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THE DIET OF THE FOUR-LINED SNAKE (*ELAPHE QUATUORLINEATA*) IN MEDITERRANEAN CENTRAL ITALY

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The feeding habits of the four-lined snake (*Elaphe quatuorlineata*) were studied in a hilly, Mediterranean locality in central Italy (Tolfa mountains, province of Rome). The adult prey consisted exclusively of rodents (about 77% of the diet) and birds (including nestlings and eggs, about 23% of the diet). Birds represented the main part of the diet during spring-time (April, May and June), whilst rodents accounted for 100% of the diet from July to November. The juveniles were found to prey exclusively on lacertid lizards. There was a significantly positive correlation between prey mass and predator mass, but the snakes tended to prey on organisms of small size in relation to themselves. Some general remarks on the snake assemblages of the Tolfa mountains are also presented.

INTRODUCTION

In recent years much field effort has been devoted to studying the feeding habits of snakes in the Mediterranean regions of central Italy, and accurate data are now available on ecologically diverse taxa, such as *Vipera aspis* (Luiselli & Agrimi, 1991; Capizzi, Luiselli, Capula & Rugiero, 1995), *Coluber viridiflavus* (Capizzi *et al.*, 1995; Rugiero & Luiselli, 1995), *Elaphe longissima* (Luiselli & Rugiero, 1993; Capizzi *et al.*, 1995), *Coronella austriaca* (Rugiero, Capula, Filippi & Luiselli, 1995), *Coronella girondica* (Agrimi & Luiselli, 1994), *Natrix natrix* and *Natrix tessellata* (Luiselli & Rugiero, 1991; Filippi, Capula, Luiselli & Agrimi, 1996). On the contrary, there is very little information available on the diet of the biggest Mediterranean species (in terms of both body length and body mass, e.g. see Böhme & Scerbak, 1993), the four-lined snake *Elaphe quatuorlineata* (Pozio, 1976; Cattaneo, 1979; Capizzi *et al.*, 1995; Rugiero & Luiselli, 1996). This is due to the fact that *E. quatuorlineata* usually (i) occurs in scattered populations, (ii) has low population density, and (iii) is extremely elusive for much of its annual activity cycle (Bruno & Maugeri, 1990; Filippi, 1995).

The aim of this paper is (i) to provide an accurate description of the dietary habits of *E. quatuorlineata*, (ii) to compare these data with the available information on this species' feeding habits, and (iii) to compare the diet of this species with that of other sympatric snakes (genera *Vipera, Elaphe, Coluber* and *Coronella*).

MATERIALS AND METHODS

This study was conducted in two areas of the Tolfa mountains (Rota, 150 m a.s.l., and Canale Monterano, 250 m a.s.l.). This is a hilly region situated approximately 60 km north of Rome, where the bioclimate is characterized by a cold winter (without snow-covering), a rainy spring and autumn, and a dry and hot summer (hypomesaxeric subregion of type B according to Tomaselli *et al.*, 1973). Rainfall and air temperatures of the study area during 1964-1994 are given in Fig. 1. The vegetation consists of riverine woodland (*Ulmus campestris*, but also *Salix* sp., *Populus* sp.), large areas covered by shrubby pasture (*Spartium junceum, Cytisus scoparius, Prunus spinosa, Rubus ulmifolius, Crataegus monogyna*) and mesophilous forests (*Quercus cerris, Ostrya carpinifolia* and *Quercus pubescens*) (Spada, 1977). Four-lined snakes are rather

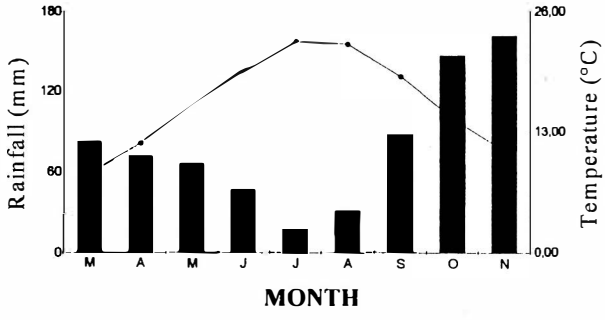

FIG. 1. Average air temperature and mean rainfall per month at the study area. Data from the Meteorological Centre at Civitavecchia (Rome).

rare and elusive, and are generally confined to stony and grassy areas (Filippi, 1995).

