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CHANGES IN COMMUNITY COMPOSITION, HABITATS AND ABUNDANCE OF SNAKES OVER 10+ YEARS IN A PROTECTED AREA IN ITALY: CONSERVATION IMPLICATIONS

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The snake fauna of different habitat types was studied in a protected Mediterranean area of central Italy ('Canale Monterano' in the Tolfa Mountains, province of Rome) during the period from August 2002 to September 2003. The collected data were compared to those collected at the same study area over 10 years before, and published by Luiselli & Rugiero (1990). We captured eight different species (seven colubrids and one viper), six of which were observed in the earlier study. During both surveys, the most common species was *Coluber viridiflavus*, followed by *Vipera aspis*. In the 2002-2003 survey there was a slight increase in the value of the species diversity index but a remarkable increase in the value of species dominance index (due especially to the proportional higher abundance of *C. viridiflavus*). We used multivariate statistics, Pianka and Czechanowski overlap indices and Monte Carlo simulations on the habitat use states during the two survey periods to document whether the various species modified their habitat preferences between surveys. In terms of habitat preferences, all these indicators showed that there were substantial interspecific differences but that the species-specific preferences remained the same over the two survey periods. There was a decrease in the abundance of *Elaphe longissima* and, to a lesser degree, *V. aspis,* caused especially by clearing brush at an archaeological site where these snakes were very common over 10 years ago. This is potentially relevant in conservation terms, as in places such as Europe, where many of the protected areas are set aside for archaeological or historical (as opposed to biological) reasons, management to maintain sites or improve access may be detrimental to native species. The various habitats differed in their conservation value for snakes. Appropriate management of the 'dry-stone walls and oak forests' habitat-mosaic appeared especially important for the conservation of this snake community, and the same may well be true for many other areas in Mediterranean central Italy.

Key words: central Italy, habitat selection, historical changes, Mediterranean protected areas, Serpentes

INTRODUCTION

The study of habitat selection is important if we are to understand the evolutionary ecology and conservation of snakes (Reinert, 1997). The concept of habitat specificity of organisms has played a major role in the formulation of general theories on species diversity and the organization of living communities (e.g. Rosenzweig, 1981). Indeed, most (perhaps all) snake species use their available habitats in a non-random way, and this non-random distribution of habitats does not seem to be the immediate result of differential survival in adjacent habitats (Reinert, 1997).

Habitat preferences in snakes may vary intraspecifically (e.g. Reinert, 1984; Shine, 1986; Burger & Zappalorti, 1989; Luiselli *et al.* 1994, etc), geographically (e.g. Sweet, 1985), seasonally (e.g. Seigel, 1986; Reinert, 1997), and even ontogenetically (e.g. Beatson, 1986; Reinert, 1997). Most studies have examined the patterns of habitat preferences in snakes over short timeframes, and long-term studies are rarer. When long-term studies are logistically problematic, short-term studies repeated over 10 or more years can at least give some indications of the temporal variation in patterns of habitat preferences of snakes within a given study area.

Over 15 years ago, Luiselli & Rugiero (1990) published a study on the habitat selection of snakes at a Natural Park in northern Latium (Canale Monterano in the Tolfa Mountains, central Italy) which was considered by the authors of great scientific interest because of its herpetofaunal richness, being inhabited by six sympatric species of snakes and several other reptiles as well. As a step toward the evaluation of the biodiversity status of this protected area after more than 10 years of protection, the Park's Authorities launched a novel field study on the snake communities of this territory. This new project provided the opportunity to compare habitat preferences and relative abundance of the snakes of this area after a relatively long time-span (>10 years after the earlier study). The results obtained are presented in this paper. In particular, we aims to address the following questions: (1) Is the snake community composed of the same species? (2) Have the various species modified their habitat preferences over the intervening years? (3) If so, can the observed changes be linked to modifications in habitats available? (4) Has the relative

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abundance of the various species change over the study period? (5) If so, what are the main factors affecting the relative abundance of species? (6) What are the main conservation implications of this study both at the local level of the study area and at the general level of the Mediterranean ecosystems in central Italy?

