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A permanent signal related to male pairing success and survival in the lizard *Psammodromus algirus*

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Abstract:
Many species of lizards have colour spots on the flanks that may function as ornaments. We investigate the between-years stability of the blue patch colour saturation and the relationships between colour saturation, mating success, and survival in males of the lizard *Psammodromus algirus*. Saturation values of the anterior blue patch of males were significantly repeatable across years. Survivors had more saturated patches than non-survivors among paired males but not among non-paired males. The positive relationship between blue patch saturation and survival suggests that this morphological trait acts as a reliable signal of male quality measured as adult survival.

Key words: *Psammodromus algirus*, coloration, pairing success, survival.

Many species of lizards have seasonally developed breeding colours and permanent chromatic sexual dimorphism (Cooper and Greenberg, 1992). At least in males, it is possible that these traits function as multiple ornaments, i. e, they may indicate different quality attributes of their bearer, give redundant information or have no specific signalling function (Moller and Pomiankowsky, 1993). The use of multiple cues can reduce mate choice costs by decreasing the number of mates inspected more closely or the time and energy spent inspecting a set of mates (Candolin, 2003). Although chromatic traits may convey honest information about the individual that exhibit them, mating success of male lizards is usually associated with their size, and mate choice based on male colouration is infrequent (Tokarz, 1995). Also, the male ornamentation may show positive, negative or neutral correlations with survival (Jennions et al., 2001). Although a positive association between ornamental traits and survival has been reported in free living populations of birds (Papeschi and Dessi-Fulgheri, 2003), there is no similar information in the case of lizards.

In the lizard *Psammodromus algirus* temporal and permanent colour traits may be recognized. Males develop head orange coloration during the breeding season, whose extension is positively associated with plasma testosterone concentration (Díaz et al., 1994). This is a costly trait (Salvador et al., 1996) that may emphasize the size of an individual's head, possibly conferring a honest signal of fighting ability (Cooper et al., 1987; Olsson, 1994). However, this badge may also signal aggressiveness and may not tightly linked to size. Such a trait may have been selected through male-male competition, but could also have a role in mate choice by females.

Both sexes of *P. algirus* present a dimorphic colour trait, the blue flank spots (Carretero, 2002). These patches are frequent in the family Lacertidae, so they could be a phylogenetic residual without a present function. Alternatively, the spots could be sexually selected signals conveying information on individual attributes, including survival abilities. In contrast with the orange throat coloration, the blue spots do not disappear at the end of the reproductive season, though their colour properties may change over the reproductive lifetime depending on condition (e. g., Candolin, 2000). In this paper we investigate the between-years stability of the blue patch colour saturation and the relationships between colour saturation, mating success, and survival in males of the lizard *P. algirus*.

We studied *P. algirus* in a deciduous oak-forest (*Quercus pyrenaica*) near Navacerrada (Madrid, Spain), during four consecutive breeding seasons (1997-2000). We established a 0.6 ha (100 x 60 m) grid with markers every 10 m. We visited the plot every day from 15 February to search for lizards immediately after emergence from hibernation. We captured adult males (N = 54) and females (N = 35) by noosing from 20 February onwards. Individuals were marked with unique combinations of toe clipping for permanent identification and four colour-coded dots on the dorsum for field observations. The lizards were transported to El Ventorrillo Field Station (5 km distant in a straight line) to quantify blue patch characteristics. Individuals were snout-vent length (SVL) measured to the nearest mm. We took a side photograph of each individual captured in the four years of study with a Nikon F-50 camera with 60 mm lens and Sensia 100 ASA colour-slide film. Light was provided by the camera flash. The individuals were placed at the same distance from the camera on a black matte paper. The slides were digitized by means of Nikon Coolscan III and Adobe Photoshop (Dale, 2000) was used to quantify colour saturation in six randomly selected points of the anterior patch of the left side. We selected the anterior blue patch because is usually larger than the others. The mean value was used in subsequent analyses. The reliability of measurements was determined by repeatability analyses of repeated measurements of the same individuals (Lessells and Boag, 1987). Saturation measurements were significantly repeatable ($r = 0.98$, $F_{1,52} = 41.75$, $P < 0.0001$). Lizards were released at the site of capture within 4 h to minimize the influence of capture on social conditions.