The data shown were mainly collected between spring and autumn 1995, with little information recorded in spring and autumn 1993-1994. Sampling was carried out primarily between 0700 and 1530 hr, and occasionally in the late afternoon. Snakes were captured by hand, sexed by examining the external tail morphology, weighed, and a measure of total length (TL, to the nearest 0.5 cm) was taken. For future identification each snake was marked by scale-clipping and paint-marking the dorsal parts. Stomach contents and faecal pellets were collected by gentle palpation of the snake abdomen until regurgitation or defecation occurred (Rugiero *et al.*, 1995). With this snake, in fact, it is quite easy to identify the food eaten by examining faecal pellets under an optical microscope: identification of hairs was done by analysis of medulla, cuticola and cross-section analyses. Unlike other colubrids (e.g. *Natrix natrix*), *E. quatuorlineata* usually does not defecate for defence upon capture, and so the faeces are not too liquid to be used for identification. No specimen was killed or injured during the study. The prey items were identified to the lowest taxon possible. The ingested biomass (calculated only from prey contained in stomachs) was calculated on the basis of the fresh weight if the prey was in optimal condition, or the mean weight of the species if it was not (e.g. see Luiselli & Agrimi, 1991). After examination and measurement, the snakes were forced to ingest the disgorged prey. This was usually found to be an easy procedure, particularly if the prey had recently been captured. When the snake did not re-ingest, the item was placed in 75% ethanol. After laboratory examination, all the remains of the faecal pellet were also preserved in 75% ethanol for further examination.

Data was analysed with SAS version 6.0 (1985), all tests being two-tailed with $\alpha = 0.05$. In the text the means are followed by ± one standard deviation (SD).

RESULTS

During this study we handled 31 different snakes (17 males and 14 females) on 58 occasions. Apparent sex ratio was close to equality (binomial test: $P>0.5$). The females averaged significantly greater TL than males (mean=132.14±32.11 cm [range: 86.1 - 177.4 cm] against 112.82±21.55 cm [range: 56.2 - 145.3 cm]; $t=2.01$, df=29, $P=0.027$), this being in agreement with morphometric data from other regions in central Italy (Rugiero & Luiselli, 1996*b*). For the above comparisons, both juveniles and adults are included. The snakes weighed on average 376.23±215g.

A summary of the diet data obtained from *E. quatuorlineata* is presented in Table 1. We obtained 65 prey items from both stomach contents and faeces.

Identifiable prey items were obtained from faeces of 39 snakes (some captured repeatedly: 67.2% of the total number of processed animals), while only 13 individuals (22.4% of the total number of processed animals) had prey in the stomachs. These frequencies differed significantly (χ^2 with 1 df, $P<0.05$), thus suggesting that to obtain a large number of food items in ecological studies on *Elaphe quatuorlineata* it is much more convenient to examine faeces than stomach contents. Moreover, from the same faecal pellet it was frequently possible to obtain more than one prey item (mean number of prey / pellet = 1.35), thus demonstrating that a faecal pellet may provide data not only on the latest snake meal, but also on the previous one. However, it is obvious that, when more than one prey item is found in a single pellet, it is not possible to recognize which of them has been eaten first.

TABLE 1. Summary of the diet data obtained from *Elaphe quatuorlineata* of the Tolfa Mountains (Rome, Italy). Data come from analysis of both faecal pellets (39 individuals) and stomach contents (13 individuals).

