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# Habitat characteristics and demography of high-altitude populations of the lacertid lizard, *Algyroides fitzingeri*

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## ABSTRACT

A capture-mark-recapture procedure was used to study the demography of a population of *Algyroides fitzingeri* inhabiting a mountain grassy area of central Sardinia. This population was artificially enclosed to avoid emi/immigrations. The *A. fitzingeri* individuals from this area were morphologically and ecologically different from other conspecifics studied to date: they had a lighter dorsal colouration, exhibited totally terrestrial habits, and used prostrate *Juniperus* bushes to hide in. Adult sex-ratio was close to 1:1, but females were more numerous and attained larger size than males. More than 80% of the marked males and females was recaptured, and the frequency of recapture was similar in the two sexes. The apparent density was 86 adults per hectare.

**KEY WORDS:** *Algyroides fitzingeri* - Lacertidae - Demography - Sex ratio - Ecology - Sardinia.

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This paper is dedicated to our friend and colleague Francesco Barbieri.

## INTRODUCTION

Lacertid lizards are undoubtedly among the most remarkable reptiles in the Mediterranean area, both because of their abundance (that assigns to them a crucial position in the trophic nets), and their ecological plasticity (see e.g. Arnold, 1987; Corti & Lo Cascio, 1999). Thus, it is not surprising that, during the last two decades, they have attracted an enormous amount of ecological researches both in the field and in the laboratory (cf. literature cited in Corti & Lo Cascio, 1999). Nonetheless, this research effort has been strongly unbalanced with respect to the various taxa studied, with some species achieving the status of 'study models' (e.g., *Podarcis muralis*, *P. sicula*, *Zootoca vivipara*), and others being virtually overlooked. No doubt *Algyroides fitzingeri* (Wiegmann, 1834), the smallest lacertid lizard of the Mediterranean region, is one of such overlooked species. It is endemic to Corsica and Sardinia (Mediterranean Sea), where it inhabits mainly thermo-Mediterranean arid areas with bushes, walls, and rocks (Schneider, 1981; Bruno, 1986).

The biology of this species is still relatively little studied (cf. Bosch, 1986, 1987; Keymar, 1988; Capula & Luiselli, 1994), and the data available are confined to populations inhabiting low-altitude sites with evergreen maquis-type vegetation. However, at least in Sardinia, *A. fitzingeri* can be found also at upper altitudes beyond the wooded zone (up to 1834 m a.s.l., according to Bruno, 1986), i.e. in unusual habitats and altitudes for a lizard species which is known to be scarcely resistant to cool and low external temperatures (Bruno, 1986). Data on the population ecology of these high-altitude populations are completely lacking, despite their being crucial for understanding the adaptation mechanisms of this endemic lizard to its environment.

The present paper presents the main results of a field enclosure study carried out on the ecology and population structure of a high-altitude population of *A. fitzingeri* from central Sardinia. Due to various sources of constraint over the planning of this research project, we were unable to produce a long-term study on the population ecology of this lizard. However, we think that the preliminary data presented here may be useful to highlight the auto-ecology patterns of this remarkable and little known lacertid lizard.

## MATERIALS AND METHODS

### *Study area*

The field study was carried out at a high-altitude locality (1455 m a.s.l.) of central Sardinia, situated in the Gennargentu massif, in the surroundings of Fonni (province of Nuoro). The study area is characterized by extensive grassy pastures beyond the tree limit, with sparse bushes of prostrate juniper (*Juniperus communis nana*). Rocks and stony walls, which are typical sites for *A. fitzingeri* in Sardinia (Bruno, 1986; Keymar, 1988; Capula & Luiselli, 1994), are totally absent, and even stones are sparsely present and moderately sized.

