Analysis of a herpetofaunal community from an altered marshy area in Sicily; with special remarks on habitat use (niche breadth and overlap), relative abundance of lizards and snakes, and the correlation between predator abundance and tail loss in lizards

Luca Luiselli[1], Francesco M. Angelici[2], Massimiliano Di Vittorio[3], Antonio Spinnato[3], Edoardo Politano[4]

[1] *F.I.Z.V. (Ecology), via Olona 7, I-00198 Rome, Italy. E-mail: lucamlu@tin.it* [2] *F.I.Z.V. (Mammalogy), via Cleonia 30, I-00152 Rome, Italy.* [3] *Via Jevolella 2, Termini Imprese (PA), Italy.* [4] *Centre of Environmental Studies 'Demetra', via Tomassoni 17, I-61032 Fano (PU), Italy*

Abstract

A field survey was conducted in a highly degraded barren environment in Sicily in order to investigate herpetofaunal community composition and structure, habitat use (niche breadth and overlap) and relative abundance of a snake predator and two species of lizard prey. The site was chosen because it has a simple community structure and thus there is potentially less ecological complexity to cloud any patterns observed. We found an unexpectedly high overlap in habitat use between the two closely related lizards that might be explained either by a high competition for space or through predator-mediated co-existence i.e. the prevention of the competitive exclusion of one lizard over the other. We also found a strong positive correlation between predator density and tail damage in lizards and we suggest that tail damage is a direct consequence of snake activity (because no other natural predators occur in the area).

Contents

Introduction

Many (most?) faunal assemblages consist of a great diversity of species with complicated ecological relationships, thus rendering the examination of the relationships between predators and prey an extremely complicated task for the ecologist (e.g., see Connell, 1975; May, 1976; Schoener, 1986). However, there is considerable literature (both theoretical and empirical) indicating that case studies of extremely simple communities, together with the use of appropriate minimal models, can help us to understand the basis of complex patterns of ecological relationships among species (Thom, 1975; Arditi and Ginzburg, 1989; Scheffer, 1991). Thus, the study of the structure and function of very simple (i.e. containing a low number of species) communities of animals may be of great advantage if we are to understand the basis of complex patterns, which in other situations would be much more difficult to analyse.

In this paper, we use an extremely simple herpetofaunal community from southern Sicily as a case study to investigate: (i) community structure; (ii) the relative abundance relationships between prey (lizards) and predators (lizard-eating snakes) in different habitats; and (iii) ecological correlations that potentially indicate the effects of predator abundance on lizard communities. As study area we selected a coastal biotope, the area of 'Capo Feto', which has been heavily altered by urbanization and habitat exploitation in the last thirty years, and that has been subjected to a restoration ecology project under the auspices of EEC's Life-Nature programmes (Politano, 2004).

In practice, we will answer the following key questions:

1. What are the taxa that comprise the community?
2. What are the dominant predator and prey species in each of the various habitats?
3. Are inter-habitat variations in prey abundance

paralleled by inter-habitat variations in predator abundance?

4. If yes, can we find accurate ecological correlates between aspects of prey animals and higher predator activity in each habitat type (e.g., higher rates of tail injuries in lizards)?

Materials and methods

Study area

The field study was conducted at a coastal locality of south-western Sicily (Capo Feto, in the province of Trapani, communes of Mazara del Vallo and Petrosino). The study area is approx. 460 ha (see the following published maps: 'foglio 617, scale 1:50,000 'Marsala', and 'tavoletta 265 IV N.O., scale 1:25,000 'Capo Feto', produced by the 'Istituto Geografico Militare'). The site has a Mediterranean climate with very dry summer and relatively rainy winter (Figure 1) and is characterized as a coastal marshy area (partially freshwater and partially brackish water) that dries up for prolonged periods (from April to late September). There are also a few artificial channels surrounded by grassy vegetation with sparse stone piles and bushy areas.

Methods

This study was carried out as a phase of a Life-Nature programme of the EEC (see Acknowledgements). This programme is aimed at restoring the coastal marshy habitats of Capo Feto to its previous state
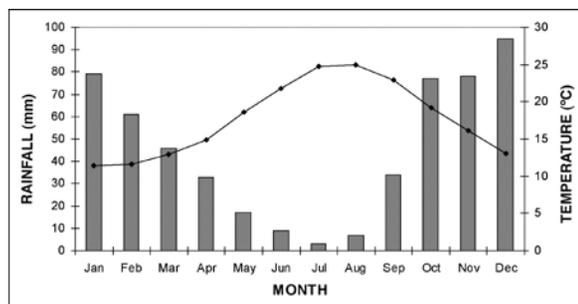
about 30 to 50 years ago, i.e. before heavy urbanization and habitat exploitation (Politano, 2004). The field study was carried out for 21 days: seven consecutive days in October 2001, seven consecutive days in March 2002, and seven consecutive days in August 2002. On each day, field effort lasted approximately 7-8 hours and randomly covered all the diel phases.