Mating success was studied during the 1997 reproductive season. To analyse mating behaviour, we walked the plot between 0800 and 1200 h (five days per week during March, April, and May). To search for lizards we made 12 paralel transects of 5 m wide and 100 m length during 4-5 times per day. We considered that a male and a female had paired when: 1) the male courted the female, 2) remained close (<20 cm) to her, and 3) followed her shortly when she moved. Duration of pairs varied between 1 and 4 consecutive days ($X \pm SE = 1.8 \pm 0.24$, $n = 18$).

To analyse male survival to the next year, we repeated capture-recapture procedures during the 1998 reproductive season. We calculated the between years repeatability of the blue patch saturation for a sub-sample of males (14 males captured in two years, 4 males in three years, and two males in four years).

To analyse the relationship between colour saturation, pairing success, and survivorship to the next year we conducted a 2-way ANCOVA with colour saturation as the dependent variable, SVL as covariate and pairing success and survival as fixed factors. Planned comparisons using SVL as a covariate were tested in paired and non-paired males. Residuals in this analysis were normally distributed.

The number of blue patches on the left flank was significantly higher in males ($X \pm SE = 3.38 \pm 0.16$, N = 54) than in females ($X \pm SE = 1.71 \pm 0.10$, N = 35) (ANOVA, $F_{1,87} = 57.6$, $P < 0.001$), males had more saturated patches ($X \pm SE = 34.7 \pm 1.5\%$) than females ($X \pm SE = 25.1 \pm 1.5\%$) (ANOVA, $F_{1,87} = 18.22$, $P < 0.001$), and the size of the anterior blue patch was significantly larger in males ($X \pm SE = 5.52 \pm 0.29$ mm^2) than in females ($X \pm SE = 1.52 \pm 0.12$ mm^2) (ANOVA, $F_{1,87} = 114.1$, $P < 0.001$). Saturation values of the anterior blue patch of males were significantly repeatable across years ($r = 0.76$, $F_{19,28} = 8.47$, $P < 0.001$).

Colour saturation varied significantly with pairing success ($F_{1,49} = 4.80$, $P = 0.033$) but not with survival ($F_{1,49} = 1.44$, $P = 0.24$). The effect of SVL as covariate was not significant ($F_{1,49} = 0.69$, $P = 0.41$). The interaction between pairing success and survival was nearly significant ($F_{1,49} = 3.60$, $P = 0.064$). Planned comparisons considering SVL as covariate indicate that survivors had more saturated patches than non-survivors among paired males ($F_{1,49} = 4.22$, $P = 0.045$) but not among non-paired males ($F_{1,49} = 0.27$, $P = 0.60$) (fig. 1).

Male ornaments in *P. algirus* may be a condition-dependent expression of a single underlying trait or may provide multiple messages on different aspects of male quality. Orange head coloration seems to be a condition-dependent trait which provide information on the ability of its bearer to cope with the costs to produce it. The expression of orange head colouration occurs in males during the reproductive season, and it is positively linked with the increase of circulating levels of testosterone. Elevated levels of androgens can be energetically costly (Marler et al., 1995) and also may compromise the immune system (Salvador et al., 1996). Thus, the expression of this temporal signal seems to be linked to male condition early in the breeding season, and the information provided by it is limited. However, saturation of blue spots of adult males is a trait not linked to condition nor age. The positive relationship between blue patch saturation and survival suggests that this morphological trait acts as a reliable signal of male quality measured as adult survival. Thus, the results of our study provide evidence that two ontogenetically unrelated ornaments may be indicating different components of male quality. In addition, the importance of different components of a male's coloration may change in relation to the distance between a displaying male and the receivers, and it is known that males may use a hierarchical arrangement of cues that may vary with this distance (Losos, 1985; Fleishman, 1992). A male's orange head may be a more effective long-distance signal, but at shorter distances, blue patches may become more important to provide information about sex identification and other male traits.

The sexual dimorphism of the blue patches and the positive relationship between colour saturation of blue patches and pairing success suggests that this morphological trait is involved in sexual signalling. The results of the present study complement previous findings on the role of body size in male *P. algirus* pairing success. The body size of males that did not pair and males paired with one female did not significantly differ; only larger males mated with two females (Salvador and Veiga, 2001). Large males may obtain more matings by female selection and/or dominance over small males (Martín and Forsman, 1999). Females may use colour saturation of blue patches as a cue to discriminate between males of similar size.

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