Prey type	*n* in faeces	*n* in stomachs	*n* in total	%
REPTILES				
Podarcis muralis	3	-	3	4.6
MAMMALS				
Apodemus sylvaticus	8	3	11	16.9
Mus domesticus	1	1	2	3.1
Clethrionomys glareolus	7	4	11	16.9
Muscardinus avellanarius	4	-	4	6.2
Rattus rattus	3	-	3	4.6
Rattus norvegicus	1	2	3	4.6
Unidentified rodents	13	-	13	20.0
BIRDS				
Turdus merula nesting	-	3	3	4.6
Turdus merula adult	-	1	1	1.5
Carduelis sp.	1	-	1	1.5
Serinus sp.	2	-	2	3.1
Unidentified passerines	4	-	4	6.2
Unidentified eggs	3	1	4	6.2
Total	50	15	65	100.0

The diet consisted only of vertebrates, and almost all the items eaten (over 95% of the total) were endotherms. Rodents, accounting for about 72% of the total diet, were eaten significantly (χ^2, $P<0.05$) more frequently than birds (accounting for about 23% of the total diet), and were also the principal food resource in terms of biomass percentage (Table 2). Shrews and other insectivores were not preyed upon by four-lined snakes, although these minute mammals are widespread in the study areas (Contoli, 1977) and are frequently eaten by other snakes, e.g. *Vipera aspis* (Capula & Luiselli, 1990). Passerine birds were prey at all life stages, including eggs, nestlings and adults. Males and females were similar in their taxonomic diet composition ($\chi^2 = 0.87$, df=1, $P>0.1$), but the largest prey (i.e. the six *Rattus* eaten) were all ingested by females. Our sample of immature snakes (specimens shorter than 80 cm TL, always easily recognizable by

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

Prey	*n*	B	%B
Apodemus sylvaticus	3	45.4	7.9
Mus domesticus	1	12.5	2.2
Clethrionomys glareolus	4	137.5	23.9
Rattus norvegicus	2	321.5	55.8
Turdus merula nesting	3	21.7	3.8
Turdus merula adult	1	26	4.5
Unidentified egg	1	11	1.9
Total biomass		575.6	100.0

their spotted livery, see Bruno & Maugeri, 1990; Böhme & Scerbak, 1993) was too small (n=6) for drawing firm conclusions about eventual ontogenetic dietary shift. However, the fact that all the three lizard prey were ingested by juveniles (individuals shorter than 75 cm TL) suggests that there may be a preference for lizards in the juveniles compared with the adult diet based on endotherms. This ontogenetic dietary pattern is rather common among Mediterranean snakes (e.g. *Vipera aspis francisciredi*, see Luiselli & Agrimi, 1991), and has already been suggested for *Elaphe quatuorlineata* (Böhme & Scerbak, 1993; Rugiero & Luiselli, 1996).

A considerable seasonal change was observed in the composition of the snake diet (Fig. 2). Birds were eaten only between April and June, and accounted for 75% of the total diet during these spring months. Conversely, rodents represented 100% of the diet from the beginning of July to mid-November.

Mean ingested biomass per snake was 38.33±55.6g (10.2% of the average snake body mass). The prey mass / predator mass ratio averaged 0.125±0.123, and

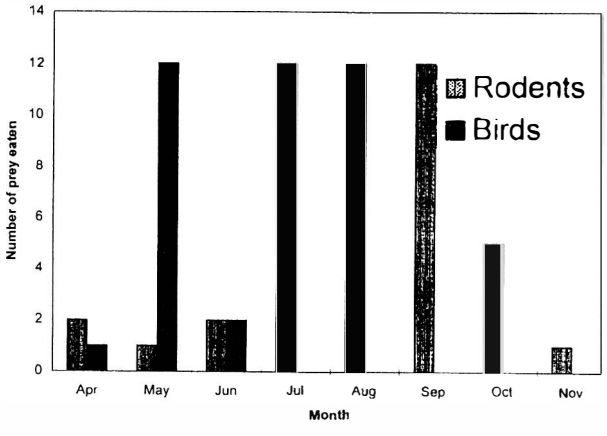

FIG. 2. Seasonal dietary changes in *Elaphe quatuorlineata* from the Tolfa mountains (Rome, Italy). Numbers represent the amount of the main prey types (birds and rodents) found in the guts of the snakes. Nestlings and eggs are included in the term "birds".