Searches for amphibians and reptiles were done on foot across random transects throughout every microhabitat of the study area by three independent researchers. All species of amphibians and reptiles captured during these surveys were recorded. Population structure, density and abundance estimates of both lizards and snakes were generated by capture-mark-recapture methods in three study plots, each 28,900 m² surface. The three study plots were representative of the various habitats available in the study area: (i) coastal dune, with low, sparse bushes on sandy soil (COD); (ii) banks of the artificial canal, with high bushes and relatively wet vegetation (BAC); (iii) open land, without bushes, and with very low grassy vegetation (OPL). The barycentres of the three study plots were at least 600 m apart, which was necessary to reduce the possibility that marked animals may travel from one plot to another plot. Indeed, we never recaptured any marked animal in any other plot apart from that of its original capture.

Lizards were permanently marked by toe-clipping, and snakes by ventral scale-clipping. Lizards were noosed, measured for snout-vent-length (SVL, to the nearest 0.1 cm) and sexed. The condition of their tail (broken or entire) was recorded during the survey done in March 2002. Several skinks (*Chalcides ocel-*

Fig. 1. Meteorological data for the area of Capo Feto. Data presented in this graphic are the means recorded over the period 1944-1994. Data were provided by the Meteorological Centre of Mazara del Vallo.
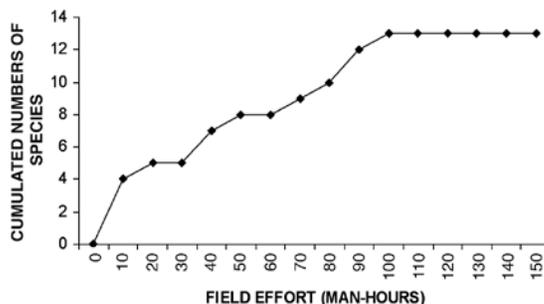

Fig. 2. Plot of discovery of new species against the field effort (expressed in hours) at the study area. Note that the plateau phase is reached, which testifies that the herpetofauna was adequately sampled.

latus tiligugu) were captured by CMR small-mammal-traps (Ugglan Model 1, 250 × 78 × 65 mm size) employed by a team of mammalogists who worked with us in the study area (for details, see Di Vittorio *et al.,* 2003). Snakes were captured by hand, measured for SVL (to the nearest 0.5 cm), sexed and palpated abdominally until regurgitation of ingested food occurred. Dietary composition was later analysed and food items were identified to the lowest taxon possible.

Species diversity and dominance indices in each habitat type were then calculated (see Hubalek, 2000, for an evaluation of the limits of these indexes). These calculations were made on combined data from the three survey periods because sample sizes were too small within individual surveys.

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 the commoner species (i.e. those for which at least 20 different individuals were captured and marked) we calculated both habitat niche breadth and habitat niche overlap. Habitat niche breadth was quantified using Simpson's diversity index (1949) (B), and habitat niche overlap by means of Pianka's symmetric formula (1973) (Q).

Statistical analyses (two-tailed and alpha set at 5%) were performed using STATISTICA (version 5.4, for Windows). In the text, we present values as the mean ± 1 SD. To avoid statistical problems due to 'pseudo-replication' of the data (cf. Licht *et al.* 1966; Mathur and Silver 1980; Hurlbert 1984) we used data only once from each individual, i.e. the recaptured individuals were never used again for data records.

Results

Community composition at the study area

A total of 150 man-hours were spent in the field, with an outcome that the herpetofauna appeared satisfactorily sampled (Figure 2). The number of species of amphibians and reptiles observed at the study area in relation to sampling period indicates that the spring survey was the most successful in terms of number of species found (Figure 3), which is an indication of the fact that spring is likely the annual phase of highest activity in the open for both amphibians and reptiles.

