude (m a.s.l.)	Tree species*	Period	*E. quercinus* (MNA)	*C. glareolus* (MNA)	*Apodemus* spp. (MNA)	Other species (MNA)
A	1670-1770	P. a., L. d.	Aug-Sep 95	10	23	0	0
A	1670-1770	"	Jun-Jul 96	2	7	0	0
A	1670-1770	"	Aug-Sep 96	16	24	1	1
A	1670-1770	"	Jun-Jul 97	13	17	0	0
B	1770-1810	P. a. (L. d., P. c.)	Aug-Sep 96	12	48	0	0
B	1770-1810	"	Jun-Jul 97	11	24	0	0

ROLE OF *APODEMUS* GENUS IN THE DIET OF TAWNY OWL AND TENGMALM'S OWL

212 specimens were identified in the tawny owl prey sample, corresponding to an overall biomass of 7519 g.
Apodemus contributed 13.7% of number and 9.4% of weight of prey; among mammalian prey it accounted for 14.5% of specimens. The *Apodemus* remains were too broken up to allow any classification attempt at the species level.
In the Tengmalm's owl prey sample 690 specimens were identified, for a total biomass of 16730 g.
Apodemus contributed 7.2% of number and 7.3% of weight of prey; among

Table 8 - Small mammals captured by line trapping in coniferous woods in summer.
I = abundance index = (N/TN) x 100, where: N = number of individuals captured, TN = trap-night number. Tree species as in Tab. 7.

Site	Altitude (m a.s.l.)	Tree species	Period	TN	*E. quercinus* (I)	*C. glareolus* (I)	*Apodemus* spp. (I)	Other species (I)
C	1820	L. d.	Jul 92	100	6.3	15.2	0	0
D	1750	P. a. (L. d., P. c.)	Jul 92	100	2.0	1.0	0	0
E	1660-1720	P. a. (L. d., P. c.)	Sep 93	156	7.7	3.8	0	0
F	1550-1560	L. d.	Aug 92	193	0	0.5	0	0
G	1700-1740	L. d.	Jul 93	243	0	4.9	0	0.8
G	1700-1740	L. d.	Aug 00	140	2.1	37.9	1.4	2.1
H	1550-1570	P. a.	Aug 93	140	0	2.8	2.1	0

Table 9 - Small mammals (N) captured inside village buildings in winter.

	Altitude (m *a.s.l.*)			
Taxon	1000-1250	1250-1500	1500-1750	1750-2000
Clethrionomys glareolus	3	1	0	0
Chionomys nivalis	0	0	0	1
Apodemus spp.	5	5	11	6
Mus domesticus	18	0	0	0