MATERIALS AND METHODS

STUDY AREA

The field study was carried out at the 'Riserva Naturale Regionale Monterano', situated about 50 km north of Rome (Tolfa Mountains, Latium, central Italy). The study area was exactly the same as that used by Luiselli & Rugiero (1990) for their field study. The study area was officially protected since the end of the 1980s, and during the 1990s it was also considered a European Community Interest Site under the program Natura2000 of the European Union (site code: IT6030001, 'Fiume Mignone - medio corso'). This hilly area, with a surface of 488.3 ha and ranging in elevation from 150 to 250 m a.s.l., was characterized by a patchy mosaic of habitat types associated with such disparate vegetation as *Ulmus, Populus, Salix, Alnus, Fraxinus angustifolia* in the riparian areas; *Quercus cerris, Q. pubescens, Ostrya, Carpinus orientalis, Acer monspessulanum, Cercis, Paliurus,* and *Castanea sativa* as mixed woodlands, and *Callitricho-* and *Thero-Brachypodetalia* and *Brometalia* in the grassy pastures (Spada, 1977). At a elevated spot, the ruins of an ancient town (Monterano) dominate the area. These ruins were completely surrounded by dense bushes of *Rubus* spp., *Rosa canina, Crataegus monogyna,* and *Cytisus scoparius* up to seven years ago, but since then they were almost entirely cleared under an archeological-historical programme supported by the European Union. The climate of the study area was Mediterranean-temperate, with cold winters (usually without snow), rainy spring and autumn, and dry and hot summer (hypomesaxeric subregion [type B] according to Tomaselli *et al.*, 1973).

PROTOCOL

The field study was conducted at the various habitat types available in the study area from August 2002 to September 2003. Fieldwork was conducted under all climatic conditions, and a total of 359 man-hours were spent in the field. In the various appropriate habitats (see below), we searched for snakes by time-fixed routes. Each route in each habitat type - surveyed by two independently walking searchers - was 60 min long. During a day with optimal weather (sunny and moderately warm), we typically carried out at least one time-fixed route in at least five different habitats, and the sequence of habitat types surveyed varied randomly in such a way to maintain a relatively constant field effort in each habitat type. Although it was impossible to standardize exactly the field effort in each habitat type in relation to the relative availability of that habitat type in the landscape, every possible effort was done to minimize eventual biases among habitats.

The following habitat types were considered: (1) mixed oak woodland (WDS); (2) grassy pastures (GPS); (3) bushlands with *Cytisus scoparius* as the prominent taxon (CTS); (4) streams 'Mignone' and 'Fosso del Bicione' and their banks (STR); (5) ponds situated at the locality called 'Mercareccia' (PON); (6) dry-stone walls (SWL); (7) cultivations around the main town (CUL).

Snakes were captured by hand, often while they were hiding under cover. We spent most of the time scanning for snakes (about 85% of the time) rather than turning cover (about 15% of the time). Exact locality and the habitat data were recorded at each capture site. Snakes were measured for snout-vent length (SVL) to the nearest 1 mm, weighed to the nearest 1 g on an electronic balance, and individually marked by ventral scale clipping for future identification.

Field data coming from this study were compared with the dataset collected by Luiselli & Rugiero (1990) in the late 1980s. In this regard, we not only used the data available in the original paper by Luiselli & Rugiero, but also re-analysed data which are available in the field notebooks relative to that study, but eventually not published in the original study (thanks to L. Rugiero, for cooperation in this regard). The research protocol employed by Luiselli & Rugiero (1990) was nearly identical to that described above.