A comparison of the species found during the present survey with those expected on the basis of previous investigations in the study area is given in Table 1. Compared with historical data, our surveys allowed us to detect three new species (i.e., *Hyla intermedia*, which however was captured just outside the study area, *Chalcides chalcides,* and *Elaphe lineata*), whereas we did not find evidence of the current presence of *Caretta caretta* (which is however a marine species which just lays eggs on the

Table 1. List of the herpetofauna species found at the study area during the present surveys, and contrasted with historical data reported in Turriti & Vaccaro (1998) and in Lo Valvo & Longo (2001).

Species	This study	Historical data
AMPHIBIA		
Bufo viridis viridis	Yes[1]	No
Rana sinklepton *esculenta*	Yes	Yes
Hyla intermedia	Yes[1]	No
REPTILIA		
Caretta caretta	No	Yes
Emys orbicularis	No*	Yes
Hemidactylus turcicus	Yes	Yes
Tarentola mauritanica	Yes	Yes
Lacerta bilineata	Yes	Yes
Podarcis sicula	Yes	Yes
Podarcis wagleriana	Yes	Yes
Chalcides ocellatus tiligugu	Yes	Yes
Chalcides chalcides	Yes	No
Coluber viridiflavus	Yes	Yes
Elaphe lineata	Yes	No
Natrix natrix sicula	Yes	Yes

[1]   not captured in the study area, but just outside it; hence likely found also inside it

*   although there are still a few old specimens in the area, they are not able to reproduce, and so the species is to be considered extinct

Table 2. Number of reptile individuals marked in the three habitats at the study area, during the three survey periods. Symbols: P.W. = *Podarcis wagleriana,* P.S. = *Podarcis sicula,* L.B. = *Lacerta bilineata,* H.T. = *Hemidactylus turcicus,* T.M. = *Tarentola mauritanica,* C.V. = *Coluber viridiflavus;* M =males, F = females, J = juveniles; COD = coastal dune; BAC = banks of the artificial canal; OPL = open grassy area.

Habitat	P.W.	P.S.	L.B.	H.T.	T.M.	C.V.
October 2001						
COD	55 (33 M, 18 F, 4 J)	151 (75 M, 45 F, 36 J)	-	-	1	6 (2 M, 4F)
BAC	8 (5 M, 3 F)	38 (19 M, 14 F, 5 J)	1 (1 M)	-	-	1 (1 F)
OPL	18 (10 M, 8 F)	76 (41 M, 26 F, 9 J)	-	1	2	3 (1M, 2F)
March 2002						
COD	78 (46 M, 22 F, 10 J)	187 (94 M, 74 F, 19 J)	-	1	-	8 (4M, 4F)
BAC	31 (15 M, 7 F, 9 J)	26 (12 M, 11 F, 3 J)	1 (1 M)	-	-	1 (F)
OPL	27 (13 M, 9 F, 5 J)	21 (13 M, 7 F, 1 J)	-	1	-	1 (M)
August 2002						
COD	59 (28 M, 21 F, 10 J)	140 (88 M, 42 F, 10 J)	-	1	-	1 (F)
BAC	29 (11 M, 9 F, 9 J)	23 (12 M, 8 F, 3 J)	2 (1 M, 1 F)	-	-	-
OPL	40 (16 M, 13 F, 11 J)	15 (10 M, 5 F)	1 (M)	-	-	

beach)*,* and of a reproductive population of *Emys orbicularis* (Table 1). Thus, a total of 13 species (3 Amphibians, 10 Reptiles) are currently found in the study area, and two species (mentioned above) may have become extinct in recent decades. Indeed, their extinction may have been very recent because a local naturalist found all of them frequently only 20 years ago (V. Sciabica, personal communication).

Amphibians were not common in the study area, and we only observed single or a very few specimens of each species. The dominant reptile species were two lizards, *Podarcis wagleriana* and *Podarcis sicula,* and a snake, *Coluber viridiflavus*.

Food habits of snakes

Analysing the diet habits of *Coluber viridiflavus* at the study area (n = 21 specimens examined, i.e. 8 males and 13 females), showed that the two *Podarcis* species and *Chalcides ocellatus* constituted the bulk of the diet of this snake (Figure 4), although small mammals (*Crocidura sicula*) were also eaten on occasion.