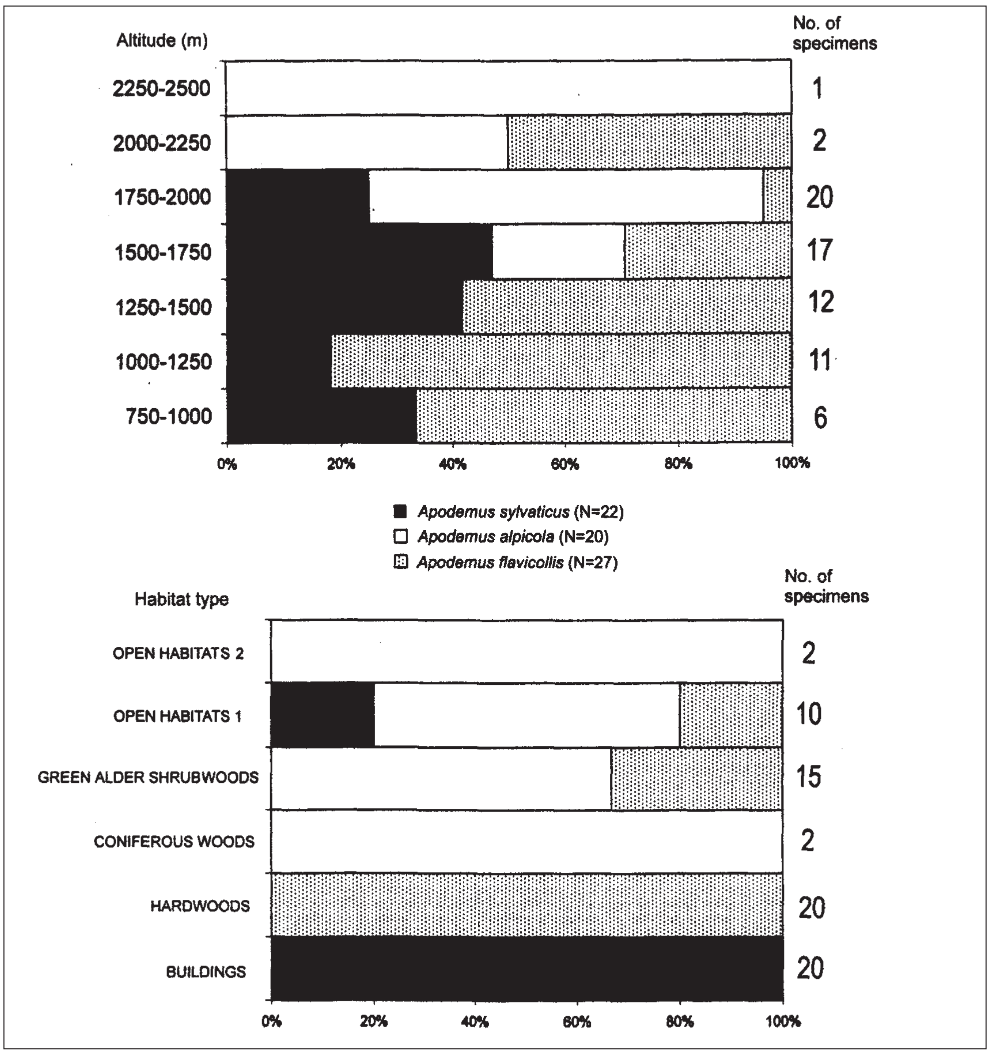

Figure 6 - Distribution of the specimens from the Park according to altitude and habitat type.

Table 10 - Mean (SE) values of habitat variables recorded at natural sites where *A. alpicola* (N = 11 sites) and *A. flavicollis* (N = 7 sites) were observed and differences (Mann Whitney U test).
G.s .= ground slope (degrees); Alt. = altitude (m a.s.l.); HL cov .= high (> 2m) ligneous layer cover (%); LL cov. = low (< 2m) ligneous layer cover (%); H cov. = herbaceous cover (%); S. cov. = stone cover (%); M. cov. = moss cover (according to a five level scale: from 0 to 4); L.d. = litter depth (according to a five level scale: from 0 to 4). NS = not significant.

	Apodemus flavicollis		*Apodemus alpicola*		
	Mean	SE	Mean	SE	P
G.s.	21.57	2.11	18.95	1.72	NS
Alt.	1401.64	185.20	1933.09	66.35	P<0.001
HL cov.	58.64	12.95	23.90	9.8	P<0.05
LL cov.	15.35	8.03	17.13	6.01	NS
H cov.	30.14	7.35	35.50	6.23	NS
S. cov	21.64	8.07	39.81	6.13	NS
M. cov.	2.57	0.42	1.54	0.28	NS
L.d.	2.00	0.57	0.63	0.27	NS

mammals it represented 7.4% of specimens. Among the remains, 10 skulls (out of 50) were comparatively less broken. It was impossible to take all the measurements necessary for determination, nevertheless 8 of the skulls had a diastema length longer than 8 mm (ranging from 8.04 to 8.48 mm, while the other two specimens had a diastema of 7.56 mm) and such high values in the area have been registered only for *A. alpicola* (Fig. 2).
The most important prey species of this owl in the area is the snow vole (*Chionomys nivalis*) (Patriarca and Debernardi, 1999), a rodent typically associated with alpine open habitats, where, according to trapping results, *A. alpicola* is the dominant *Apodemus* species. Together with the considerations concerning the skulls, this suggests that *A. alpicola* could be the main *Apodemus* prey-species for Tengmalm's owl in the study area.

DISCUSSION

A. alpicola, *A. flavicollis* and *A. sylvaticus* are sympatric and partly syntopic in the study area.
Among the morphological and morphometric criteria taken from literature sources, the relation cited by Spitzenberger and Englisch (1996) to distinguish *A. alpicola* from the other species, and the method by Reutter *et al.* (1999b) to determine each of the three species, gave reliable results on the material from the study area, while other methods were of little or no help in determination.
The contribution of the taxon *Apodemus* to small mammal communities of the study area resulted lower

Table 11 - Matrix of the Pearson correlation coefficient for the 10 habitat variables of natural sites (N= 17; buildings are excluded), where Apodemus, determined at the species level, were collected.
G.s.= ground slope; Alt.= altitude; HL cov.= high (> 2m) ligneous layer cover; LL cov.= low (< 2m) ligneous layer cover; H cov.= herbaceous cover; S. cov.= stone cover; M. cov.= moss cover; L.d.= litter depth; W.h.= presence/absence of water habitats; D. HL= distance (> or < 300 m) from high ligneous vegetation.
*P< 0.05 (Two-tailed test), **P< 0.01 (Two-tailed test).