## Methods

An area with nearly flat ground and exactly 50 × 50 m surface, where several *A. fitzingeri* specimens were observed during preliminary surveys (conducted between 1990 and 1993), was selected as study plot, because it appeared to house an averagely dense population of lizards. What had to be avoided was the possibility that the plot, if randomly selected, would produce arbitrary data relative to a single small spot, rather than to a more general condition in the study site. Selection was made after preliminary lizard counts at 10 randomly selected plots of 20 × 20 m surface. We chose the one where we counted a number of lizards which best approximated the arithmetic mean of the numbers of lizards observed in the ten plots. At the study plot, grass occupied approximately 70% of the surface, *Juniperus* bushes 15%, and stones 15%.

During the night, when the lizards were hidden, the study plot was entirely surrounded by a Plexiglas fence (with walls of 100 cm height, plus 20 cm beneath the ground surface), in order to avoid immigration and/or emigration of the various lizard individuals. The fence surface was perfectly smooth, and *A. fitzingeri* individuals were not able to climb on it (Capula *et al.*, unpubl. obs.). The study plot was surveyed throughout a seven-day period (from 15 to 21 May 1998) during the hours of highest lizard above-ground activity (see Capula & Luiselli, 1992), i.e., between 9.30 a.m. and 1.30 p.m. The total field effort was 1680 minutes. Each *Algyroides* specimen was noosed or captured by hand, measured for snout-vent length with a precision calliper (svl, to ± 1 mm precision), sexed by checking the size and numbers of femoro-anal pores (11-13 enlarged in males, see Bruno, 1986), and individually marked by painting a colour on the back (using non-injurious paint). Each lizard received a specific paint mark which made it possible to recognize the individual easily without further capture. The colour assigned to each individual varied each day, thus allowing us to immediately assign the individuals to the day of sampling they were captured. Permanent marking techniques (i.e., toe-clipping) were not used in order to avoid ethical problems and not to affect lizard long-term survival.

Juveniles (specimens shorter than 25 mm svl) were neither sexed nor marked, and were immediately released in the field. They were not used for any statistical elaboration presented in this paper.

After routine measurements, the lizards were released unharmed at the capture point. The marked lizards were considered to be recaptured when they were met with again and identified by their individual painting marks, even without being newly handled. Only one recapture per sampling day was recorded. Fences were removed after the conclusion of the sampling period.

Statistical analyses ( $\chi^2$  test, Fisher exact test, ANOVA) were performed using the STATISTICA for Windows PC package, with all test being two-tailed and alpha set at 5%.

## RESULTS

*Algyroides fitzingeri* was the most common reptile at the study locality. The area was inhabited also by the lizard *Podarcis tiliguerta* and the snake *Natrix n. cetti*, which can occasionally be a natural predator of lizards (Capula *et al.*, 1994). Considering that *A. fitzingeri* were very common throughout the surveyed area, the study plot did not enclose more than a small part of the whole lizard population. However, we selected an area that appeared to house an averagely dense population of lizards (see Methods).

*Algyroides fitzingeri* individuals from the study locality were characterized by a quite unusual light-brown or yellowish dorsal livery, with a dark line along the backbone. It should be stressed that the usual dorsal

colouration of Sardinian populations of the species is uniformly dark-grey, brown-blackish, or black (see, e.g., Bruno, 1986; Keymar, 1988).

*Algyroides fitzingeri* individuals were observed always on the ground, moving on the grassy substratum, and hiding in *Juniperus* bushes. They were rarely observed on rocks, stones, or other substrata which are known to be typical for this species (Bruno, 1986; Keymar, 1988; Capula & Luiselli, 1994). The two sexes used the three types of available microhabitats as follows: grass (40% by males and 35% by females), bushes (40% by males, and 55% by females), and stones (20% by males, and 10% by females; all these percentages are approximated to the nearest entire value). Thus, comparing microhabitat availability at the study plot and micro-habitat use by the lizards, bushes were used significantly more often than that might be supposed on the basis of their availability ( $\chi^2$  test, df = 2,  $P < 0.05$  in both sexes).