The single *Elaphe lineata* captured had a brown rat (*Rattus norvegicus*) in the stomach, and one *Natrix natrix* (total sample examined, n = 3) had a fish (*Mugil cephalus*) in the stomach.
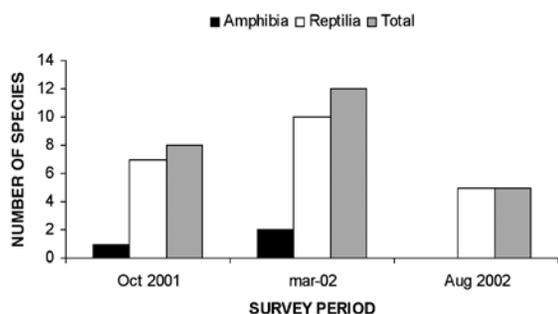

Fig. 3. Number of species of amphibians and reptiles observed at the study area in relation to sampling period. Note that the spring survey was the most successful in terms of number of species found.
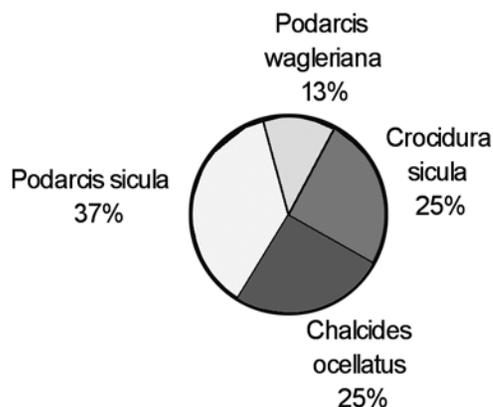

Fig. 4. Diet composition of *Coluber viridiflavus* at the study area, based on the forced regurgitation of 21 specimens (eight of them containing food items in stomach).

*Habitat partitioning, niche breadth,
and relative abundance of lizards and snakes*

Data summarizing the numbers of lizard and snake specimens caught in each habitat type, during the three survey periods, are given in Table 2. In this table we did not include the numbers of captured specimens for the following species: *Chalcides ocellatus* ($n = 11$), *Chalcides chalcides* ($n = 6$), *Elaphe lineata* ($n = 1$), *Natrix natrix sicula* ($n = 3$) because they were captured at the study area, but outside our experimental plots. In any case, *Chalcides ocellatus* was observed in all habitats, *Chalcides chalcides* only at OPL, *Elaphe lineata* and *Natrix natrix sicula* only at BAC.

COD was the habitat type housing the largest number of lizards at all study periods (Table 2). In addition, there was a statistically significant positive correlation between within-habitat number of marked lizards and number of marked snakes ($r = 0.82$, adjusted $r^2 = 0.69$, $n = 9$, $P < 0.006$), that is: snakes were more abundant in the habitats where lizards were more abundant. This relation was also evident when comparing the percent frequency of occurrence of the two commonest lizards (*Podarcis wagleriana*, *Podarcis sicula*) and the commonest snake (*Coluber viridiflavus*) among habitats (Figure 5). In this case, the 'ecological distribution' of the snake was not statistically different from that of the two lizards (χ^2 test with df = 2, $P > 0.2$), and was especially similar to that of *Podarcis sicula* (Figure 5). Interestingly,

the two *Podarcis* did not differ significantly in terms of 'ecological distribution' (χ^2 test with df = 1, $P > 0.3$), thus suggesting that these lizards did not partition habitat at the study area. This suggestion is verified by the fact that *Podarcis wagleriana* and *Podarcis sicula* exhibited an almost total habitat niche overlap ($Q = 95.4\%$), although their habitat use also overlapped widely with that of *Coluber viridiflavus* (habitat overlap of *Podarcis wagleriana* with *Coluber viridiflavus*: $Q = 89.4\%$; *Podarcis sicula* with *Coluber viridiflavus*: $Q = 93.2\%$).

An analysis of the habitat niche breadth of the various species revealed that *Podarcis wagleriana*, although less abundant than *Podarcis sicula* in terms of total sample size (see raw data in Table 2), had a wider habitat niche breadth ($B = 2.448$ versus 1.845), whereas *Coluber viridiflavus* had a narrower habitat niche breadth ($B = 1.570$).

The value of D_{mg} was significantly higher ($P < 0.01$, Mantel test) at OPL ($D_{mg} = 0.955$) than at the two other habitats (0.459 at COD, 0.590 at BAC), whereas the value of d was not significantly different among the three habitats ($d = 0.696$ at COD, 0.540 at BAC, 0.543 at OPL).