	G.s.	Alt.	HL cov.	LL cov.	H cov.	S. cov.	M. cov.	L.d.	W.h.	D. HL
G.s.	1.000									
Alt.	-0.330	1.000								
HL cov.	0.430	-0.690**	1.000							
LL cov.	0.337	0.202	-0.038	1.000						
H cov.	-0.443	0.335	-0.446	-0.140	1.000					
S. cov.	-0.152	0.182	-0.227	-0.156	-0.429	1.000				
M. cov.	0.330	-0.749**	0.838**	-0.019	-0.513*	-0.234	1.000			
L.d.	0.418	-0.783**	0.929**	-0.064	-0.498*	-0.163	0.932**	1.000		
W.h.	-0.067	-0.086	0.245	0.149	0.330	-0.297	0.223	0.211	1.000	
D. HL	0.223	0.394	-0.361	-0.272	0.100	0.478	-0.326	-0.308	0.091	1.000

than the one recorded in different human-transformed biotopes of the North Italian Plain, where *Apodemus* was the most frequently captured taxon (Canova and Fasola, 1991; Canova, 1992). For more natural habitat types of the same plain area, represented by relict woodlots, cases of dominance of the taxon were observed (Canova and Fasola, 1991; Canova, 1993), together with cases in which *Apodemus* resulted as the second most trapped taxon, contributing to the communities in a similar proportion as to the one recorded for hardwoods of the study area (Canova, 1992; Fasola and Canova, 2000).

Moving from hardwoods to coniferous woods, a significant decrease in the proportion of *Apodemus* captured was recorded. For the same habitat shift, negative trends were cited by Locatelli and Paolucci (1995; 1998), with reference to an area of the Eastern Italian Alps, and by Praz and Meylan (1973) and Jerabek and Winding (1999) for alpine areas of other countries.

Above the present upper limit of forest vegetation, *Apodemus* was common in alder shrubwoods and gradually less represented moving towards open habitats characterized by a lower occurrence of high ligneous elements and a greater distance from woods and shrubwoods. The rarefaction of *Apodemus* in alpine open habitats is confirmed by the scarce recordings of the taxon cited in the few published studies concerning Italian areas (Cresti, 1985; Cantini, 1991; Sindaco, 1999), while the importance of the presence of ligneous vegetation has already been underlined by Douheret (1970) and Janeau (1980) for alpine stage areas of French Alps.

Data obtained from the analysis of the owl's diet are also consistent with a minor abundance of *Apodemus* in the study area compared with areas of lower altitudes, and with the cited decrease moving from broadleaf to coniferous woods.

The limited literature with data about the diet of the tawny owl in woodland habitats of Northwestern Italy refers to low altitude areas, with mature woods dominated by oak species: La Mandria Regional Park (Debernardi and Patriarca, 1988) and Rocchetta Tanaro Regional Park (Debernardi and Patriarca, 2000). In these two areas, predation on *Apodemus* is a much more important phenomenon than in the study area, corresponding to 47.7% of the number of mammals preyed on at the first site and to more than 50% at the second site. Values closer to the one observed in the study area have been reported for the only two other sites of Italian alpine chain considered in literature: the first, situated in the Central Eastern Alps, *Apodemus* accounted for 25% of the number of mammals preyed upon (Pedrini, 1982); at the second site, in the Eastern Alps, *Apodemus* corresponded to 16.2% of the number of mammals preyed upon (Giovo, in: Capizzi, 2000).

As for the Tengmalm's owl, data recorded in the study area are very similar to the results obtained in another area of the Western Italian Alps, the Val Troncea Natural Park, where the owl, nesting in coniferous woods, was found to prey on *Apodemus* in a proportion of 11.4% of total mammals eaten (Rosselli and Giovo, 1999). Different results were recorded in Cansiglio, in the Venetian Pre-Alps, where an average predation on *Apodemus* of 53.9% was observed among mammal prey (Mezzavilla and Lombardo, 1997). It must be stated that in this case, unlike the study area and the Val Troncea Park, the nesting habitat of Tengmalm's owl comprised large areas covered by hardwoods.

