ELSEVIER

Biological Conservation 94 (2000) 63–68

BIOLOGICAL CONSERVATION

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Habitat selection of the common chameleon (*Chamaeleo chamaeleon*) (L.) in an area under development in southern Spain: implications for conservation

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Received 23 February 1999; received in revised form 18 September 1999; accepted 24 September 1999

Abstract

We studied the features of the habitat selection of the common chameleon [*Chamaeleo chamaeleon* (L.)] in a population located in an area under development in south-eastern Spain. Chameleons were recorded in zones characterised by the presence of roads, lack of natural vegetation and presence of cultivation at the macrohabitat level, and tree-dominated vegetation and bare soils at the microhabitat level. This particular habitat selection increases the propensity for casualties due to illegal collection, accidental road deaths or nest losses because of ploughing. However, chameleons were not present in nearby natural environments in which these sources of mortality are much less intense or absent. We suggest that the sustainability of chameleon populations requires a combination of maintaining traditional human land uses and the adoption of preventive measures, such as road barriers in some selected sites or the protection of safe sites for nesting, since both the more aggressive human pressures (settlements for tourism) and the promotion of natural landscapes (reforestation) could be negative for the species.

Keywords: Common chameleon (*Chamaeleo chamaeleon*); Habitat selection; Natural vs. human environments; Land uses; Road barriers; Safe nesting sites

1. Introduction

Conservation of a single species by itself, regardless of status, has proven to be an inadequate approach to the preservation of natural biodiversity, since no wild species can survive without simultaneous protection of its natural environment (Velázquez and Heil, 1996). On the other hand, even if protected areas are adequate, they can preserve only a small percentage of the world's biodiversity (Caughley and Sinclair, 1994). This underscores the need for research on ecological relationships of habitat-endangered species for appropriate conservation planning. In this sense, it is especially important to conduct research not only within protected areas but also outside them (Fahrig and Merriam, 1994) to assess the extent to which the management policy of protected areas, or the policy of creating new protected areas, is suitable to preserve a given species. Furthermore, an analysis at different spatial scales is needed when working with animals of small size and small home range sizes, since habitat features required for a particular species at reduced scales may vanish at broader resolution (Rubio and Carrascal, 1994).

The common chameleon [*Chamaeleo chamaeleon* (L.)] is a good case in point. In Europe, this species is found in the wild only in the southern Iberian peninsula and some Mediterranean islands, although the species is also distributed in North Africa, Turkey and the Near and Middle East (Martin, 1992). The common chameleon was registered as "insufficiently known" in the Red List of Spanish vertebrates in 1986 (ICONA, 1986), and shifted to "endangered" only 6 years later (Blanco and González, 1992). In Europe, it is catalogued as a species of interest in Annex IV of the EU Habitat and Species Directive (92/43/CE), as strictly protected in the Annex II of the Bern Convention, and at the highest level (C1) in the CITES convention (3626/82/CE) (see Lizana and Barbadillo, 1997, for a thorough review). However, it has not received sufficient scientific attention to provide the necessary information for effective conservation. Although Honneger (1981) and Corbett (1989) stressed

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0006-3207/00/$ - see front matter
PII: S0006-3207(99)00163-9

the necessity of establishing reserves in order to protect the chameleon, most of the populations are located in man-made landscapes, outside protected areas, with varying conservation problems (Rosário et al., 1995; SCV, 1996; Cuadrado and Rodríguez, 1997; Lizana and Barbadillo, 1997). As in most cases of endangered species, habitat loss is the main problem: the chameleon's distribution at lower altitudes and usually near the sea strongly overlaps with the most developed areas (Klaver, 1981; Cuadrado and Rodríguez, 1990, 1997; Blanco and González 1992). Consequently, most of the populations are in clear regression (Fernández 1990). For instance, Blasco (1978) registered a decrease of up to 60% in only 3 years in populations in the Cádiz province.

No study has examined the habitat selection of the common chameleon throughout its distribution area; most works simply describe the habitat occupied by certain populations (Morocco: Bons, 1967; Spain: Zimmermann, 1976; Blasco, 1978, 1979; Blasco et al., 1985; Cuadrado and Rodríguez, 1990, 1997; Portugal: Rosario et al., 1995). There is scant information about the processes of habitat selection, and this hampers the formulation of a successful conservation policy (Blanco and González, 1992; Rubio and Carrascal, 1994).