*Inter-habitat incidence of tail loss
in lizard populations*

The frequency of adult lizards (*Podarcis wagleriana* and *Podarcis sicula*) with broken/regenerated tails
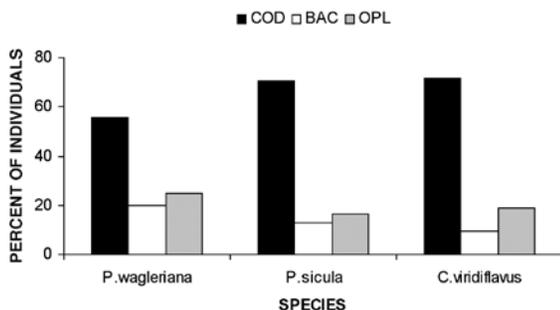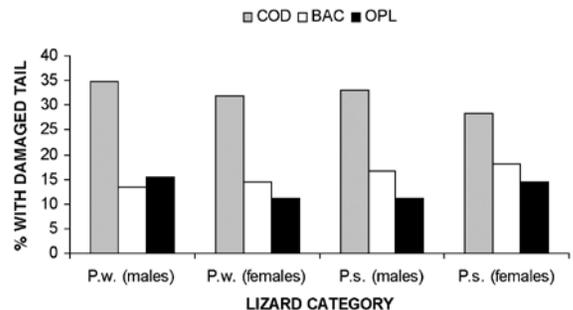

Fig. 5. Percent distribution among habitats of the two commonest species of lizards (*Podarcis wagleriana* and *Podarcis sicula*) and of the most common species of snakes (*Coluber viridiflavus*). Note that the among-habitats distribution of the snake parallels that of the lizards. Sample sizes: *P. wagleriana, n* = 345; *P. sicula, n* = 677; *C. viridiflavus, n* = 21. Symbols: COD = coastal dune; BAC = banks of the artificial canal; OPL = open grassy area.

Fig. 6. Percent frequency of occurrence of adult lizards (*Podarcis wagleriana,* P.w., and *Podarcis sicula,* P.s.) with tail broken/regenerated in the three habitat types, during the March 2002 survey. Sample sizes: *P. wagleriana* – males: *n* = 46 (COD), 15 (BAC), 13 (OPL), females: *n* = 22 (COD), 7 (BAC), 9 (OPL); *P. sicula* – males: *n* = 94 (COD), 12 (BAC), 13 (OPL), females: *n* = 74 (COD), 11 (BAC), 7 (OPL). Symbols: COD = coastal dune; BAC = banks of the artificial canal; OPL = open grassy area.

in the three habitat types, during the March 2002 survey, is given in Figure 6. The frequency of specimens with damaged tails was significantly higher in COD than in any other habitat type, in both sexes of *Podarcis sicula* (χ^2 test, $P < 0.01$), as well as in both sexes of *Podarcis wagleriana* (χ^2 test, $P < 0.05$). Males had generally higher rates of damaged tail, but the frequency of occurrence of damaged tail was not significantly different between sexes in any species and in any habitat type (in all cases, χ^2 test, $P =$ N.S.).

Discussion

Community composition at the study area

As expected, because of the very degraded environment at the study area the herpetological community was extremely simple, with just four species of reptiles that could be considered abundant (i.e. *Podarcis wagleriana, Podarcis sicula, Chalcides ocellatus,* and *Coluber viridiflavus*) and several other species which were very rare (and possibly remnant individuals of populations which were much more abundant before the environmental degradation). This is indirectly demonstrated by the extinction of several species, which were certainly found at the study area only 20 years ago (e.g., *Emys orbicularis*). It should be mentioned that the four 'dominant' herpetological species are generally widespread and very abundant in the whole of Sicily, and are considered to be the most adaptable species in this geographic region (e.g., Bruno and Maugeri, 1977; Turriti and Vaccaro, 1998; Lo Valvo and Longo, 2001).

Food habits of snakes

Our data on the food habits of *Coluber viridiflavus* did not reveal any unexpected pattern, given that this species is well known to feed mainly on lacertid lizards and, secondarily, on small mammals (e.g., see Rugiero and Luiselli, 1995; Capizzi and Luiselli, 1996). No data are available on the diet of *Elaphe lineata* in the wild, but our single food record (a brown rat) could not be considered surprising given that this rodent (i) is very abundant at the study area (Di Vittorio *et al.,* 2003; Angelici, 2004), and (ii) is regularly eaten by the closely related species *Elaphe*

longissima in mainland Italy (Capizzi and Luiselli, 1996). Regarding *Natrix natrix,* it is not unusual for this species to prey on fish (e.g., Luiselli *et al.,* 1997; Gregory and Isaac, 2004), but the peculiarity of our record is that the fish ingested was a marine species. It is most likely that the snake ingested the fish in the brackish and salt-water of the artificial channel, where these fish can be found in large numbers. Our record therefore certifies that Sicilian grass snakes can forage in brackish waters on occasions.