Among the three species, *A. flavicollis* was found to be dominant in the natural habitats of lower altitude, corresponding to mature hardwoods, and *A. alpicola* in habitats of higher altitude, preferring alder shrubwoods and open habitat types characterized by patches of rocky elements, low ligneous and herbaceus vegetation. The maximum altitude where *A. alpicola* was recorded, 2423 m, represents the maximum altimetric record ever registered for the species. The possible occurrence of *A. alpicola* at an height of 2450 m had been cited by Yoccoz (1992) for the French Alps, but the observed individuals were determined with uncertainty as *A. alpicola* or *A. flavicollis*.

Although it has been recorded in many different habitats, *A. flavicollis* is regarded primarily as a mature deciduous woodland species (Montgomery, 1999). *A. alpicola*, on the basis of data collected in Austria, has been described as a species preferring a combination of debris and rocks, water and grassy spots, mostly in the montain woodland zone (Spitzenberger and Englisch, 1996). In Hohne Tauern forests (Central Austrian Alps), *A. alpicola* was observed both in broadleaf and coniferous woods, with an increase in the latter, while *A. flavicollis* resulted the dominant *Apodemus* species in the former (Jerabek and Winding, 1999).

Within the study area, *A. sylvaticus* would seem to be a secondary species, showing a closer bond with human settlements and entering the communities of less artificialized habitats as a subordinate species.

Considering that *Apodemus* species often exhibit important annual fluctuations in animal numbers, long term surveys are needed to clarify their ecological distribution both in the study area and in other areas of the Alps.

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REFERENCES

Amori G., Cristaldi M. and Contoli L. 1986. Sui Roditori (Gliridae, Arvicolidae, Muridae) dell'Italia peninsulare ed insulare in rapporto all'ambiente bioclimatico mediterraneo. *Animalia,* 11: 217-269 (1984).

Brown R., Ferguson J., Lawrence M. and Lees D. 1987. Tracks and signs of the Birds of Britain and Europe: an identification guide. Christopher Helm, London. 232 pp.

Canova L. and Fasola M. 1991. Communities of small mammals in six biotopes of northern Italy. *Acta Theriol.*, 36 (1-2): 73-86.

Canova L. 1992. Distribution and habitat preference of small mammals in a biotope of the north Italian plain. *Boll. Zool.*, 59: 417-421.

Canova L. 1993. Resource partitioning between the bank vole *Clethrionomys glareolus* and the wood mouse *Apodemus sylvaticus* in woodland habitats. *Boll. Zool.*, 60: 193-198.

Cantini M. 1991. Comunità di piccoli Mammiferi (Mammalia: Insectivora, Rodentia, Carnivora) nell'Alto Lario Orientale (Lombardia, Italia) e valutazioni della qualità ambientale. *Il Naturalista Valtellinese* - Atti del Museo Civico di Storia Naturale di Morbegno, 2: 71-98.

Capizzi D. 2000. Diet shifts of the tawny owl *Strix aluco* in central and northern Italy. *Ital. J. Zool.*, 67: 73-79.

Chaline J., Baudvin H., Jammot D. and Saint Girons M.C. 1974. Les proies des rapaces. Doin ed.; Paris. 141 pp.

Cresti M. 1985. Dati sul popolamento di micromammiferi nella Valle di Belviso (Alpi Orobie). *Natura*. Soc. ital. Sci. nat. Museo civ. Stor. nat e Acquario civ. Milano 76 (1-4): 33-48.

Cuisin J. 1981. Identification des cranes de petits Passeraux. L'Oiseau et la R.F.O., 51: 17-31.

Cuisin J. 1982. Identification des cranes de petits Passeraux. L'Oiseau et la R.F.O., 52: 15-19.

Debernardi P. and Patriarca E. 1988. Dati preliminari sull'alimentazione dell'Allocco *Strix aluco* nel Parco Regionale La Mandria (TO). (*Aves Strigidae*). *Riv. Piem. St. Nat.*, IX: 189-196.

Debernardi P. and Patriarca E. 1999. Tecnica di collocazione e monitoraggio di cassette-nido per Strigidi forestali. X Convegno italiano di ornitologia, Caorle, 23-26/09/99. *Avocetta*, 23: 104.