In this study we considered the site of capture of each snake specimen as indicative of its habitat. However, the site of capture and the actual habitat are not strictly equivalent. Capture sites are typically those used for basking, mainly during digestion or sloughing, but most of the time the snake is not exposed to capture, i.e. it is invisible and consequently its habitat is unknown.

Vouchers of all the species are stored, in alcohol, in the collections of the 'Riserva Naturale Regionale Monterano' (Canale Monterano, Rome).

STATISTICAL ANALYSES

To avoid pseudoreplication of data (Hurlbert, 1984; Mathur & Silver, 1980) habitat type was recorded only once from each individual (i.e. it was not recorded in recaptured individuals).

Having counted and recorded all the sighted/sampled specimens, we calculated species diversity and dominance indexes of each habitat type (but see Hubalek, 2000, for an evaluation of the limits of these indexes which are sensitive to sample sizes). These calculations were made for all months of research pooled, because the sample sizes were not enough to evaluate these indexes month-by-month. Species diversity (D_{mg}) was calculated using Margalef's Diversity Index (Magurran, 1988):

$$D_{mg} = (S - 1) / \ln N$$

where S is the number of species and N is the total number of individuals sampled in each zone. Species dominance (d) was assessed using the Berger-Parker Index (Magurran, 1988):

$$d=N_{\max}/N$$

where N_{max} is the total number of individuals of the most abundant species sampled in the zone. According to Magurran (1988), an increase in the value of $1/d$ (the reciprocal of the Berger-Parker index) indicates an increase in diversity and a decrease in dominance. For calculating the similarity in habitat use of the various snake species between the two survey periods, we calculated the overlap indices of Pianka (1973) and Czechanowski (Feinsinger *et al.*, 1981) for the habitat type frequency use of the six species observed in both the Luiselli & Rugiero's (1990) and the '2002-2003' surveys. Pianka's formula for species j and k, with resource utilizations p_{1i} and p_{2i}, is:

$$O_{j,k}= O_{k,j}= \Sigma\, p_{2i}\times p_{1i}/\{\Sigma\,(p_{2i}^{\,2}\times p_{1i}^{\,2})\}^{1/2}$$

In this formula the values range from 0 (no overlap) to 1 (total overlap). Czechanowski's formula for species 1 and 2, with resource utilizations p_{1i} and p_{2i}, is:

$$O_{1,2}=O_{2,1}=1.0-0.5\times\Sigma\,|\,p_{1i}-p_{2i}\,|$$

Graphically, this index corresponds to the intersection of the utilization histograms of the two species, and also ranges from 0 (no overlap) to 1 (total overlap) (Gotelli & Entsminger, 2000). We calculated these indices using the program 'EcoSym 700' (Gotelli & Entsminger, 2000). We performed a cross-tabulation on those frequencies to determine where differences in habitat types used existed for each species between the two survey periods. By means of the 'EcoSym' package, we performed Monte Carlo simulations to create 'pseudocommunities' (Pianka, 1986) and statistically compared the derived patterns with those in the actual data matrix. We used the RA3 model in 'EcoSym' to evaluate the similarity in habitat use (= overlap); this model randomises particular resource states used by each species while retaining niche breadth. This model has been shown to have robust statistical properties for detecting non-random niche overlap patterns (or, as in our study case, similarity in resource use between survey periods of a same species; Winemiller & Pianka, 1990), and has also been successfully used previously with snakes (Laurent & Kingsbury, 2003). As we did not have a static measure of habitat type availability at the study area, we therefore used the default setting of equiprobable resource states available in 'Ecosym', exactly as done by Laurent & Kingsbury (2003). The assumption of equiprobability of resource states means in our study case that the various habitat type states (= resource states) are equally usable (= abundant) by all species in each of the two survey periods. Statistical analyses were done by 'Statistica version 6.0' for Windows PC package, with all tests being two-tailed and alpha-set at 5%, and Monte Carlo simulations were done by 'Ecosym 700' PC package. When χ^2 tests had df=1, the Yates' correction factor was applied.

