SHORT NOTES

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FOOD HABITS OF MEDITERRANEAN POPULATIONS OF THE SMOOTH SNAKE (*CORONELLA AUSTRIACA*)

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Some European snakes (e.g. *Coronella austriaca*, *Natrix natrix* and *Vipera berus*) have large distribution ranges and occur from regions with cold climates at northern latitudes (e.g. Scandinavian peninsula) to regions with Mediterranean climates at the southern latitudes (e.g. Italian peninsula). These broadly distributed species are normally found in very different habitats in the various parts of their geographic ranges and thus may use different food resources.

The smooth snake (*Coronella austriaca*), a small (< 80 cm long) live-bearing colubrid, occurs from the Scandinavian peninsula (latitude about 64°N) to the Mediterranean regions of southern Europe (Greece, southern Italy) and is found from mountainous areas over 2000 m elevation to sea level (Bruno, 1984). Despite its very broad distribution range, the ecology of the smooth snake is poorly understood because of its highly secretive behaviour. Some data on the dietary habits of *Coronella austriaca* are available from southern Britain, Sweden and western France (Duguy, 1961; Andrén & Nilson, 1976; Spellerberg & Phelps, 1977; Goddard, 1981, 1984), as well as from mountain areas of the Italian peninsula (Darsa, 1972), but no data from Mediterranean habitats is available.

In this paper we present (1) data on the food habits of the smooth snake in Mediterranean environments of central Italy, and (2) address some remarks on trophic and ecological relationships of snakes in such Mediterranean habitats. All data given here were collected between spring 1987 and summer 1994 in a Mediterranean region of central Italy (Tolfa Mountains, province of Rome, about 150-400 m above sea level), during the course of long-term ecological research on the snakes of this area, especially *Vipera aspis, Coronella girondica* and *Elaphe longissima* (e.g. see Luiselli & Agrimi, 1991; Luiselli & Rugiero, 1993; Agrimi & Luiselli, 1994).

Coronella austriaca is the rarest snake species of the Tolfa Mountains (Bruno, 1977; Capula *et al*., unpublished), where it occurs with scattered populations only at the bushy edges of wooded zones (*Quercus cerris*, *Q. pubescens* and *Fagus silvatica* forests), especially in the vicinities of spiny shrubs (e.g. *Rubus*). The rarity and the highly secretive habits of this species in the study area placed a constraint on the amount of data that could be collected, thus explaining the relatively small sample sizes.

When encountered in the field, the smooth snakes were captured by hand, sexed, measured for body length, weighed and processed in order to obtain food items, by collection and analysis of both stomach contents and faecal pellets. These were collected by gentle palpation of the snake abdomen until regurgitation or defecation occurred (see Monney, 1990; Luiselli & Agrimi, 1991). This procedure does not harm the handled specimens. The food items were identified to the lowest taxon possible. The ingested biomass (calculated only from prey contained in stomachs) was calculated by the methods of Braña *et al*. (1988), based on fresh weight if the prey was in optimal condition, or the mean weight of the species if it was not. After identification and measurement of food items, we forced the snakes to reingest the disgorged prey. When the snake did not reingest the food, the item was placed in 75% ethanol and preserved in the private collections of the authors. After laboratory examination, all remains from faecal pellets were preserved in 75% ethanol for further analysis. The data were analysed with an SAS computer package (version 6.0), all statistical tests being two-tailed and with alpha level = 0.05.

The handling of 86 different smooth snake individuals during 1987-1994 yielded a total of 44 prey items from the stomachs and faeces of 43 individuals (25 males and 18 females) (Table 1). Unfortunately, as our sample was composed only of adult snakes, we cannot give any consideration to eventual ontogenetic shift in this species' diet. However, an ontogenetic dietary shift in *Coronella austriaca* has been suggested by Goddard (1981) who predicted an innate preference for lizard prey in juveniles. A similar dietary pattern was proved to occur in other Mediterranean snakes, for instance *Vipera aspis francisciredi* (Luiselli & Agrimi, 1991).

The diet consisted almost exclusively of small vertebrates, but a single invertebrate item was found. This was a carabid beetle (genus *Pterostichus*) possibly ingested secondarily by the snake. Indeed, the stomach also contained the remains of a lizard (*Podarcis muralis*) that is an insectivorous generalist, frequently eating small terrestrial beetles (Capula, Luiselli & Rugiero, 1993). The other prey items were reptiles and small mammals. Lacertid lizards were the principal prey types in terms of both frequency of occurrence in stomachs (over 81% of the total diet) and ingested biomass (about 55% of the total) (Table 2). The wall lizard (*Podarcis muralis*) was preyed on by smooth snakes significantly more frequently than the other lacertid lizards (χ^2 test, $P < 0.05$). This may have been related to the much higher frequency of occurrence of this taxon in the relatively wet habitats frequented by *Coronella austriaca*. Other reptiles (a juvenile slow worm, *Anguis fragilis*, and a newborn viper, *Vipera*

TABLE 1. Summary of the diet data obtained from *Coronella austriaca* of the Tolfa Mountains (Rome, Italy). Data come from analysis of both faecal pellets (31 specimens) and stomach contents (12 specimens) of living snakes.

