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Type of soil and temperature range explain the preferred habitat and current distribution of the endemic lizard *Aspidoscelis hyperythra* in southern Baja California peninsula

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ABSTRACT

The Baja California peninsula herpetofauna is composed by more than 160 species, many of them endemic. In the last years the region is experiencing an accelerating population growth and land use change, specially in the lowlands and coastal areas. Based on GLM models we described and predicted the distribution patterns of the regional endemic whiptail lizard, *Aspidoscelis hyperythra* Cope, 1863 (Sauria: Teiidae). We verified the accuracy of the predictive occurrence map in the field and then we generated a final suitable habitat model for the species. The soil characteristics have a great influence on occurrence probability. The highest values correspond to sandy areas with low slope, temperatures between 18 and 22 °C, annual range temperature below 15 °C, NDVI values ranged 0.60–0.73, rainfall between 200 and 400 mm, and altitude lower than 800 m. Vegetation was also important; the establishment of the species requires woody plants that produce (a) plant litter where the lizards find prey; (b) burrowing sites for clutches, daily shelter, or hibernation and (c) open areas with light shade available for effective thermoregulation. These areas where natural tropical deciduous forest and sarcocaulescent scrub are stablished are also the most attractive to human settlements; so the conflict between conservation and development is stronger there.

1. Introduction

The detailed knowledge of the evolutionary and ecological determinants of space pattern distribution, ecological niche, and habitat suitability of animal species are essential information for effective conservation planning (Elith et al., 2006; Graham et al., 2006; Hirzel and Le Lay, 2008; Newbold et al., 2010). The precise distribution patterns of the currently existing species in an area reflect the phylogeography of their populations (Wiens et al., 2013), but local distribution is also influenced by environmental variables and species–environmental relationships (Peres-Neto et al., 2001; Pastro et al., 2013). The variables affecting species distributions could be summarized as: restrictive (factors controling or regulating the species ecophysiology); disturbances (all types of disturbance affecting environmental systems); and resources, all of which can be used or assimilated by organisms (Guisan and Thuiller, 2005).

In the case of reptile species living in deserts or arid areas, their distribution could be strongly determined by phylogeography and time of residence in those environments (Wiens et al., 2013) but locally the optimal niche would be defined by suitable conditions for thermoregulation (Kearney et al., 2009), protection or food availability (Heithaus, 2001; Beck and Jennings, 2003; Christian et al., 2003) as well as intra or interspecies relationships (Kearney, 2003; Greenville and Dickman, 2009; Read et al., 2012, Pastro et al., 2013).

About 80% of the Baja California peninsula has an arid climate and is covered by sarcocaulescent vegetation. However, as a result of its dynamic geological history, it is not homogeneous, but formed by a mosaic of ecoregions with different topographic, climatic and vegetation characteristics (González-Abraham et al., 2010). The convergence of these factors creates a great biodiversity with more than 3700 species of vascular plants and at least 140 species of terrestrial reptiles, many of them endemic (Riddle et al., 2000; Grismer, 2002; Riemann and Ezcurra, 2007). The ecoregions have

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distinctive plant communities including coastal scrub, desert scrub, montane woodlands and forests, and subtropical thornscrub (Wiggins, 1980), and each of these plant communities has a distinctive assemblage of herpetofauna (Lovich et al., 2009).

Following the Grinnell (1917) concept of ecological niche as "the environmental requirements needed for a species to subsist without immigration", a habitat suitability model of any species would require a carefully selected set of environmental variables (Kearney, 2006; Hirzel and Le Lay, 2008).

Here we describe and predict the distribution patterns of *Aspidoscelis hyperythra* Cope 1863 (Sauria: Teiidae), an endemic and widely distributed lizard in the Baja California peninsula, and identify the ecological characteristics of its suitable habitat.

For this, (1) we assessed the habitat characteristics where the species occurs in the southern half of the Baja California peninsula, (2) we generated a spatial model and an occurrence map for the known distribution of *A. hyperythra*, (3) we verified the accuracy of the predictive occurrence map in the field, and (4) we generated a final model of potential suitable habitat distribution for the species in the area.

Our final goal was to identify the areas with higher probability of occurrence for the species, focusing on its habitat conservation from the forthcoming human activities.