We have studied these problems in one of the easternmost populations of the common chameleon in Spain. This population coincides with a particularly popular tourist area and of intense development in the region, where human activity is inflicting severe interference and habitat loss on the population. In the present study, we seek to answer the following questions: (1) What habitat features does the common chameleon select in the study area, both at a coarse- (macrohabitat) and fine-grained (microhabitat) scale? (2) Does human activity influence the sustainability of this population, either positively or negatively, in terms of habitat destruction? (3) What conservation policy would be most effective for this population?

2. Methods

The study area is situated at the southwestern edge of Granada province, between the border with Málaga province (3° 47′ E) and the city of Almuñécar (3° 38′ E). It ranges from sea level to 700 m in altitude, and covers a total of ca 120 km^2. Microhabitat selection was studied in the locality of Taramay (Almuñécar, Granada province, 36° 45′ N, 3° 39′ E), a small ravine of ca 3 ha in area, with abandoned avocado (*Persea americana*) and chirimoya (*Annona cherimola*) orchards, some shrubs and wild trees (*Ceratonia siliqua*, *Spartium junceum*, *Maytenus senegalensis* and *Thymelaea hirsuta*, among others). The gully has an altitude of 120 m. The zone has a Mediterranean climate, with hot, dry summers and mild winters, average yearly temperature of 15–19°C, and annual rainfall from 400 to 550 mm (Castillo-Requena, 1989).

For the study at the macrohabitat scale, the study area was gridded into 100 1×1 km squares from sea level up to 700 m. By combining direct observations and questionnaires, we found 82 squares with no records of chameleons, and 18 in which chameleons were present. To test the accuracy of questionnaires and searches, we performed a more intensive search in 16 squares with no records, and again failed to locate any chameleon. Sampling efforts were evenly distributed among the squares. Although chameleons reach 700–800 m in altitude in the nearby region of the Axarquía (Málaga province), we found all the chameleons below 400 m, and all but one below 300 m. Therefore, we randomly selected another set of 18 squares within the group of squares with no records of chameleons below 400 m. To avoid sampling biases due to smaller sampling area, coastal squares with >50% of sea surface were replaced. In both samples of squares, hereafter referred to as positive and negative, we evaluated the following eight habitat variables: (a) number of total km of road; (b) number of total km of permanent watercourses (rivers); (c) constructions (scored from 1 to 5: 1=<30 isolated houses; 2=>30 isolated houses, 3= hamlets and grouped houses, 4=residential area with gardens, 5=urban environment); (d) slope orientation; (e) slope steepness (in %); (f) natural vegetation cover (% square covered by forest and shrublands); (g) orchard cover; and (h) other crop cover (non-tree species). Data were collected by combining direct measurements on 1:25.000 maps (Instituto Geográfico Nacional) and visits to the study area.

Slope steepness was calculated for each square by tracing on the 1:25,000 map eight 1 cm transects in directions N, NE, E, SE, S, SW, W and NW, from the middle of the square to the periphery, and measuring the difference in altitude between the extremes of the transect (equivalent to a 250 m transect). Steepness was then calculated and averaged for the eight lines. Square orientation was calculated by taking the average at the outer points of these eight transects. The percentage cover of each type of vegetation was calculated by approximating on 1:25,000 maps the surface covered by each vegetation type to geometric figures, and then calculating its area.

To evaluate the habitat selection of the chameleon at a microhabitat scale, we located individuals in the site selected for this purpose. The study site was systematically searched by two or three observers looking for chameleons or for signs of their activity (excrement, sloughed skins, etc.). Once a chameleon was located, we marked a plot of 5 m in radius by placing four metric tapes of 5 m in the cardinal directions, with the animal at the centre. In this plot, we estimated the following variables: (a) perch height (m); (b) plant height (m); (c) perch diameter (mm); (d) vegetation cover; and (e) vegetation density.

Perch height and diameter were measured exactly at the point where the animal was found, while plant height was the maximum reached by the plant. Measurements of vegetation cover and density were taken using a graduated rod of 3 m in length and 1 cm in diameter. The rod was placed vertically at every metre of the tape, and the number of contacts with woody vegetation was recorded for each metre of the rod. Vegetation cover was estimated as the percentage of points making any contact with woody vegetation (100×points with contact/20), while vegetation density was calculated as the average number of contacts for each metre of height (100×Σ contacts/20). We restricted the variables to woody vegetation, since the common chameleon uses only this type of vegetation during most of the year.