A total of 43 adult lizards (16 males and 27 females) was captured and marked during the present study. Adult sex-ratio (0.6:1) did not depart significantly from equality (Fisher exact test,  $P > 0.75$ ).

Snout-vent length distribution frequencies in both sexes are presented in Figure 1. Females (37.7 mm svl on average) attained larger mean size than males (34.4 mm svl on average) (one-way ANOVA:  $F_{1,41} = 20.20$ ,  $P = 0.00006$ ), and even larger maximum sizes (41 mm svl in females vs 38 mm svl in males).

The capture-mark-recapture study is summarized in Table I. The great majority of marked males (81.2%) and marked females (85.2%) was recaptured at least once during the research period (Table I). The frequency of recaptured individuals did not differ significantly between sexes ( $\chi^2$  test with df = 1,  $P > 0.3$ ). The highest number of recaptures was five (a female, 38 mm svl). Individual snout-vent length and recapture fate were not significantly correlated (Spearman's  $r = 0.071$ ,  $P = 0.65$ ), and neither snout-vent length nor sex significantly influenced the fate of the various individuals (i.e., individuals recaptured or not, ANOVA:  $P > 0.62$ ).

Considering that (i) most of the captured individuals were recaptured at least once, (ii) the progression of

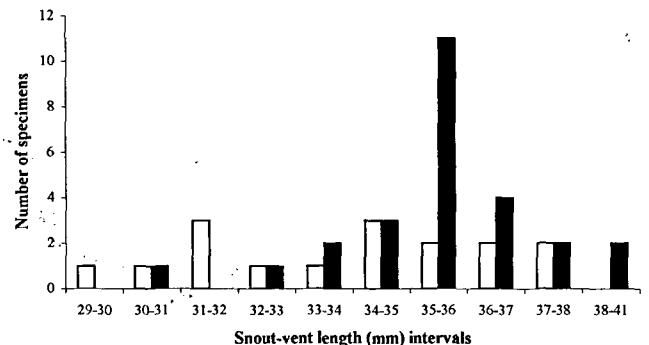


Fig. 1. Distribution of snout-vent length (mm) in males (white bars) and females (black bars) *Algyroides fitzingeri* from the study area. For statistical details, see text.

TABLE I - Fate of the various individuals of *Algyroides fitzingeri* captured and marked during the present study.

Individuals (n)	Sex		Recaptures
	Males	Females	
6	3	3	0
12	6	6	1
12	5	7	2
8	2	6	3
4	1	3	4
1		1	5

the field days was accompanied by a regular reduction in the numbers of newly marked individuals (the encounter rates of new unmarked adults was 0.026 individuals/min) (see Table II), and (iii) no unmarked individual was found during the last two days of sampling (Table II), it can be concluded that the number of individuals found by us approximated closely the effective number of specimens present in the study plot. Thus, the apparent density should be nearly identical with the effective density of lizards in the study plot, i.e., 86 adults/ha. However, it should be stressed that we observed a large number of juveniles and subadults (not included in our analyses due to their being unsexable), and thus it may well be that the effective lizard population density was higher than that estimated.

DISCUSSION

*Algyroides fitzingeri* is usually described as a small, dark-coloured, diurnal, insectivorous lacertid (Bosch, 1986), characterized by rupicolous habits and by a typical demographic structure, with small demes (10-15 individuals per deme), quite isolated from each other, thus constituting an obvious metapopulation structure

TABLE II - Number of *Algyroides fitzingeri* individuals captured, marked, and recaptured, in the study plot during the study period. For more details, see text.

Sampling Day	Captured	Marked	Recaptured
First	26	26	-
Second	18	8	10
Third	20	7	13
Fourth	17	1	16
Fifth	17	1	16
Sixth	17	0	17
Seventh	19	0	19

(Schneider, 1981; Bruno, 1986; Keymar, 1988; Capula & Luiselli, 1994). In this respect, the demography of this lizard is apparently similar to the demographic structure of a small Mediterranean gecko, i.e. *Euleptes europaea* (Allosia *et al.*, 1999).

