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Comparing Filippi and Luiselli's (2000) method with a cartographic approach to assess the conservation status of secretive species: the case of the Iberian snake-fauna

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Abstract. The conservation status of the snake fauna of a given region or territory is often hard to estimate due the secretive habits of these animals, as well as of the lack of long-term demographic studies and generally low population densities. We examined the conservation status of the snakes from the Iberian Peninsula by applying two complementary methods. The first method, created by Filippi and Luiselli for a study of the Italian snakes conservation status, takes into account the ecological and non-ecological attributes which make species vulnerable to extinction. The second is a cartographic analysis which consists of calculating two indexes derived from the comparison of old and recent citations in UTM 10 × 10 km squares of Iberian snakes by means of extensive database sets. For each species, we calculated the percentage of recent citations, and the percentage of squares with both old and recent citations. Species with low proportion of recent citations and new squares appeared to be in decline. We found considerable coincidence between the two methods in the identification of the most threatened snake species: *Vipera latastei*, *Coronella girondica*, and *Natrix natrix*. We suspect that the ecological specialisation and the low reproductive output make *C. girondica* and *V. latastei* prone to extinction when faced with environmental changes (i.e. habitat loss). For *N. natrix*, we argue that this semi-aquatic snake experiences suboptimal environmental conditions in Mediterranean habitats. A combination of both methods proved adequate to detect vulnerability to extinction of snake species, hence revealing an effective tool for establishing conservation strategies in snakes and other secretive faunas.

Introduction

Gibbons et al. (2000) reported that reptile species are declining as a result of habitat loss and degradation, introduction of invasive species, environmental pollution, disease, unsustainable habitat use, and global climate change. Population declines are often difficult to detect in reptiles, as long-term studies of natural populations, indispensable for understanding population trends and fluctuations, normally lack in this group (Tinkle, 1979; Gibbons et al., 2000). Within reptiles, many snake species display elusive behaviour and secretive habits, hence preventing accurate appraisal of their conservation status. Iberian snakes follow this trend, and consequently their IUCN categories could be biased by difficulties which entail the study of this taxonomic group (Seigel, 1993). This is due to the lack of basic biological information for most snake species, such as biophysical, genetic, social, behavioural, demographic, and habitat data (Dodd, 1993). However, snakes are good candidates for population declines because of their long life span, large size, exclusive carnivorous dietary habits, and low reproductive output (Scott and Seigel, 1992; Dodd, 1993; Fitzgerald et al., 2004), as well as high mortality associated to human activities (Bonnet et al., 1999; Webb and Shine, 2000).

Filippi and Luiselli (2000) assessed the conservation threats of the Italian snake fauna taking into account ecological, distributional and non-natural traits that are known to influence survival of natural populations. In this paper, we collate the application of the Filippi and Luiselli's (2000) method and a cartographic contribution to the conservation status of Iberian snakes based on shifts in their distribution range. One of the most useful criteria to determine vulnerability in reptiles is

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the geographic range (criterion B of the 2001 IUCN Red List Categories and Criteria version 3.1, IUCN, 2005) as it is the most accurate information that researchers normally have for this animal group (Pleguezuelos et al., 2002). Thus, we analysed the temporal variation in the number of citations and 10 × 10 UTM squares of snake species distributed along the Iberian Peninsula. This pattern can be used to describe changes in distribution over broad spatial scales, hence helping to clarify the conservation status of species. The combination in the use of these two methods, one based on ecological and non-ecological specific traits, and another based on cartographic (i.e. distribution) data, would be a major contribution to the knowledge of the current conservation status of secretive faunas as snakes.

Material and methods

Data source

We collated the distribution records of Iberian snakes that were published in the Atlases in Portugal (Godinho et al., 1999) and Spain (Pleguezuelos, 1997; Pleguezuelos et al., 2002), as well as additional records provided by Spanish and Portuguese herpetologists. For each citation, we compiled (i) species identification, (ii) UTM 10 × 10 km square where the snake was recorded, and (iii) year of citation. UTM 10 × 10 km square could be considered rough for depicting the distribution of Iberian snake species, because of their general small home range. However, the UTM cartographic projection and the 10 × 10 km grid-size have been recommended for national and regional projects dealing with distribution of European organisms (Mitchell-Jones et al., 1999).