RESULTS

Apparent Abundance and Diversity of Snakes

Despite the research effort (expressed as the number of man-hours in the field) was slightly higher in the 2002-2000 survey, both the total number of snakes captured and the snake abundance (expressed as the number of snakes × hr^{-1}) were slightly higher in Luiselli & Rugiero's (1990) surveys (Table 1). Six species of snakes were observed by Luiselli & Rugiero (1990), and eight species were observed in 2002-2003 (i.e. the six species found by Luiselli & Rugiero plus *Coronella girondica* and *Natrix tessellata;* Table 1). During both the survey periods, the most common species was *Coluber* (= *Hierophis*) *viridiflavus*, followed by *Vipera aspis* and *Natrix natrix*. All the other species were much less common in the 2002-2003 survey, but *Elaphe* (=

TABLE 1. Total number of snakes observed at the study area, and their percentage occurrence, during the two survey periods.

Species	No. of specimens (%) Luiselli & Rugiero (1990)	No. of recaptures Luiselli & Rugiero (1990)	No. of specimens (%) 2002-2003 survey	No. of recaptures (%) 2002-2003 survey
Vipera aspis	73 (26.4%)	39	57 (21.8 %)	36
Coluber viridiflavus	83 (30.1%)	16	114 (43.7%)	24
Coronella austriaca	3 (1.1%)	0	1 (0.4%)	0
Coronella girondica	0	0	3 (1.1%)	0
Elaphe longissima	37 (13.4%)	8	15 (5.7%)	7
Elaphe quatuorlineata	13 (4.7%)	4	13 (5.0%)	5
Natrix natrix	67 (24.3%)	19	53 (20.3%)	21
Natrix tessellata	0	0	5 (1.9%)	0
Total sample	276	86	261	93
Field effort (man-hours)	334		359	
Snake abundance (snakes × hr^{-1})	0.826		0.727	

Zamenis) *longissima* was common during the Luiselli & Rugiero's (1990) survey. If we compare the frequency of occurrence of the various species in relation to the total number of snakes captured during the two survey periods (Table 1), it appeared that: (1) *C. viridiflavus* was significantly more abundant in the 2002-2003 survey than in Luiselli & Rugiero's (1990) survey (χ^2=4.56, df=1, P<0.033); (2) *E. longissima* (χ^2=39.72, df=1, P<0.0001) and *V. aspis* (χ^2=26.46, df=1, P<0.0001) were significantly less abundant in the 2002-2003 survey; (3) *N. natrix* (χ^2=0.37, df=1, P=0.545) and *Elaphe quatuorlineata* (χ^2=0.09, df=1, P<0.786) did not show significant changes in abundance over the two survey periods; (4) *Coronella austriaca* was extremely rare during both the survey periods, but the small sample size impeded any statistical analysis.

Compared to Luiselli & Rugiero's (1990) survey, in the 2002-2003 survey there was a slight increase in the value of D_{mg} due to the addition of two species, but a remarkable increase in the value of *d* due to the proportional higher abundance of *C. viridiflavus* and the relative decrease in the abundance of *E. longissima* and *V. aspis* (Table 2).

Habitat Preferences

Luiselli & Rugiero's (1990) study. The original study by Luiselli & Rugiero (1990) did not analyse in full the habitats in which all the species were captured, and so we have performed a reanalysis of the original dataset (Fig. 1; *C. austriaca* was not included because of its small sample size). There were some remarkable interspecific differences in habitat type (P<0.0001 at χ^2 test), with *V. aspis* and *E. longissima* being linked mainly to WDS, *C. viridiflavus* and *E. quatuorlineata* to GPS and to CTS (but the former was very generalist), and *N. natrix* to STR and PON (Fig. 1). The habitat types in which we observed the higher numbers of snakes were WDS, CTS, and STR (Fig. 1). However, in WDS most of the observed specimens belonged to a single species (*V. aspis*) which was particularly abundant there, and the same was true for GPS (*C. viridiflavus*) and STR (*N. natrix*).