Habitat partitioning, niche breadth, and relative abundance of lizards and snakes

The advantages of studying this Sicilian herpetofaunal community were that the number of vertebrate species was extremely low and particularly because the only abundant natural predator of the two dominant lizards was the snake *Coluber viridiflavus* (the area contains no mammals or birds of prey that specialize on lizards - Di Vittorio *et al.,* 2003; Angelici, 2004; Sciabica, 2004). Because of this, the analysis of the relationships between lizards and their predators are here easier and more direct than in most previous studies (e.g., see Barbault, 1991).

The main result of our study is that the abundance of snakes was positively correlated with the abundance of the two commonest lizards, and that these abundances peaked at one specific habitat type (COD), where a high productivity was also found in terms of small mammals (Di Vittorio *et al.,* 2003; Angelici, 2004). Interestingly, the two *Podarcis* species showed a very high spatial overlap, although *Podarcis sicula* was more abundant than *Podarcis wagleriana*. The high spatial overlap was not expected, given that it is reported that these two lizards usually differ in terms of micro-habitat use as well as thermal needs (Sorci, 1989; Corti and Lo Cascio, 1999, 2002), and possibly indicates a strong interspecific competition for space in this very altered coastal habitat (Pianka, 1973). In this regard, it should be mentioned also that we have to consider the potential effects of the generalist lizard predator (*Coluber viridiflavus*). This snake may be allowing the co-existence of the two lizard species to occur by reducing the rate of competitive exclusion by one lizard over the other (i.e. 'exploiter-mediated co-existence' - Paine, 1966). That is to say, lizard population growth rate is reduced by the effects of

predation from the snake and so neither lizard species is able to completely out-compete the other and become dominant in any particular habitat. It seems likely from the field data that *Podarcis sicula* is a better competitor (greater numbers of this lizard in our study) and may become the dominant lizard in certain habitats if snake numbers were reduced. *Podarcis sicula* may then be able to competitively exclude *Podarcis wagleriana* in that habitat, and habitat overlap between the two lizard species would then obviously be reduced. However, this interesting hypothesis needs to be tested by ad-hoc experiments.

The niche breadth difference between *Podarcis wagleriana* and *Podarcis sicula* is likely not as important, and may simply be a result of the fewer numbers and lower proportion of *Podarcis wagleriana* found in COD compared to other habitats. After all, the graphs (Figure 5) of the relative numbers of the two species in the various habitats appear quite similar. According to previous authorities, *Podarcis sicula* is the most versatile lizard species in the Mediteranean regions of insular Italy (Bruno and Maugeri, 1977; Corti and Lo Cascio, 1999, 2002).

Inter-habitat incidence of tail loss in lizard populations

Concerning the inter-habitat variations in the frequency of lizards with damaged tails, our results seem to be particularly interesting because they demonstrate a much higher frequency of occurrence of 'damaged' lizards in a habitat type (COD) where the density of a lizard-eating snake was highest (at least based on the number of specimens caught in that habitat type). Since at the study area there are no mammals which feed on lizards (Di Vittorio *et al.,* 2003; Angelici, 2004) and very few birds of prey (Sciabica, 2004), it is obvious that most of the lizards killed by natural predators are therefore prey of *Coluber viridiflavus*. Thus, the different frequency of occurrence of 'damaged' lizards between the habitats may be correlated to the differential risk of predation by snakes, which is a direct consequence of differential snake abundance between the habitats. Conversely, the frequency of specimens with damaged tail did not vary significantly between BAC and OPL in any sex of any species (in all cases, χ^2 test, P = N.S.). In this regard, it is obvious that the