The high-altitude population studied in this paper was ecologically different from those living at low altitudes in its being characterized by high population densities, demes extending over larger surfaces, and being constituted by individuals that were lighter in colour and totally terrestrial. The study revealed an unexpected plasticity in the colouration, habitat, and demographic characteristics of a lizard species that has been described as a specialized taxon almost exclusively inhabiting Mediterranean environments (cf. Bruno, 1986). It should be noted that there was not any longitudinal/latitudinal trend in these population structure differences, the only associated factor probably being altitude (as the altitudes of the sites inhabited by 'usual' *A. fitzingeri* populations were all less than 700 m a.s.l.).

Different hypotheses can be proposed to explain the observed pattern. The first is that *A. fitzingeri* exhibits a remarkable phenotypic plasticity in its life-history traits, which enables it to colonize both rupicolous sites in the thermo-Mediterranean arid zone of southern Sardinia (Capula *et al.*, unpubl. data), and the grassy pastures of the upper elevations in the Gennargentu massif. Among the various reptile species inhabiting Sardinia, only the lizard *Podarcis tiliguerta* and the snake *Coluber viridiflavus* exhibit the same natural history plasticity (Bruno, 1986). It is likely that the higher densities and terrestrial habits of the high-altitude populations may reflect a relative scarcity of potential competitors for space and food in these mountain environments, thus enabling *A. fitzingeri* to invade spatial niches which are usually occupied by other species at lesser elevations (e.g., *Podarcis sicula*, *P. tiliguerta*, *Lacerta bedriagae*, *Chalcides ocellatus*, *Tarentola mauritanica*, *Hemidactylus turcicus*). Similar mechanisms of 'ecological invasion' of empty niches have been already described in lizards (e.g., Pianka, 1986), including Mediterranean lacertids (Capula, 1992). The second, not mutually exclusive, hypothesis is that *A. fitzingeri* can invade the terrestrial spatial niche at the upper altitudes because of a remarkable scarcity of potential predators. This hypothesis is supported by the fact that the only potential predator of high mountain *A. fitzingeri* is the snake *Natrix n. cetti*, which is quite rare and mainly batracophagous (Capula *et al.*, 1994). On the contrary, low altitude *A. fitzingeri* can be eaten by several reptiles (*Coluber viridiflavus*, *C. hippocrepis*, *Chalcides ocellatus*) and birds of prey (*Falco tinnuculus*, *F. naumanni*) (see Bruno, 1986), and it is likely that they have strictly rupicolous habits to avoid such a strong predation pressure.

Body size of adult individuals recorded during the present study was nearly identical with that typically described for this species (Schneider, 1981), and the fact that females were on average larger than males entirely

mirrors Bruno's (1986) opinion. This evidence is a little surprising, as in Mediterranean lacertids males usually exceed females in size (Bruno, 1986; Capula, 1990, Ph.D. Thesis, Univ. of Bologna); data on male aggressive behaviour and mating behaviour are now needed in order to afford explanations for this phenomenon.

Our study also demonstrated that, although the adult sex-ratio was not significantly different from 1:1, females were more numerous than males. This result is surprising too, as males are usually more numerous than females in the lacertid lizards studied to date (see, e.g., Edsman, 1986), whereas females are more numerous than males in other lizard families with highly structured social systems (e.g. Agamidae, Anibaldi *et al.*, 1998). Exceptions to these rules are, however, well-known (see, e.g., Olsson, 1986, and later studies). Whether the observed adult sex-ratio of *A. fitzingeri* is related to its mating and/or social system is still unknown.

A research project is now in progress to further investigate both ecological plasticity and population genetics of the high-altitude populations of *A. fitzingeri*, in order to understand whether the remarkable data presented in this paper are related to adaptive (eco-phenetic) or historical (phylogenetic) patterns.

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