2002-2003 survey. The number of snake specimens observed in relation to habitat type is presented in Fig. 1B

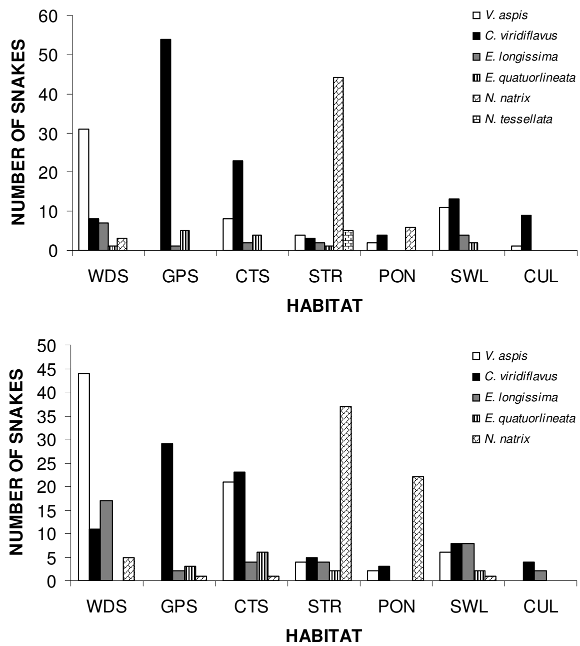

FIG. 1. Number of snakes observed at the study area in relation to the habitat of observation. Top: based on data by Luiselli & Rugiero (1990); bottom: based on data collected during the 2002-2003 survey. Symbols for habitat types: WDS, mixed oak woodland; GPS, grassy pastures; CTS, bushlands with *Cytisus scoparius* as prominent taxon; STR, stream 'Mignone' and its banks; PON, pond; SWL, dry-stone walls; CUL, cultivations.

(data for the two species of *Coronella* not included because of small sample sizes). The three specimens of *C. girondica* were of dead specimens taken by local people, so their habitat of capture was unknown. The single *C. austriaca* was captured in SWL. There were some remarkable interspecific differences in habitat type (P<0.0001, χ^2 test), with *V. aspis* and *E. longissima* being linked mainly to WDS, *C. viridiflavus* and *E. quatuorlineata* to GPS and to CTS (but the former was very generalist), and the two *Natrix* species to STR. Interestingly, *N. tessellata* did not occur at PON, whereas *N. natrix* did. The habitat types in which we observed the higher numbers of snakes were WDS, CTS, STR, and SWL (Fig. 1). However, in WDS most of the specimens belonged to

TABLE 2. Values of species diversity (D_{mg}) and species dominance (*d*) indexes at the various habitat types in relation to the numbers of snakes captured. Symbols for habitat types: WDS, mixed oak woodland; GPS, grassy pastures; CTS, bushlands with *Cytisus scoparius* as prominent taxon; STR, stream 'Mignone' and its banks; PON, pond; SWL, dry-stone walls; CUL, cultivations.

Habitat type	D_{mg} - Luiselli & Rugiero (1990)	*d* - Luiselli & Rugiero (1990)	D_{mg} - 2002-2003	*d* - 2002-2003
WDS	0.691	0.571	0.990	0.449
GPS	0.844	0.829	0.488	0.900
CTS	0.998	0.419	0.831	0.622
STR	1.012	0.711	1.226	0.746
PON	0.509	0.815	0.806	0.500
SWL	1.243	0.320	0.882	0.433
CUL	0.558	0.333	0.435	0.900
Total	0.890	0.300	1.078	0.437