slightly higher percentage of animals (the snake and both lizards) in habitat OPL than in habitat BAC (Figure 5), not mirrored with the fact that there are slightly more lizards with damaged tails in BAC than in OPL (Figure 6), could not be considered as an opposite trend to what might be expected (i.e. the positive correlation between a greater number of snakes and greater tail loss in lizards), because the inter-habitat differences are for both cases statistically insignificant, and so likely attributable to different sample sizes. Although correlational studies must be interpreted carefully, as many environmental variables cannot be properly controlled or accounted for, the extremely simplified model system used in this paper (a heavily altered habitat with very low biodiversity) strongly suggests that a correlation between frequency of lizard tail damage and predation intensity does occur. This finding is in agreement with Placyk and Burghardt (2005), and we therefore urge researchers to reconsider this traditional but controversial view of tail loss in reptiles, i.e. tail loss increases with predator intensity (but see also Congdon *et al.,* 1974; Schoener, 1979, 1985; Schoener and Schoener, 1980; Dial, 1981; Dial and Fitzpatrick, 1981, 1983; Vitt, 1983; Jacksic and Greene, 1984; Arnold, 1988; Smith, 1996; Cooper, 1997, 2000, 2003; Martin and Lopez, 2003; etc, for alternative points of view).

References

Angelici FM. 2004. I mammiferi di Capo Feto. In: Capo Feto: un progetto di riqualificazione e ripristino ambientale finalizzato alla conservazione e allo sviluppo sostenibile, in press. Politano, E., Ed, Consiglio Nazionale delle Ricerche, Mazara del Vallo.

Arditi R, Ginzburg LR. 1989. Coupling in predator-prey dynamics: ratio-dependence. *J. Theor. Biol.* **139**: 311-326.

Arnold EN. 1988. Caudal autotomy as a defense. In: Biology of the Reptilia, Vol. 16, Ecology B, Defense and life history, p. 235-273. Gans, C., Huey, R.B., Eds, New York, Alan R. Liss, Inc.

Barbault R. 1991. Ecological constraints and community dynamics: linking community patterns to organismal ecology. The case of tropical herpetofaunas. *Acta Oecol.* **12**: 139-163.

Bruno S, Maugeri S. 1977. *Rettili d'Italia*. Firenze, Giunti-Martello.

Capizzi D, Luiselli L. 1996. Feeding relationships and competitive interactions between phylogenetically unrelated predators (owls and snakes). *Acta Oecol.* **l7**: 265-284.

Congdon JD, Vitt LJ, King WW. 1974. Geckos: adaptive significance and energetics of tail autotomy. *Science* **184**: 1379-1380.

Connell JH. 1975. Some mechanisms producing structure in natural communities. In: Ecology and Evolution of Communities, Cody, M.L., Diamond, J.M., eds. Pp. 460-490. Cambridge (Massachusetts), Harvard University Press.

Cooper WE Jr. 1997. Threat factors affecting antipredator behavior in the broad-headed skink (*Eumeces laticeps*): repeated approach, change in predator path, and predator's field of view. *Copeia* **1997**: 613-619.

Cooper WE Jr. 2000. Tradeoffs between feeding and predation risk in a lizard, the broad-headed skink (*Eumeces laticeps*). *Behaviour* **137**: 1175-1189.

Cooper WE Jr. 2003. Effect of risk on aspects of escape behavior by a lizard, *Holbrookia propinqua*, in relation to optimal escape theory. *Ethology* **109**: 617-626.

Corti C, Lo Cascio P. 1999. *I Lacertidi Italiani.* Palermo, L'Epos.

Corti C, Lo Cascio P. 2002. *The Lizards of Italy and adjacent areas.* Frankfurt am Main, Chimaira Edition.

Dial BE. 1981. Function and energetics of autotomized tail thrashing in *Lygosoma laterale* (Sauria: Scincidae). *Am. Zool.* **21**: 1001.

Dial BE, Fitzpatrick LC. 1981. The energetic costs of tail autotomy to reproduction in the lizard *Coleonyx brevis* (Sauria: Gekkonidae). *Oecologia* **51**: 310-317.

Dial BE, Fitzpatrick LC. 1983. Lizard tail autotomy: function and energetics of post autotomy tail movement in *Scincella lateralis*. *Science* **219**: 391-393.

Di Vittorio M, Angelici FM, Politano E, Spinnato A. 2003. I mammiferi dell'area di Capo Feto (Trapani). *Hystrix* **14** (suppl.): 95-96.

Gregory P, Isaac LA. 2004. Food habits of the grass snake in southeastern England: is *Natrix natrix* a generalist predator? *J. Herpetol.* **38**: 88-95.

Hubalek Z. 2000. Measures of species diversity in ecology: an evaluation. *Folia Zool.* **49**: 241-260.

Hurlbert SH. 1984. Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.* **54**: 187-211.

Jacksic FM, Greene HW. 1984. Empirical evidence of non-correlation between tail loss frequency and predation intensity on lizards. *Oikos* **42**: 407-411.