Records were classified as old or recent according to year of observation. For Spain, observations gathered to compile the Atlas of 1997 (Pleguezuelos, 1997) plus other additional citations up to that year, were considered old. Citations gathered from 1998 to 2002 were considered recent. Most of these recent records were collected to update the Spanish Herpetological Atlas (Pleguezuelos et al., 2002). Both datasets were obtained for the <1997 period and the 1998-2002 period in the same way: i) thorough review of the published information, ii) revision of collections in museums, and iii) field surveys performed by Spanish and Portuguese herpetologists, designed and funded by the AHE (Asociación Herpetológica Española). As methodologies were similar for the two periods (details in Martínez-Rica, 1997; Godinho et al., 1999; Pérez-Mellado and Cortázar, 2002), we assumed that the datasets gathered were useful for comparisons. For Portugal, citations up to 1998 were considered old, and those gathered from 1999 to 2002 were considered recent. This was due to the fact that the last herpetological Portuguese Atlas was released in 1999 (Godinho et al., 1999). Number of citations per each snake species varied between 2225 and 9567 in the whole Iberian Peninsula (table 1).

Assessment of conservation status

Cartographic method: According to the number of 10 × 10 UTM squares with old and recent citations in the 2002 database, we calculated the following indexes for each snake species: 1) percentage of recent citations (number of recent citations of a given species divided by the total number of citations for that species). Within the context of the snake fauna, a low percentage of this index for a given species would indicate a trend for population decline; 2) percentage of squares with both old and recent citations

Table 1. Results of the cartographic method for eight Iberian snake species: percentage of recent citations, and percentage of squares with old and recent citations in the Iberian Peninsula (*Iberia* in the table), Iberian Spain, Andalusia and the Mediterranean coastal belt (*Mediterr.* in the table). *Macroprotodon brevis* is absent from the Mediterranean coast. In brackets, total number of citations and 10 × 10 UTM squares for each snake species.

Species (citations-squares)	% of recent citations				% of squares with old and recent 10 × 10 UTM squares			
	Iberia	Spain	Andalusia	Mediterr.	Iberia	Spain	Andalusia	Mediterr.
Hemorrhois hippocrepis (3514-1326)	38.7	36.7	45.0	24.7	35.2	41.1	62.6	27.2
Coronella girondica (3735-1569)	24.0	19.7	31.8	16.9	24.7	20.2	35.3	16.7
Rhinechis scalaris (7766-2657)	32.3	29.6	55.0	18.3	36.1	30.5	57.0	29.1
Macroprotodon brevis (1424-570)	31.8	29.0	34.0		41.2	38.6	50.7	
Malpolon monspessulanus (8267-3453)	39.0	35.7	62.6	25.6	32.0	31.3	57.0	34.4
Natrix maura (9567-3465)	39.0	36.1	64.2	30.6	39.2	31.6	67.8	26.0
Natrix natrix (3717-1701)	29.4	22.2	48.2	20.8	25.3	18.7	100.0	18.3
Vipera latastei (2225-968)	29.2	22.8	41.3	28.2	23.1	18.3	35.4	23.2
Mean	32.9	29.0	47.8	23.6	32.1	28.8	58.2	25.0

(number of squares with both old and recent citations for a given species divided by the total number of squares where that species was located). A low value for a given species would indicate the potential extinction of that species, by the absence of recent citations, in areas where it was previously reported. Therefore, a species was considered to be in decline if it presented low values for any of the above indexes. We calculated these indexes at four geographic scales: the Iberian Peninsula (including Spain and Portugal), Spain without the Spanish islands, Andalusia (southernmost Spanish area of the Iberian Peninsula), and the Iberian Mediterranean coastal belt (Spanish Mediterranean coast).