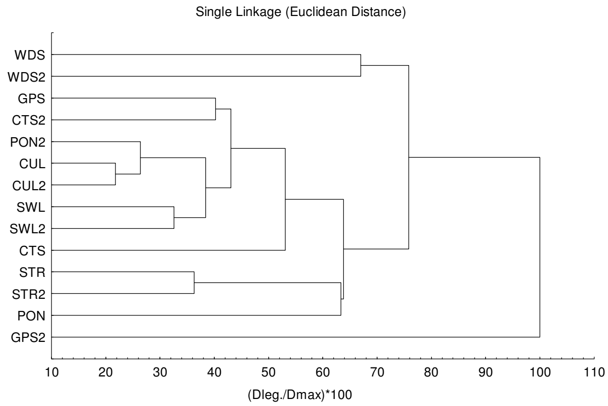

FIG. 2. Dendrogram yielded by hierarchical cluster analysis (UPGMA, standardized to 100%) of percentage composition of snake assemblages in the various habitat types at the study area, during the 2002-2003 survey and the Luiselli & Rugiero's (1990) study. Symbols for habitat types as in Fig. 1. In all cases, the symbol '2' after the habitat symbol (e.g., WDS2, GPS2, etc) indicates data from Luiselli & Rugiero (1990).

a single species (*V. aspis*), and the same was true for GPS (*C. viridiflavus*) and STR (*N. natrix*).

Comparisons Between the Two Surveys

D_{mg} for four habitat types differed remarkably between survey periods: the values were higher during the 2002-2003 survey in WDS and PON, but were higher during the Luiselli & Rugiero's (1990) survey in GPS and SWL (Table 2). With regard to *d*, there were noteworthy differences between survey periods in the values relative to habitats PON (higher in Luiselli & Rugiero's survey) and CUL (higher in the 2002-2003 survey). A hierarchical cluster analysis indicated that the snake community composition was similar between surveys in only three habitats (CUL, SWL, and STR), which indeed clustered very clearly in the UPGMA graphic (Fig. 2). These similarities can be explained as follows: (1) CUL was characterized by a very low number of species and the preponderance of *C. viridiflavus*; (2) SWL was characterized by a relatively high number of species, and the frequency of occurrence was stable; (3) STR was characterized by a great preponderance of *N. natrix*.

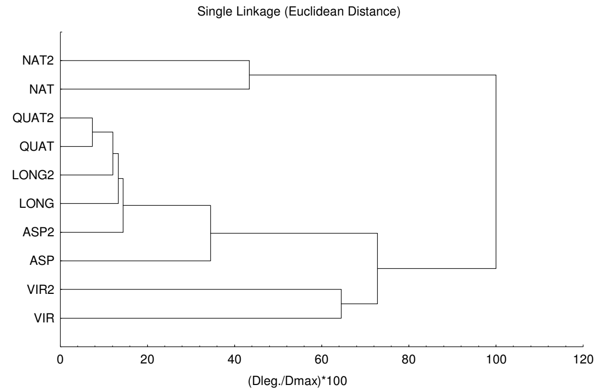

FIG. 3. Dendrogram yielded by hierarchical cluster analysis (UPGMA, standardized to 100%) of percentage use of habitat types by snakes at the study area, during the 2002-2003 survey and the Luiselli & Rugiero's (1990) study. Symbols for snake species: ASP, *Vipera aspis*; NAT, *Natrix natrix*; LONG, *Elaphe longissima*; QUAT, *Elaphe quatuorlineata*; VIR, *Coluber viridiflavus*. In all cases, the symbol '2' after the species' symbol (e.g. ASP2, NAT2, etc) indicates data from Luiselli & Rugiero (1990).

In terms of similarity of habitat use by snakes between surveys, a hierarchical cluster analysis (Fig. 3) indicated that all species were relatively consistent in terms of habitat use during the two survey periods. The highest similarity in habitat use between surveys was observed in *E. quatuorlineata* and, to a lesser degree, *E. longissima* and *V. aspis* (Fig. 3).