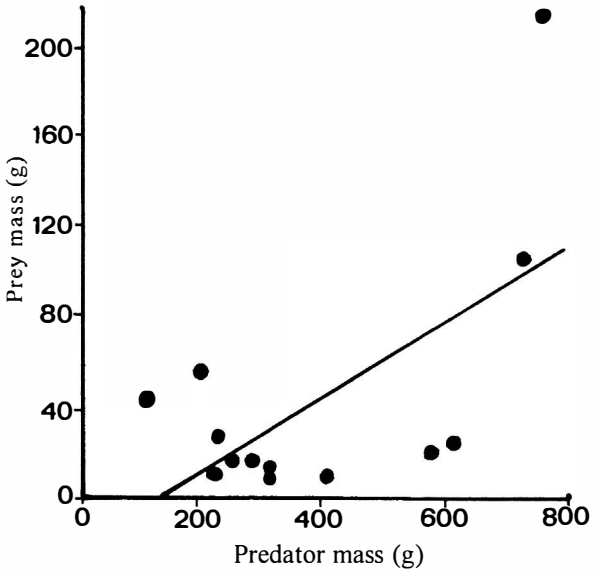

FIG. 3. Relationship between prey mass and predator mass in *Elaphe quatuorlineata* from the Tolfa mountains (Rome, Italy). Statistics: r=0.63, n=13, ANOVA: $F_{1,11}$= 7.24, P=0.02.

ranged between 0.028 and 0.4. Prey mass and predator mass were significantly correlated (r=0.63, n=13, ANOVA: $F_{1,11}$=7.24, P=0.02, see Fig. 3).

DISCUSSION

On the whole, the taxonomic dietary composition of four-lined snakes in the Tolfa mountains resembles that previously described for this species (Cattaneo, 1979; Böhme & Scerbak, 1993; Capizzi *et al.*, 1995; Rugiero & Luiselli, 1996). Birds (including eggs) accounted for about 23% of the total diet, while they represented from about 15% to over 80% of the prey in other Mediterranean *Elaphe quatuorlineata* populations (Cattaneo, 1979; Capizzi *et al.*, 1995; Rugiero & Luiselli, 1996). The presence of bird remains in the diet suggests that four-lined snakes have semi-arboreal predatory habits. Although a direct relationship between arboreality and avian prey has not always been observed in snake studies (Shine, 1983; Luiselli & Rugiero, 1993), this suggestion seems to be reliable in the case studied, as (i) these snakes were occasionally seen in trees at heights of more than 4 m (Filippi, 1995; Capizzi & Luiselli, unpubl. data), and (ii) semi-arboreal or strictly arboreal rodents (i.e. *Rattus rattus* and *Muscardinus avellanarius*) were also eaten.

Interestingly, the diet composition of *E. quatuorlineata* changed seasonally, with a spring diet based on avian prey and a summer-autumn diet based on rodent prey. Considerable seasonal changes in snake diets have rarely been documented (but see Agrimi & Luiselli, 1992), but a nearly identical trend to ours has already been observed in another four-lined snake population from a coastal locality of the Roman county (Cattaneo, 1979). Thus, this comparative evidence suggests that a seasonal dietary change (from a spring diet based on birds to a later diet based on rodents) could be

TABLE 3. Summary of some major ecological traits of the snake species co-existing in the Tolfa mountains (Rome, central Italy). Data from several papers by Luiselli & associates (see references) and original, unpublished material.