When search effort varied among time periods and/or regions, biases can be expected in the above indexes. In fact, we assume that the Iberian Peninsula is not uniformly prospected, although this is impracticable for a region of 6212 UTM 10×10 km squares. Cartographic indexes would not be useful for narrow range species as intensive field work is expected in the areas where they were. For this reason, species with reduced distribution in the Iberian Peninsula were removed from the analysis (see below). Other potential biases of the cartographic approach could occur if, for instance, a particular habitat has been altered between the two survey periods in such a way to damage only a few species and not others. For example, the aquatic species may have been highly damaged if the water bodies of a given study region became polluted, whereas the terrestrial species might have suffered nothing for the same reason. Notwithstanding, there is a single aquatic species in the study area, *Natrix maura*, clearly not threatened, and most of the man-induced effects of habitat destruction would affect to all kind of species approximately in the same way. Assuming some methodological biases inherent to the cartographic method, as the two indexes were calculated for each Iberian snake, biases should be equivalent and consequently interspecific comparisons in the indexes can be done. The search effort for compiling data for the Spanish Atlases of 1997 and 2002 was almost identical.

The Filippi and Luiselli's method (2000) was used to assess conservation threats of the Italian snake fauna using 10 independent variables including ecological and non-natural traits, known to influence survival of free-ranging snake populations (table 2). For each species, the mean value of variables (all scored between 0 and 3) represented the expected risk of population decline in the study area. We applied this method to snakes of the southern Iberian Peninsula (Andalusia), as many life-history traits for Iberian snakes are available only for populations in this region (Salvador, 1998). We removed the variable "Maximum age" from our analysis for the lack of reliable data on this trait for the snake populations in the Iberian Peninsula. Filippi and Luiselli's method proved to be quite flexible, and indeed it has been used also for assessing the conservation status of the amphibian fauna in Italy (Andreone and Luiselli, 2000) and Madagascar (Andreone and Luiselli, 2003).

Iberian snakes

We calculated cartographic indexes only for those snake species for which the distribution breadth extends over 50% of the whole Iberian Peninsula. Hence we included in the analysis eight Iberian snake species (*Hemorrhois hippocrepis*, *Coronella girondica*, *Rhinechis scalaris*, *Macroprotodon brevis*, *Malpolon monspessulanus*, *Natrix maura*, *Natrix natrix*, and *Vipera latastei*). Another five snake species restricted to the northern Iberian Peninsula were removed from the analysis because of they were absent (*Hierophis viridiflavus*, *Zamenis longissimus*, *Vipera aspis*, and *Vipera seoanei*) or very scarce (*Coronella austriaca*) in Andalusia and the Mediterranean coastal belt. Although our study analysed only secretive species with wide ranges, the conservation status for these species is difficult to evaluate by other ways, hence increasing the interest of comparing two methodologies.

Results

Three snake species (*Coronella girondica*, *Natrix natrix* and *Vipera latastei*) showed the lowest cartographic scores at all geographic scales. *Macroprotodon brevis* also had low values in Andalusia, and *Rhinechis scalaris* along

Table 2. Scores (range 0-3) for nine ecological and non-ecological variables which explain threats for the snake fauna. Data are based on studies of these species in Andalusia. The procedure follows the Filippi and Luiselli's (2000) methodology. IUCN categories extracted from Pleguezuelos et al. (2002).

	IUCN category	Illegal trade	Body size	Distribution breadth	Frequency of reproduction	Litter size	Dietary breadth	Habitat breadth	Habits	Adaptability	Mean
Hemorrhois hippocrepis	LC	0	2	1	0	2	0	0	3	0	0.8
Coronella girondica	LC	0	1	2	0	3	3	1	1	2	1.3
Rhinechis scalaris	LC	0	2	1	0	2	3	0	1	2	1.1
Macroprotodon brevis	NT	1	0	2	1	3	3	1	0	3	1.4
Malpolon monspessulanus	LC	0	3	0	0	2	0	0	3	1	0.9
Natrix maura	LC	0	1	0	0	2	2	0	3	0	0.8
Natrix natrix	LC	0	2	2	0	0	2	2	3	2	1.3
Vipera latastei	NT	2	1	2	2	2	1	2	2	3	1.7

the Mediterranean coastal belt (table 1). Furthermore, in Andalusia the percentages for all the snake species were higher than along the Mediterranean coastal belt (table 1), suggesting better conservation status for the Mediterranean snake fauna in the former region.

The application of the Filippi and Luiselli's (2000) method to the Andalusian snakes gave to *V. latastei* the highest score (table 2). Within the Colubridae, three species had similar high mean scores (*Macroprotodon brevis*, *Coronella girondica* and *Natrix natrix*).