We investigated the habitat use similarity between survey periods of the four most abundant species (i.e. *C. viridiflavus, V. aspis, N. natrix, E.longissima*) by calculating Pianka and Czechanowski overlap indices and by performing Monte Carlo simulations on the resource use states during the two survey periods. Both niche indices suggested a strong habitat overlap (= similarity) between two survey periods in all four species, although the probability that the observed indices are less than expected was greater than the probability that they were higher than expected in all cases (Table 3).

The values of habitat overlap between species pairs were in general similar between survey periods, both using Pianka's and Czechanowski's indices (Table 4),

TABLE 3. Habitat use similarity between surveys for the various snake species assessed by calculating Pianka and Czechanowski overlap indices, and by calculating the probability that the observed indices were (1) less than expected and (2) greater than expected than those generated by Monte Carlo randomisations. Only the snake species which appeared more abundant in the study area were used for this analysis.

Snake species	Pianka's index	Czechanowski's index	*P* of indices being less than expected	*P* of indices being higher than expected
Vipera aspis	0.960	0.840	(Pianka = 0.8)	(Pianka = 0.2)
			(Czech. = 0.9)	(Czech. = 0.1)
Coluber viridiflavus	0.953	0.827	(Pianka = 0.7)	(Pianka = 0.3)
			(Czech. = 0.8)	(Czech. = 0.2)
Elaphe longissima	0.991	0.924	(Pianka = 0.8)	(Pianka = 0.2)
			(Czech. = 0.8)	(Czech. = 0.2)
Natrix natrix	0.919	0.722	(Pianka = 0.8)	(Pianka = 0.2)
			(Czech. = 0.6)	(Czech. = 0.4)

TABLE 4. Values of Pianka's (above diagonal) and Czechanowski's (below diagonal) overlap indices for the habitat type resource between the various snake species during the two survey periods.

	Vipera aspis	*Coluber viridiflavus*	*Elaphe longissima*	*Elaphe quatuorlineata*	*Natrix natrix*
LUISELLI & RUGIERO'S (1990) SURVEY					
Vipera aspis	****	0.527	0.916	0.406	0.205
Coluber viridiflavus	0.561	****	0.540	0.870	0.211
Elaphe longissima	0.697	0.499	****	0.374	0.287
Elaphe quatuorlineata	0.402	0.664	0.424	****	0.269
Natrix natrix	0.182	0.216	0.227	0.199	****
2002-2003 SURVEY					
Vipera aspis	****	0.287	0.970	0.380	0.185
Coluber viridiflavus	0.403	****	0.404	0.946	0.066
Elaphe longissima	0.826	0.398	****	0.509	0.285
Elaphe quatuorlineata	0.441	0.797	0.495	****	0.154
Natrix natrix	0.162	0.118	0.182	0.133	****

thus indicating that the type of habitat niche relationships between species pairs remained quite constant across the study periods. Indeed, between surveys there were no significant differences in the means of Pianka's index values ($O_{j,k}$=0.460±0.256 versus 0.419±0.312, t=0.328, df=18, P=0.746) nor in the means of Czechanowski index values ($O_{1,2}$=0.407±0.196 versus $O_{1,2}$=0.396±0.259, t=0.113, df=18, P=0.911). Moreover, as expected Pianka's index values were significantly correlated with Czechanowski's index values (r=0.961, adjusted r^2=0.919, n=20, P< 0.0001).

DISCUSSION

SPECIES COMPOSITION OF THE SNAKE COMMUNITY

All the species observed almost 15 years ago by Luiselli & Rugiero (1990) were observed again during the present study, and the species which were dominant at that time (*C. viridiflavus* and *V. aspis*) were also the most abundant species during the present study. However, in the recent survey we discovered two additional species (*C. girondica* and *N. tessellata*) which remained undetected during the earlier survey probably because of extreme elusiveness (*C. girondica,* see Agrimi & Luiselli, 1994) or because of relative rarity (*N. tessellata*). Indeed, as *N. tessellata* is easily observed in appropriate freshwater habitats (Filippi, 2000), and the numbers of observed specimens were also low during the recent survey (n=5, see Table 1), we hypothesize that this aquatic species may have existed at the site in low numbers for some time.