Species	Mean body size (cm)	Primary prey	Secondary prey	Habitat feature
Vipera aspis	60-75	rodents + shrews	lacertids	mesophilous and damp woods
Natrix natrix	70 - 120	frogs + toads	fish	riverine and damp woods
Natrix tessellata	50 - 100	fish (over 90% of prey)	-	streams and their banks
Coronella girondica	40 - 60	lacertids	arthropods	grassy areas
Coronella austriaca	40 - 60	lacertids	rodents	damp woods
Coluber viridiflavus	90 - 120	rodents	lacertids	all areas, but mainly dry
Elaphe longissima	100 - 130	rodents	lacertids	woods
Elaphe quatuorlineata	100 - 170	rodents	birds	bushy pastures

a general pattern in the Mediterranean *E. quatuorlineata* populations. These seasonal dietary changes are probably due to remarkable fluctuations in the levels of prey availability, as many snakes tend to prey on the most common prey types available in the environment (Agrimi & Luiselli, 1992; Capizzi *et al.*, 1995; Rugiero *et al.*, 1995; Luiselli, 1996). In fact, most passerine birds nest in the spring months at the study area.

Another main point emerging from our study is that, although the four-lined snakes are large and vigorous colubrids, able to capture large and vigorous prey (such as brown rats or rabbits, see Pozio, 1976 and this study), they usually tend to capture relatively small prey. In this regard, it should be noted that the average prey mass / predator mass ratio observed in our *E. quatuorlineata* is even lower than that observed in a small and comparatively less vigorous predator such as *Coronella austriaca* (Rugiero *et al.*, 1995). Prey mass / predator mass ratio observed in *Elaphe quatuorlineata* was similar to that (0.18) reported as usual for colubrids by Pough and Groves (1983), while the mean value for viperids was 0.36. However, the four-lined snakes tended to select prey of appropriate size to their own, as demonstrated by the statistically significant positive correlation between prey mass and predator mass (Shine, 1991).

Snake Assemblages in the Tolfa Mountains

Summarized ecological aspects of snakes in the Tolfa mountains are presented in Table 3. The annual activity cycle (length of the active period, reproductive timing, etc) of all Tolfa snakes is almost identical (Filippi, 1995). However, in this territory there are two ecologically diverging snake groups: (i) the "semi-aquatic" species (including the two *Natrix* species), and (ii) the "terrestrial" species. Group (i) typically partitions the available food resource (Luiselli & Rugiero, 1991; Filippi *et al.*, 1996), while the same pattern is not so clear among the members of group (ii). This latter group consists of two "subgroups": subgroup (1) includes the lacertophagous species (*Coronella austriaca* and *Coronella girondica*), that are very similar in diet composition (Agrimi & Luiselli, 1994; Rugiero *et al.*, 1995) and other ecological traits (Capula, Luiselli & Rugiero, 1995). As a consequence, they partition very clearly the habitat resource: their distributions are perfectly complementary (coexistence in the same place has never been observed), with *Coronella austriaca* restricted to wet woodlands and *Coronella girondica* restricted to sunny open grassy zones with walls and stones. The subgroup (2) includes morphologically diverging taxa (such as vipers and colubrids) characterized by terrestrial habits and a diet shifting from ectotherms to endotherms with age. It is suspected (and this will be studied in the immediate future) that the juveniles of subgroup (2) are potential competitors for food with the two *Coronella* species, and in fact these latter are especially concentrated in places where the density of the other snakes, primarily *Coluber viridiflavus*, is very low (Rugiero *et al.*, 1995). Among the snakes of subgroup (2) there are no marked differences in diet composition or in habitat features, and there are several places where all four taxa (*Vipera aspis, Coluber viridiflavus* and two *Elaphe*) are sympatric (Filippi, 1995). Thus, further studies are necessary to better define the ecological niches of these taxa. On the whole, the tendency is that (i) *Vipera aspis* and *Elaphe longissima* inhabit wetter areas than *Coluber viridiflavus* and *Elaphe quatuorlineata* (Filippi, 1995), and (ii) the dietary habits of *Elaphe quatuorlineata* and adult *Vipera aspis* are more strictly limited to endothermic prey than those of *Coluber viridiflavus* and *Elaphe longissima.*

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