Prey type	*N* in faeces	*N* in stomach contents	*N* total	%
INSECTA				
Coleoptera (Carabidae)	1	-	1	2.27
REPTILIA				
Podarcis muralis	13	6	19	43.18
Podarcis sicula	1	2	3	6.81
Podarcis sp.	5	-	5	9.08
Lacerta viridis juv.	4	-	4	9.08
Lacertidae sp.	6	-	6	13.63
Anguis fragilis	-	1	1	2.27
Vipera aspis	-	1	1	2.27
MAMMALIA				
Muridae (*Apodemus*)	2	2	4	9.08
Total	32	12	44	100

aspis) were also found, but their relevance in terms of biomass percentage was small (Table 2). Small mammals (Muridae) were rarely preyed on by *Coronella austriaca*, but their biomass contribution to the total diet was relevant. Mediterranean smooth snakes preyed on both nesting and subadult mice. In southern Britain smooth snakes were found to prey upon adult pygmy shrews (*Sorex minutus*), with two shrews being found in the stomach of the same individual (T. Gent, personal communication). Mean ingested biomass per snake was 7.16 ± 4.05 g, that means about 17.50% of the average snake body mass ($\bar{x}$ = 40.91 ± 10.94 g). The biggest prey item found was a murid (*Apodemus*), weighing 16.3 g. The mean prey mass/predator mass ratio was 0.175 ± 0.114. This ratio ranged between 0.058 and 0.416. We did not find any correlation between prey mass and predator total length ($P > 0.9$), or between prey mass and predator mass (in g) ($P > 0.9$). Moreover, the correlation between prey mass (in g) and snake "weight status" (sensu Forsman & Ås, 1987) was not statistically significant ($P > 0.2$).

The populations of *Coronella austriaca* studied here are, to our knowledge, the southernmost populations of this taxon analysed for dietary data. Comparisons with populations living at more northern latitudes are therefore interesting to study the geographic variation in the diet composition of this widely distributed species.

Despite several hundred kilometres and a great deal of habitat difference separating our smooth snake populations from those studied in Britain, Sweden and France, the dietary habits of the Mediterranean *Coronella*

TABLE 2. Relative biomass (B in g and as percentage of the total biomass, % B) of the prey items found in the stomach contents of *Coronella austriaca* from the Tolfa Mountains (Rome, Italy).

Prey (*N*)		B	%B
Podarcis muralis	(*N* = 6)	37.0	43.02
Podarcis sicula	(*N* = 2)	10.3	11.97
Anguis fragilis	(*N* = 1)	3.6	4.18
Vipera aspis	(*N* = 1)	5.8	6.74
Apodemus sp.	(*N* = 2)	29.3	34.07
Total biomass:		86.0	100.00

austriaca populations appear to be very similar to those of other populations of this species studied previously (Rollinat, 1934; Duguy, 1961; Appleby, 1971; Darsa, 1972; Goddard, 1984). In our study area the principal prey of smooth snakes was the commonest lizard species (*Podarcis muralis*) and the commonest rodent species (*Apodemus sylvaticus*) available in the field. Thus the prey ratio taken by smooth snakes in our study areas was 9 lizards : 2 mice : 1 snake, and the ratio of abundance of different prey types was estimated, by mark-and-recapture studies, to be 12 lizards : 2 mice : 1 snake. Thus, these findings indicate some opportunism in the choice of prey by the Mediterranean populations of the smooth snake. The same was also observed in smooth snakes from central France (eating principally *Podarcis muralis*, Rollinat, 1934; Duguy, 1961) and in those from southern Britain (eating principally *Lacerta vivipara*, Appleby, 1971). With regard to British *Coronella austriaca* populations, Goddard (1984) reports that small mammals and lizards are taken in relation to their abundance and that, contrary to popular opinion, *Lacerta agilis* is not a primary prey for this snake. In our studied populations, moreover, there was also a single case of ophiophagy. Ophiophagy has been documented in this species (e.g. Darsa, 1972), but is possibly not a frequent occurrence in the field (Monney, Luiselli & Capula, *in prep.*). Lizard eggs were not observed in the guts of the examined *Coronella austriaca*, though this prey type was eaten by French specimens of the species (Saint Girons, 1955).

The stomach contents were always small. This probably results from the reduced swallowing ability of *Coronella austriaca* because of the small size of its mouth. Considering that the small size of the mouth would represent a strong constraint on the feeding performance of *Coronella austriaca*, it is reasonable to hypothesize that the remarkable homogeneity in the diet composition of smooth snake populations inhabiting very different geographic areas and experiencing very different environmental conditions, depends not only on genetically induced food preferences but also on the need for prey organisms to be either small-sized or, possibly, elongated. Goddard's (1981, 1984) view was that the genetic preference for lizards may be altered in life to allow feeding on small mammals, depending on local resource availability.

In the territory of the Tolfa Mountains, *Coronella austriaca* is usually sympatric with both strictly terrestrial (*Vipera aspis*, *Coluber viridiflavus*) and semi-arboreal snakes (*Elaphe longissima*, Bruno, 1977). On the other hand, it is parapatric with the congeneric *Coronella girondica* and with *Elaphe quatuorlineata*, both species usually selecting more dry and sunny spots. Moreover, *Coronella austriaca* populations are especially concentrated in places where the density of the other snakes, primarily *Coluber viridiflavus*, is very low (Filippi *et al*., unpublished). Though our data on this issue are very preliminary, we suggest that this depended on both direct predation pressure by these sympatric snakes (e.g. *Coluber viridiflavus*, that may prey on snakes, including the venomous species, Duron & Acolat, 1956) and strong interspecific competition for food. In fact, the dietary habits of young *Vipera aspis*, adults and young *Coronella girondica* and *Coronella austriaca*, young *Coluber viridiflavus* and *Elaphe longissima,* are extremely similar to each other in this Mediterranean region (e.g. compare this study with data given in Luiselli & Agrimi, 1991; Luiselli & Rugiero, 1993; Agrimi & Luiselli, 1994), and interspecific competition may be very strong amongst small snakes essentially feeding on *Podarcis muralis* and other lacertid lizards. In this regard it is noteworthy that the average biomass per ha of snakes (considering together all the species of this area) was always greater than that of lizards in 12 different study areas within the territory of the Tolfa Mountains (Filippi *et al*., unpublished).

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