Comparisons of the results between the two methodologies are summarized in figure 1. After arcsine transformation of the percentages, correlations were almost significant in both cases, despite the small sample sizes: percentage of recent citations (Spearman $R = -0.67$, $P = 0.066$, $n = 8$, fig. 1a), and percentage of old and recent squares (Spearman $R = -0.66$, $P = 0.073$, $n = 8$, fig. 1b). In figure 1b, *Natrix natrix*, a species with a reduced distribution range in Andalusia, appears to be an outlier. However, after this species was removed from the analysis, the strength of the correlation was highly significant (Spearman $R = -0.95$, $P = 0.0008$, $n = 7$).

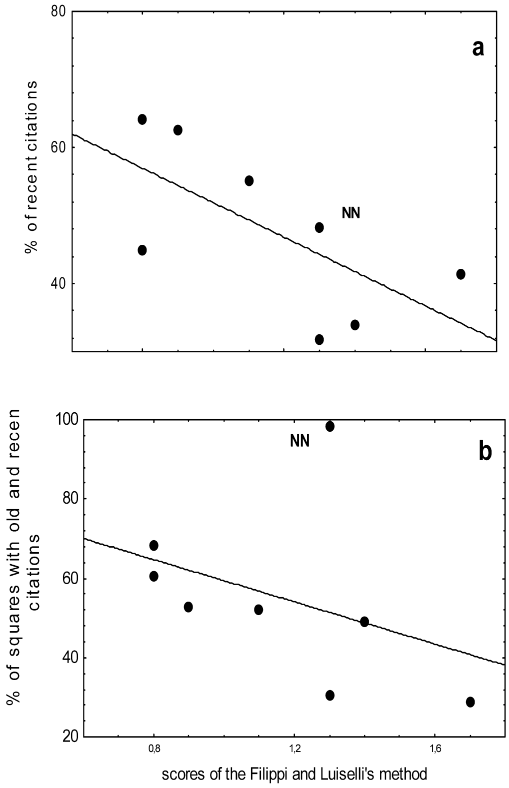

Figure 1. Relationship between the Iberian snake scores calculated by the Filippi and Luiselli's (2000) method, against those calculated by the cartographic method (a: percentage of recent citations, b: percentage of squares with old and recent citations) applied to the snake fauna in Andalusia. NN: *Natrix natrix*.

Discussion

The most interesting evidence of our study is that there is a considerable coincidence between the two methods used to identify the species undergoing the severest conservation threats: species with the highest values by the Filippi and Luiselli's method were the same that the species with the lowest values by the cartographic method (*V. latastei*, *C. girondica* and *N. natrix*). The most threatened species by their ecological and non-ecological attributes also appeared to be affected by population declines, suggesting a causal link between the two trends. This validates the combined use of both methods for conservation purposes and defining the most endangered species in the Iberian snake-fauna. Extensive field work by Busack in 1969-1972 and 1982-1983 in southern Spain also recognized the same species as the most endangered among the south Iberian snake fauna (Busack, pers. com).

By the cartographic method, species were ranked in a roughly similar way with the two indexes (table 1). Furthermore, comparisons of the analysis at different geographic scales (i.e. Iberian Peninsula, Iberian Spain, Andalusia, and the Mediterranean coast), also gave comparable results. Correlations between the two methods were marginally significant, and were fully significant when the outlier (*Natrix natrix*) was removed from the analysis. In Andalusia, this species is very rare and restricted to pristine streams (Santos et al., 2002), thus suggesting that the cartographic method could be biased in species with limited geographic distribution, by the intensive sampling effort in those few localities where they are known to occur.

Vipera latastei had the highest score by the Filippi and Luiselli's method, as was found for most Italian viperids (Filippi and Luiselli, 2000). A double effect of particular life-history traits (Santos et al., 2006) and illegal trade (Brito et al., 2001) are probable causes for the vulnerability of this species. *Vipera latastei* also showed low values in the cartographic indexes, suggesting that their traits may be the cause for population decline in the Iberian Peninsula. We can argue a similar trend for *Coronella girondica*. Both species show small population sizes and small clutches / litters (Bea and Braña, 1998, Gálan, 1998; unpub. data from authors). Furthermore, they have some degree of specialization as deduced from the low number of occupied habitats (Brito, 2003), as well as prey specialization (*C. girondica*, Luiselli et al., 2001) or ambush predation (*V. latastei*, Bea and Braña, 1998). The later trait is reportedly very sensitive to predict endangerment in Australian elapids (Reed and Shine, 2002). Thus, our results (i.e. high conservation threats and population declines) in both *C. girondica* and *V. latastei* agree with general theories that correlate vulnerability to extinction in species with specialized habitat requirements (Brown, 1995), and/or with slow life histories (McArthur and Wilson, 1967; Webb et al., 2002).