Debernardi P. and Patriarca E. 2000. Insettivori e Roditori delle aree protette astigiane: inventario e caratterizzazione ecologica preliminare. *Riv. Piem. St. Nat.*, 21: 263-276.

Douheret J. 1970. Première étude sur les micromammifères du Parc National de la Vanoise. Travaux Scientifiques du Parc National de la Vanoise, I: 183-213.

Fasola M. and Canova L. 2000. Asymmetrical competition between the bank vole and the wood mouse, a removal experiment. *Acta Theriol.*, 45 (3): 353-365.

Filippucci M.G., Cristaldi M., Tizi L. and Contoli L. 1984. Dati morfologici e morfometrici in popolazioni di *Apodemus* (*Sylvaemus*) dell'Italia centro meridionale determinati elettroforeticamente. In: Recenti acquisizioni sul genere *Apodemus* in Italia. Atti I Seminario dell'Ass. Teriologica Romana. Roma 19/03/1982. Supplemento Ricerche di Biologia della Selvaggina, IX (num.unico): 127-142.

Filippucci M. G. 1992. Allozyme variation and divergence among European, Middle Eastern, and North African species of the genus *Apodemus* (Rodentia, Muridae). Proceedings of the 6th International Colloquium on the Ecology and taxonomy of Small African Mammals. *Israel Journal of Zoology*, 38: 193-218.

Heinrich G. 1951. Die deutschen Waldmäuse. Zoologische Jahrbücher. Abteilung fur Systematik, *Okologie, Geographie und Biologie der Tiere*, 80: 99-122.

Heinrich G. 1952. *Apodemus flavicollis alpicola. J. Mamm.*, 33: 260.

Jammot D. 1973. Mise au point d'un "bloc comparateur optique" pour les nécessités d'une ostéométrie fine. *Mammalia*, 37: 122-125.

Janeau G. 1980. Répartition écologique des micromammifères dans l'étage alpin de la région de Briancon. *Mammalia*, 44 (1): 1- 25.

Jerabek M. and Winding N. 1999. Verbreitung und Habitatwahl von Kleinsäugern (Insectivora, Rodentia) in der Bergwaldregion der Hohen Tauern (Salzburg). Wissenschaftliche Mitteilungen aus dem Nationalpark Hohen Tauern, 5: 127-159.

Krapp F. 1984. Gli *Apodemus* d'Italia in rapporto alla situazione europea del Genere. In: Recenti acquisizioni sul genere *Apodemus* in Italia. Atti I Seminario dell'Ass. Teriologica Romana. Roma, 19/03/1982. Supplemento Ricerche di Biologia della Selvaggina, IX (num.unico): 51-63.

Locatelli R. and Paolucci, P. 1995. Micromammiferi della Foresta demaniale di Cadino. Natura Alpina, XLVI (4): 1-16.

Locatelli R. and Paolucci P. 1998. The structure of small mammal communities in some alpine habitats. *Hystrix* (n.s.), 10 (2): 41-48.

Mennella C. 1967. Il clima d'Italia nelle sue caratteristiche e varietà e quale fattore dinamico del paesaggio. Vol. 1. EDART, Napoli.

Mezzavilla F. and Lombardo S. 1997. Biologia riproduttiva della Civetta capogrosso *Aegolius funereus* nel bosco del Cansiglio. *Fauna*, 4: 101-114.

Montgomery W.I. 1999. *Apodemus flavicollis.* In: Mitchell-Jones A.J., Amori G., Bogdanovic W. Krystufek B., Reijnders P.J.H., Spitzenberger F., Stubbe M., Thissen J.B.M., Vohralik V. and Zima J. (eds). Atlas of European Mammals. The Academic Press, London. 496 pp.

Moreno E. 1985. Clave osteologica para la identificacion de los Passeriformes Ibericos, I. *Ardeola*, 32: 295-377.

Moreno E. 1986. Clave osteologica para la identificacion de los Passeriformes Ibericos, II. *Ardeola*, 33: 69-129.

Niethammer J. and Krapp F. 1978. Handbuch der Säugetiere Europas. Band 1/I: Rodentia I. Akademische Verlagsgesellschaft, Wiesbaden. 476 pp.

Niethammer J. and Krapp F. 1982. Handbuch der Säugetiere Europas. Band 2/I: Rodentia II. Akademische Verlagsgesellschaft, Wiesbaden. 649 pp.