To compare the microhabitat availability with that selected by chameleons, we made six transects, 50 m long, and selected the nearest tree or shrub to the 10-m points in the tape. We selected a random twig at 1.5 m height (the individuals recorded were at 1.59 ± 0.12 m in height, $n = 32$) in the canopy of the tree as the equivalent of a chameleon's perch, and recorded the same variables as those when an individual was found.

Both for the macrohabitat and the microhabitat study, we compared the features of the positive and negative samples by means of the Mann–Whitney test, except categorical variables, such as slope exposure or tree species, which were analysed with χ^2 tests. Non-parametric tests were applied because of the heteroscedasticity and non-normal distribution of data (Zar, 1996). To avoid type-I error, we used the sequential Bonferroni test for determining the significance level (Rice, 1989).

3. Results

Table 1 shows the results for the variables measured in the macrohabitat sampling, and the results for the statistical tests. Only two variables showed significant differences between groups: length of roads, with higher values for positive squares; and slope orientation, with a clear bias towards the south and west for positive squares and towards the southeast for negative squares (Fig. 1). Percentage of cover with "other cultivated crops", was noticeably higher while "steepness" was noticeably lower in positive squares, but the differences did not reach significance after Bonferroni correction (Table 1). Neither natural vegetation nor orchard cover showed differences between positive and negative squares. The quantity of constructions also failed to show significant differences, despite the fact that positive squares appeared to be more inhabited by humans.

Table 2 shows the results for the variables measured in the microhabitat sampling. We found statistical differences in two types of variables: (1) plant species, and (2) all variables related to the vegetation density from the first metre upwards.

Table 1
Results of the analysis of the variables recorded on the macrohabitat sampling for the common chameleon in the Granada province (SE Spain)

Variable	Positive[a] Mean ± S.E.	Negative[b] Mean ± S.E.	U or χ^c	P^d
Roads (km)	0.8 ± 0.2	0.2 ± 0.1	243.0	0.007*
Rivers (km)	0.3 ± 0.1	0.3 ± 0.1	167.0	0.846
Constructions	2.3 ± 0.4	1.3 ± 0.1	212.5	0.056
Slope exposure	S-SW	SE	16.82	0.032*
Slope steepness	17.1 ± 1.8	22.5 ± 0.9	233.0	0.024
Natural vegetation	8.8 ± 6.1	11.1 ± 6.1	202.0	0.096
Orchards	71.2 ± 9.2	87.1 ± 6.1	190.5	0.340
Other crops	20.1 ± 8.2	1.8 ± 1.0	214.0	0.044
n		18	18	

[a] Positive indicates 1×1 km squares with records of the species.
[b] Negative indicate squares with no record.
[c] All test values are Mann–Whitney U, except χ^2 for slope exposure.
[d] Asterisks denote $P < 0.05$ after Bonferroni correction.

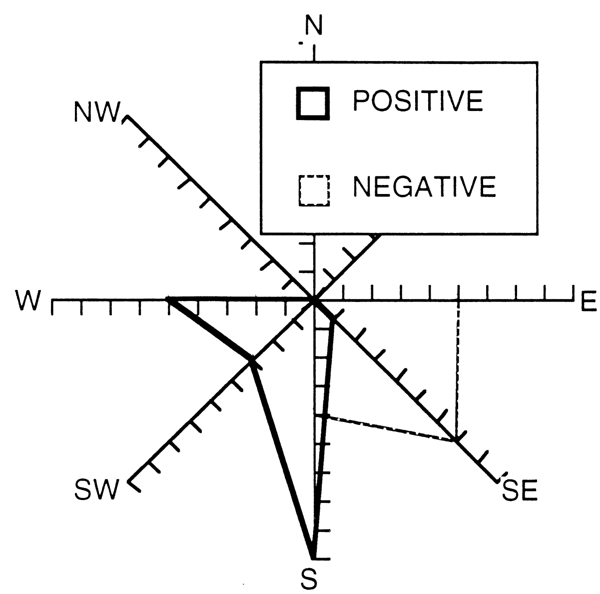

Fig. 1. Distribution of the exposures of the squares used in the macrohabitat analysis of the habitat selection of common chameleon in SE Spain. Sample size is 18 for both positive and negative squares.