2. Methods

2.1. Species characteristics

A. hyperythra is a small insectivorous, oviparous whiptail ranging from 3 to 7 cm from snout to vent length and weighs about 6 g. The life expectancy is three to seven years (Stebbins and McGinnis, 2012). It is an active forager that feeds primarily on termites, other small insects (larvae and adults), and spiders (Galina-Tessaro, 1994). It is common to observe them moving under the litter of shrubs *Cyrtocarpa edulis*, *Jatropha cinerea* and the cacti *Stenocereus gummosus* and *Cylindropuntia cholla*, searching for food (Grismer, 2002; pers. obs). It reproduces from August to October, after the summer rains. Their daily energy expenditure (DEE) is one of the highest of the North American desert lizards (Karasov and Anderson, 1984) and the length of daily activity is dependent on body temperature and feeding rate. Individuals are able to maintain their mean body temperature (38–39 °C) ranging from 33.4 to 42.2 °C. The range of air and substrate temperatures to register activity is 21°C–36 °C, and 32–50 °C, respectively. They spend the night and periods of unfavorable temperatures in shallow tunnels dug by the lizards in sandy loose soils (Bostic, 1966).

All these factors are important in the life history and fitness of the species: lizards need shade for effective thermoregulation. The lizards dig under plant litter for shelter as well as foraging for food under the litter. We propose that this species may depend on a medium vegetation cover. Big differences in activity hours, feeding and growth rate, and population numbers have been reported between neighboring sites with different plant cover (Karasov and Anderson, 1984).

The general distribution of the species ranges from southern California (USA) to the whole length of Baja California peninsula and several islands of the Gulf of California and the Pacific Baja coast (Grismer, 2002). It is listed in the International Union for the Conservation of Nature (IUCN) (Hollingsworth and Hammerson, 2007) and catalogued in Mexico as threatened (NOM59-2001-SEMARNAT). In the Baja California peninsula its distribution ranges throughout most regions except for the Vizcaino Desert in central Baja, and the pine forest at high elevations of Sierra de la Laguna in the south. Its phylogeography is not well known. There are up to six sister species recognized in the *Aspidoscelis hyperythra* complex through its distribution area (Radtkey et al., 1997; Grismer, 1999; Reeder et al., 2002). There is no precise previous information about what climate and ecological variables influence its distribution pattern. However, Delibes et al. (2011) suggest it could be sensitive to human disturbance. It is more common in open spaces with clumps of thick vegetation, on fine or loose soils that it needs for oviposition (Grismer, 2002). In the southern part of the Baja California peninsula, *A. hyperythra* has been reported active almost all year round (Blázquez and Ortega-Rubio, 1996).

2.2. Study area and soil characteristics

The study area is the mexican state of Baja California Sur (BCS). It ranges between 22.8° N and 28° N latitude in the southern half of the Baja California peninsula, Mexico (Fig. 1a). The surface is 71.480 km^2, altitude ranges from sea level to 2200 masl. Most of the study area is considered "thermotropical" with annual mean temperature of 23 °C. Rains, concentrated mainly in the summer, are very scarce and uncertain at the northern increasing towards the south where they are monsoonal.

Along the peninsula soils are very closely related with the geological origin and substrate. We obtained soils layers (INIFAP-CONABIO, 1995; INEGI, 2003), and overlapped them to a modified González-Abraham et al. (2010) map of the ecopregions for our study area (Fig. 1b). Only the eight predominant soil types were considered (See Table 1). At the Desierto de Vizcaino and Desierto Central (ecoregions 6 and 7, Fig. 1b) soils are sandy and loose, with variable content of mineral salts and sodium; Arenosols and Solonchaks (IUSS, 2007) are representative of this region. Arenosols are soils with poor moisture retention and very low organic matter content that do not allow the construction of durable lizard shelters. Solonchaks are characterized by a strong salt chemical phase that restricts the vegetation establishment. At the Provincia of Magdalena (ecoregion 5), there are Arenosols but also Calcisols and Cambisol soils which are mainly deep, sandy, with good particle aggregation and stability; Vertisol soils with a high clay content are also found there. These soils are rich in nutrients for plant growth. The mountains of Sierra de la Giganta from the Central Gulf coast (Ecoregion 4) have shallow loamy soils (Leptosols) overlaying a continuous rock substrate; and in this region areas with a high content of expansive clays (Vertisols) are also found. At the southern tip of the peninsula, (in Ecoregion 2 and 3), soils are sandy, with variable thickness and structure depending on the physiography, i.e. they are depth but well structured on plains (Calcisols, Cambisols, Arenosols). At the rocky Sierra de la Laguna slopes (Ecoregion 1), soils are shallow and with brittle aggregates (Leptosols).

2.3. Data collection

Several studies recording reptile biodiversity of the region and a phylogeographic study of the species throughout the area during the period 2003–2008 resulted in 312 localities where *A. hyperythra* was recorded (Fig. 1a). We added 59 new localities for model evaluation (see text below and Fig. 1a). In all cases censuses were conducted from 9:00 to17:00 h by two people walking slowly 10 m apart from each other, covering about 500 m long, and lasting from 45 to 60 min. The total area sampled in each census was approximately one hectare.

2.4. Environmental variables

A variety of statistical models may be used to emulate the species spatial distribution. For this study we used Generalized Linear Models (GLM) that give results with high levels of certainty, in