Niethammer J. and Krapp F. 1990. Handbuch der Säugetiere Europas. Band 3/I: Insectivora, Primates. AULA-Verlag, Wiesbaden. 523 pp.

Panzironi C., Cerone G., Cristaldi M. and Amori G., 1993. A method for the morphometric identification of southern Italian populations of *Apodemus (Sylvaemus)*. *Hystrix* (n. s.), 5 (1-2): 1-16.

Patriarca E. and Debernardi P. 1997. Insectivora, Chiroptera, Lagomorpha, Rodentia and Carnivora of the Gran Paradiso National Park: checklist and preliminary ecological characterization. Ibex, *Journal of Mountain Ecology*, 4: 17-32.

Patriarca E. and Debernardi P. 1999. Dieta di Civetta capogrosso (*Aegolius funereus*) nel Parco Nazionale Gran Paradiso in periodo tardo primaverile ed estivo. Considerazioni su disponibilità e selezione dei Mammiferi-preda. X Convegno italiano di ornitologia, Caorle, 23-26/09/99. *Avocetta*, 23: 105.

Pedrini P. 1982. L'alimentazione di un Allocco (*Strix aluco* L.) nel Trentino (Aves : Strigiformes: Strigidae) Studi Trentini di Scienze Naturali - *Acta Biologica,* 59: 221-226.

Perosino G.C. and Scarpinato T. 1981. Introduzione allo studio del clima del Parco Nazionale Gran Paradiso. *Riv. Piem. St. Nat.*, 2: 135-149.

Praz J.C. and Meylan A. 1973. Insectivores et Rongeurs de Basse-Engadine. (Note preliminaire). *Revue Suisse Zool.*, 80 (3): 675-680.

Reutter B. A., Brunner H. and Vogel P. 1999a. Biochemical identification of three sympatric *Apodemus* species by protein electrophoresis of blood samples. 3rd European Congress of Mammalogy. Jyvaskyla, Finland, 29/05-02/06/99. Abstracts: 196.

Reutter B. A. Hausser J. and Vogel P, 1999b. Discriminant analysis of skull morphometric characters in *Apodemus sylvaticus, A. flavicollis, and A. alpicola* (Mammalia Rodentia) from the Alps. *Acta Theriol.*, 44 (3): 299-308.

Reutter B. A., Brünner H. and Vogel P. 2001. Biochemical identification of three sympatric *Apodemus* species by protein electrophoresis of blood samples. *Mammalian Biology*, 66: 84-89.

Reutter B. A., Petit E. and Vogel P. 2002. Molecular identification of an endemic Alpine mammal, *Apodemus alpicola* using a PCR-based RFLP method. *Revue Suisse de Zoologie*, 109: 1-8.

Rosselli D. and Giovo M. 1999. Dieta di Civetta capogrosso (*Aegolius funereus*) nel Parco Naturale della Val Troncea (Torino). X Convegno italiano di ornitologia, Caorle, 23-26/09/99. *Avocetta*, 23: 117.

Sindaco R. 1999. I piccoli mammiferi del Parco naturale regionale del Monte Avic e della Valtournanche (Valle d'Aosta) (Mammalia: Insectivora, Rodentia). *Revue Valdotaine d'Histoire Naturelle*, Aosta, 53: 101-115.

Spitzenberger F. and Englisch H. 1996. Die Alpenwaldmaus (*Apodemus alpicola* Heinrich, 1952) in Österreich. Mammalia austriaca 21. Bonner zoologische Beiträge, 46 (1-4): 249-260.

Steiner H.M. 1968. Untersuchung über die Variabilitat und Bionomie der Gattung *Apodemus* (Muridae, Mammalia) der Donau-Auen von Stockerau (Niederösterreich). *Zeitschrift der Wissenschaftlichen Zoologie*, 177: 1-96.

Storch G. and Lütt O. 1989. Artstatus der Alpenwaldmaus, *Apodemus alpicola* Heinrich, 1952. *Zeitschrift für Säugentierkunde,* 54: 337-346.

Vogel P., Maddalena T., Mabille A. and Paquet G. 1991. Confirmation biochimique du statut spécifique du mulot alpestre *Apodemus alpicola* Heinrich, 1952 (Mammalia, Rodentia). *Bull. Soc. Vaud. Sc. Nat*., 80 (4): 417-481.

Yoccoz N.G. 1992. Presence de mulot (*Apodemus alpicola* ou *flavicollis*) en milieu alpin. *Mammalia*, 56 (3): 488-489.