With respect to plant species, Fig. 2 shows that the common chameleon in this zone prefers trees and rejects shrubs as well as dead trees. For instance, there is a clear difference of selection between live and dead chirimoya trees, stressing the importance of cover. This agrees with the results on variables related to the density of vegetation: plots with chameleons had a denser structure than did plots selected at random, perhaps increasing camouflage possibilities and allowing better

Table 2
Results of the analysis of the variables recorded on the microhabitat sampling for the common chameleon in the Taramay site (SE Spain)

Variable	Record[a] Mean ± S.E.	Random[b] Mean ± S.E.	Z or χ^c	P^d
Plant species			22.99	0.008*
Tree height (m)	3.66 ± 0.31	2.93 ± 0.24	−1.86	0.0635
Perch diameter (mm)	14.2 ± 4.2	7.1 ± 0.5	−1.83	0.0661
Vegetation cover (%)	42.5 ± 2.6	35.0 ± 3.1	−2.11	0.0349
Vegetation density				
0–1 m	0.31 ± 0.06	0.29 ± 0.06	−0.14	0.8928
1–2 m	0.45 ± 0.07	0.19 ± 0.03	−3.45	0.0006*
2–3 m	0.55 ± 0.08	0.28 ± 0.07	−2.60	0.0087*
> 3 m	0.22 ± 0.07	0.03 ± 0.02	−3.24	0.0012*
n	32	30		

[a] Record indicates plots 5 m in radius with some record of common chameleon.
[b] Random indicates randomly selected plots in the zone.
[c] All test values are Mann-Whitney, except χ^2 for plant species.
[d] Asterisks denote $P < 0.05$ after Bonferroni correction.

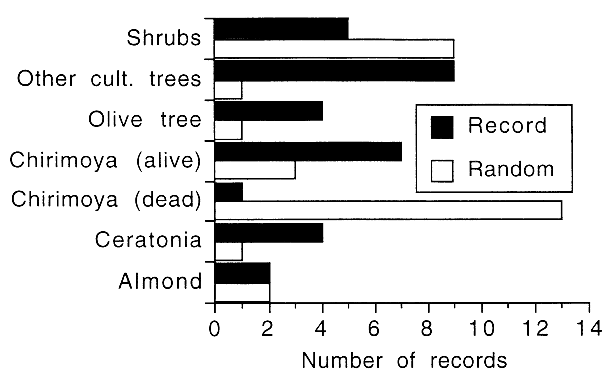

Fig. 2. Selection of different plant species for the common chameleon in the Taramay site (SE Spain). Sample size: record 32, random 30.

thermoregulation. No differences were found in vegetation density below 1 m in height, a zone that chameleons use only during movement between plants.

4. Discussion

In the study area, the common chameleon inhabits areas with a high density of roads and exposed to the south south-west. No other feature of the landscape showed reliable differences between positive and negative squares. The higher density of roads suggests a relatively high tolerance to anthropic impact, apparently selecting anthropogenic landscapes, and rejecting the natural areas. These results in part coincide with the findings of other authors, especially for the populations located in SE Spain (e.g. Málaga province, Blasco, 1979, and pers. comm.). By contrast, in southern Portugal and SW Spain, chameleons seem to select a more patchy environment in which both natural and humanized landscapes are intermingled (e.g. Cuadrado and Rodríguez, 1990, 1997; Rosário et al., 1995).

At the microhabitat scale, the chameleon selected mainly trees that provide a certain twig and foliage density from the first metre upwards. Chameleons chose relatively tall plants (average height 3.66 m) that offer enough foliage density for effective camouflage against predators and for protection against excessive irradiance, and that offer ample prey, mainly Diptera and Hymenoptera (Pleguezuelos et al., 1999). It is noteworthy that vegetation density was important to the common chameleon above 1 m. Below 1 m cover is not needed because this zone is not used for feeding or basking, while, for egg laying, the soil is better without cover. In general, local natural vegetation is much more shrubby below 1 m in height, reducing radiation on the soil, and most of the natural shrubs are lower than the height preferred by chameleons (Blasco et al., 1985).