Natrix natrix is another species with a high score in conservation threats in Andalusia (table 2), contrary to findings in Italy (Filippi and Luiselli, 2000). Furthermore, values of the cartographic indexes were usually very low for this species (table 1). In a significant part of its Iberian range, *N. natrix* exhibits small and isolated populations (Pleguezuelos, 1989; Santos et al., 2002). Among the species analysed in this study, *N. natrix* is the only species with a distribution extending into the northern Europe, the Iberian populations occupying almost its southernmost range. Theory predicts that peripheral populations of species are generally isolated and with small densities because of suboptimal climatic conditions (Lesica and Allendorf, 1995). Ecological requirements for *N. natrix* include aquatic habitats and availability of amphibians as prey, which are limited in Mediterranean areas of the southern Iberian Peninsula because of limited rainfall (Pleguezuelos, 1989). Global climate change that alters temperature and rainfall patterns will likely affect biodiversity through changes in abundance and quality of aquatic habitats (Gibbons et al., 2000). Hence, aquatic and semiaquatic species are expected to suffer population declines as suitable habitats disappear. Our results in the south of the Iberian Peninsula, where almost no new squares for *N. natrix* were detected during the last five years (pers. obs. of authors) suggest this linkage.

Low cartographic scores for *Macroprotodon brevis* in Andalusia and *Rhinechis scalaris* on the Mediterranean coast (table 1) deserve separate comment. *Macroprotodon brevis*, also showing high threat scores (table 2), is a feeding specialist (mainly *Blanus cinereus,* Pleguezuelos et al., 1994) with biennial reproduction and a small clutch size (Pleguezuelos and Feriche, 1998). These traits may increase vulnerability in a species that is scarce and threatened in eastern Andalusia due to lack of suitable habitats (Pleguezuelos and Fernández-Cardenete, 2002). *Rhinechis scalaris* is also a specialized predator (almost exclusively small mammals, Pleguezuelos, 1998), scarce at low elevations, and apparently needs natural Mediterranean vegetation and/or patchy environments (Busack and Jaksic, 1982; Pleguezuelos and Honrubia, 2002). In a current on-going long-term study of Mediterranean habitats, *R. scalaris* has declined in numerous localities whereas *Malpolon monspessulanus* has become abundant over the last 20 years (C. Segura, unpublished data). Furthermore, road mortality of *R. scalaris* is common due to its nocturnal habits to thermoregulate on paved roads. Further information is necessary to evaluate local declines of *R. scalaris*.

Within the Iberian Peninsula, comparisons of cartographic results showed higher values in

Andalusia than along the Mediterranean coastal belt (table 1) suggesting interregional differences in habitat quality, the major single factor contributing to snake declines (Dodd, 1987). As both areas are geographically and climatically similar, we posit that human pressure is the probable cause for these geographic differences. Human presence constitutes an overwhelming form of habitat degradation (Gibbons et al., 2000) and is quite dramatic along the Mediterranean coast, where human population densities have increased enormously in recent years. The concomitantly increasing road network and construction in coastal area has reduced and/or degraded natural habitats (Greenpeace, 2005). On the contrary, Andalusia still maintains large and well-preserved natural areas. Thus, the cartographic method appears also to be sufficiently sensitive to detect areas with differing degrees of conservation status for snake communities.

In summary, the combination of two methods based on cartographic data and ecological plus non-ecological traits proved adequate to detect the vulnerability to extinction of snake species. This is relevant in conservation biology for species that are poorly studied by difficulties in allowing ecological and demographic field data, as in the case of snakes. This will be an effective tool prior the establishment of conservation strategies for snakes and other secretive faunas. In this sense, this study is a new contribution for the effective protection of snakes and their habitats.

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