Licht P, Dawson WR, Shoemaker VH, Main AR. 1966. Observations on the thermal relations of western Australian lizards. *Copeia* **1966**: 97-110.

Lo Valvo F, Longo AM. 2001. *Anfibi e Rettili in Sicilia*. Palermo, WWF-DoraMarkus.

Luiselli L, Capula M, Shine R. 1997. Food habits, growth rates and reproductive biology of grass snakes, *Natrix natrix* (Colubridae) in the Italian Alps. *J. Zool., Lond.* **241**: 371-380.

Magurran AE. 1988. *Ecological diversity and its measurement*. Princeton, Princeton University Press.

Martín J, López P. 2003. Changes in the escape responses of the lizard *Acanthodactylus erythrurus* under persistent predatory attacks. *Copeia* **2003**: 408-413.

Mathur D, Silver CA. 1980. Statistical problems in studies of temperature preferences of fishes. *Can. J. Fish. Aquat. Sci.* **37**: 733-737.

May RM. 1976. *Theoretical Ecology.* Blackwell, London.

Paine RT. 1966. Food web complexity and species diversity. *Am. Nat.* **100**: 65-75.

Pianka ER. 1973. The structure of lizard communities. *Annu. Rev. Ecol. Syst.* **4**: 53-74.

Pianka ER. 1975. Niche relations of desert lizards. *In*: Cody, M.L. and Diamond, J.M. (eds.), Ecology and Evolution of Communities, pp. 292-314. Belknap Press, Cambridge (USA).

Pianka ER. 1986. *Ecology and Natural History of Desert Lizards*. Princeton University Press, Princeton.

Placyk JS Jr, Burghardt GM. 2005. Geographic variation in the frequency of scarring and tail stubs in eastern gartersnakes (*Thamnophis s. sirtalis*) from Michigan, USA. *Amphibia-Reptilia* **26**: 353-358.

Politano E. 2004. Le problematiche concernenti le operazioni di ripristino e riqualificazione ambientale del 'biotopo Capo Feto'. In: Capo Feto: un progetto di riqualificazione e ripristino ambientale finalizzato alla conservazione e allo sviluppo sostenibile, in press. Politano, E., Ed, Consiglio Nazionale delle Ricerche, Mazara del Vallo.

Rugiero L, Luiselli L. 1995. Food habits of the snake *Coluber viridiflavus* in relation to prey availability. *Amphibia-Reptilia* **16**: 407-411.

Scheffer M. 1991. Fish and nutrient interplay determines algal biomass: a minimal model. *Oikos* **62**: 271-282.

Schoener TW. 1979. Inferring the properties of predation and other injury-producing agents from injury frequencies. *Ecology* **60**: 1110-1115.

Schoener TW. 1985. Are lizard population sizes unusually constant through time? *American Naturalist* **125**: 633-641.

Schoener TW. 1986. Resource partitioning. In: Community Ecology: Pattern and Process, Kikkawa, J., Anderson, D.J., eds. Pp. 91-126. Melbourne, Blackwell Scientific Publications.

Schoener TW, Schoener A. 1980. Ecological and demographic correlates of injury rates in some Bahamian *Anolis*. *Copeia* **1980**: 839-850.

Sciabica V. 2004. Gli uccelli di Capo Feto. In: Capo Feto: un progetto di riqualificazione e ripristino ambientale finalizzato allo sviluppo sostenibile, in press. Politano, E., Ed, Consiglio Nazionale delle Ricerche, Mazara del Vallo.

Simpson EH. 1949. Measurement of diversity. *Nature* **163**: 688.
Smith GR. 1996. Correlates of approach distance in the striped plateau lizard (*Sceloporus virgatus*). *Herp. J.* **6**: 56-58.
Sorci G. 1989. Nicchia trofica di quattro specie di Lacertidae in Sicilia. *Naturalista Siciliano* **14:** 83-93.
Thom R. 1975. *Structural stability and morphogenesis: an out-line of a general theory of models.* Reading (Massachusetts), Benjamin.

Turriti GF, Vaccaro A. 1998. Contributo alla conoscenza degli Anfibi e dei Rettili di Sicilia. *Bollettino dell' Accademia Gioenia di Scienze Naturali* **30** (353): 5-88.
Vitt LJ. 1983. Tail loss in lizards: the significance of foraging and predator escape models. *Herpetologica* **39**: 151-162.