The microhabitat approach suggests that orchards are suitable for chameleons: the soft and bare ploughed soil invites oviposition, and the widely spaced trees allow the soil a high degree of insolation. However, the microhabitat approach failed to detect a positive selection of this kind of habitat: there is no difference in orchard cover between positive and negative squares. This is surprising, since almond orchards are abundant in the area and would afford chameleons a much wider distribution than recorded. In fact, the chameleon is common in orchards, such as almonds or olive trees in Málaga, and even gardens with trees in Cádiz and Málaga (Cuadrado and Rodríguez 1990, 1997), while introductions to natural landscapes like Doñana national park have repeatedly failed.

Cultivated areas provide certain favourable aspects for the life of the common chameleon, but they increase the probability of their being killed on the roads (roads are much more frequent in these areas; see Table 1) during the reproductive period (Lizana, 1993; SCV, 1996), and increase the chances of nests being destroyed by ploughing (eggs are incubated in the soil for 10–12 months, Bons and Bons, 1960; Fernández, 1989). Furthermore, the high degree of human activity in these areas increases the danger of illegal collection and trade. In addition, uncontrolled changes of humanized habitats, such as a shift from crops and subtropical orchards (quite acceptable for common chameleon) to intense cultivation in greenhouses, or massive urbanization, are extremely negative for this reptile (SCV, 1996; and references therein). Increased tourism has been also reported as the main problem for the preservation of *Chamaeleo africanus*, the other chameleon species that inhabits Europe (in the Peloponnesus, Greece: Böhme et al., 1998).

The high degree of coincidence between the populations of chameleon and the most humanized zones, as happens in this present study, implies severe problems for the preservation of this population. The conversion of the distribution area into a protected area could have exactly the opposite results to those intended: stopping cultivation and allowing colonization by autochthonous shrubs and trees would produce a dense natural vegetation that could be undesirable for the chameleon. Furthermore, a ban or severe restriction on human activities would be unrealistic since the zone is heavily populated and economically dynamic. The chameleon needs anthropic landscapes: the link between the chameleons and humanized habitats in the northern Mediterranean rim is so strong that Blasco et al. (1985) took it as evidence of the possible historic introduction by man (Phoenicians, Greeks, Romans, Arabs) in this area.

Taking these findings into account, we believe that the preservation of chameleon populations requires other measures than the systematic protection of their distribution areas. The most important measure is the continuation of current land management but the control of insecticides and herbicides that can kill or reduce their insect prey. Some cultivated areas should be selected and protected as safe nesting sites, matching the ploughing and tilling rhythms to the chameleon's breeding. Another basic measure is to reduce accidental road deaths, the common chameleon being one of the most susceptible species to traffic casualties (Caletrio et al., 1996; SCV, 1996). Barriers should be erected to prevent chameleons getting onto roads at sensitive points (SCV, 1996; M. Cuadrado, pers. comm.). They would not isolate populations since movements are readily possible where there are road tunnels and bridges. Studies on chameleon movements would, however, be useful.

In conclusion, we suggest that an adequate policy to protect the common chameleon in the southern Iberian peninsula requires the consideration of three basic points: (a) to preserve the agricultural landscapes inhabited, (b) to avoid deaths due to roads, and (c) to decrease the reproductive failures by protecting selected breeding areas. These recommendations may improve, at low economic cost, the situation of the chameleon population studied here. We believe these recommendations are applicable to most of the Iberian populations, since coastal proximity, low altitude, variable mixture of agricultural and natural habitats, risk of road deaths, tourist pressure and urban development, are common features in all of them.

Acknowledgements

We are indebted to Raquel Monterrubio and Diego Ontiveros for field assistance. The work has benefited from the information and comments of Trevor Beebee, Manuel Blasco, Mariano Cuadrado, Brian Davis, José M. Gómez, José A. Mateo and two anonymous referees. The Agencia de Medio Affibiente, Junta de Andalucía, granted permission to work with the chameleons. David Nesbitt looked over the English. This work was partially financed by grants from Ministerio de Educación y Ciencia AMB95-0479 (J.A.H.), the Dirección General de Universidades e Investigación, Junta de Andalucía, to the research group RNM 254 (J.M.P.), and the delegación Provincial de Granada, Consejería de Medio Ambiente, Junta de Andalucía (J.M.P.).

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