CHANGES IN HABITAT PREFERENCES

We used multivariate (UPGMA) analyses, diversity and dominance indices, Pianka and Czechanowski overlap indices and Monte Carlo simulations on the habitat use states during the two survey periods, to document whether the various species modified their habitat preferences between surveys. All of our analyses indicated that all the species did not exhibit any evident habitat variation between surveys. We suggest that the snakes did not change their habitat use because of the relatively stable general conditions of the study area which is a permanently managed natural reserve. In addition, Pianka and Czechanowski overlap indices on habitat data between pairs of species suggested that the habitat niche relations among species remained the same between survey periods, which is also consistent with the hypothesis of relatively stable habitat conditions at the study area during the survey periods.

CONSERVATION IMPLICATIONS

It is noteworthy that two species (*E. longissima* and, to a lesser extent, *V. aspis*) declined substantially between the two survey periods. It is likely that their apparent decline depended on that they were regularly found around the ruins of the ancient Monterano at the time of Luiselli & Rugiero's (1990) study, but now the ruins have been cleared bushes for archaeological reasons, and this has probably impacted negatively on the populations of these snakes (Luiselli & Capizzi, 1997; Filippi, 2003). The negative effects of such management at an archaeological site is potentially significant in conservation terms. In places such as Europe, where many of the protected areas are set aside for archaeological or historical (as opposed to biological) reasons, land managers attempting to maintain sites or improve access to them may do real harm to native species. For instance, other potential examples of archaeological areas which are concurrently characterized by rich snake communities in central Italy are 'Vejo' (about 15 km N of Rome) and 'La Marcigliana' (about 10 km NE of Rome), and in both these areas the archaeological sites are 'maintained' through clearance of scrub. In both areas the effects of such clearance on snake communities are now under study by us, in order to document whether there is really a conflict between the goals of archaeologists and conservation biologists in the archaeological sites which are managed in this manner. In the meantime, we urge herpetologists to report the effects of archaeological management on species-rich snake communities in other regions of Europe. Our analyses also indicated that, in terms of biodiversity value, the WDS-SWL habitat mosaic was crucial during both survey periods. The mosaic combination of these habitats should therefore be specially preserved for snake conservation, not only at the local level of the study area, but also more generally within the Mediterranean landscape, as it occupies very important fragments of the whole landscape in central Italy (Tomaselli *et al.,* 1973; Spada, 1977). SWL may be especially important during the spring, when the males of most species tend to use dry-stone walls surrounded by dense spiny bushes as corridors for mate searching (Luiselli & Capizzi, 1997, and unpublished data), whereas WDS is used primarily during the hot and dry summer, when snakes often need to retreat from high ambient temperatures (often >32-35°C). Dry-stone walls represent optimal habitat for Mediterranean snakes if they are surrounded by bushes (especially *Rubus* spp., and *Cytisus* spp.), whereas clearance of such vegetation may strongly affect the abundance of snakes if the walls are not directly removed or damaged (see Filippi, 2003). The mosaic of dry-stone walls crossing woodlands and fields are essential not only for the snakes in this study area, but also for threatened snake populations elsewhere in Italy (e.g. *Elaphe situla* in Apulia and *Vipera ammodytes* in north-eastern Italy, see Filippi & Luiselli, 2000), as well as for *E. longissima* in the Neckar-Odenwald region of Germany (Gomille, 2002). Other habitat types are also certainly important for the conservation of snake biodiversity, but probably they are less crucial than the combination of SWL and WDS in order to maintain an optimal level of stability in Mediterranean snake communities.

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