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Biases in the current knowledge of threat status in lizards, and bridging the 'assessment gap'

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ABSTRACT

Reptiles represent the world's most diverse group of terrestrial vertebrates (~10,300 recognized species). Knowledge of their conservation status, however, lags behind that of birds, mammals and amphibians. Only ~40% of the world's reptile species have had their conservation status assessed by the IUCN, and detailed analysis of extinction risk has been limited to a subset of 1500 species. Using lizards (Sauria and Amphisbaenia), the most diverse group of reptiles, we investigated whether biases in distribution, ecology, life-history and taxonomy exist in the species that have been assessed to date by the IUCN. Our results highlight that only 36% of the ~6300 described lizard species have had their conservation status assessed. Whilst data deficiency is a key concern in lizards (16% of assessed species), the large number of non-assessed species (~4000 species) represents a larger and more pressing issue. Accentuating this 'assessment gap' is the fact that biases exist in the subset of lizard species that have been assessed by the IUCN. Australia and Asia, as well as tropical areas in general, were the least assessed regions. Assessed lizard species were more likely to have larger body and clutch sizes, broader distributional and elevational ranges, occur at more northerly latitudes, and have a viviparous mode of reproduction. Some evidence suggests that they also tend to be diurnal, surface active, and with developed limbs. The level of assessment also differed significantly among lizard families and higher taxa. We recommend the implementation of an integrated approach to bridge the 'assessment gap' in lizards, involving regional and taxon-specific working groups associated with the IUCN's Global Reptile Assessment, predictive modelling, enhanced knowledge of lizard distribution and biology, and improved taxonomic methods.

1. Introduction

Human activities have led to the documented loss (extinct, extinct in the wild, possibly extinct) of ~620 vertebrate species over the last 500 years, marking the onset of a sixth mass extinction event (Ceballos et al., 2015). The key threatening processes for terrestrial vertebrates are habitat loss and degradation, overexploitation, invasive species, and climate change (Thomas et al., 2004; Sinervo et al., 2010; Hoffmann et al., 2010; Foden et al., 2013; Böhm et al., 2016–in this issue), with most species impacted by multiple threat processes (Cardillo et al., 2005; Böhm et al., 2013). Whilst the drivers of species extinction risk have been extensively investigated over the last two decades in mammals (e.g., Cardillo et al., 2005; Fritz et al., 2009; Davidson et al., 2012; Di Marco et al., 2012), birds (e.g., Bennett and Owens, 1997; Owens and Bennett, 2000; Lee and Jetz, 2011), and amphibians (Stuart et al., 2004; Wake and Vrendenburg, 2008; Sodhi et al., 2008; Cooper et al., 2008; Howard and Bickford, 2014), the first global analysis of the conservation status of reptiles was completed relatively recently (Böhm et al., 2013). To further exemplify the extent to which our understanding of extinction risk in reptiles lags behind other terrestrial vertebrate groups, Böhm et al.'s (2013) analysis only considered 1500 randomly selected species (just 14.6% of the 10,270 described species as of August 2015; Uetz and Hosek, 2015), and many of these (21%) were classified as 'Data Deficient' (see Bland and Böhm, 2016–in this issue).

In contrast, the IUCN has successfully completed assessing the threat status of birds (~99%, 9895 of ~9900 species; AviBase, http://avibase.bsc-eoc.org/avibase.jsp?lang=EN) and mammals (~99%, 5413 of ~5500 species; Mammal Species of the World, http://vertebrates.si.edu/msw/mswCFApp/msw/index.cfm), and the vast majority of described amphibians (6247 of ~7500 species; Amphibian species of the World Database, http://research.amnh.org/vz/herpetology/amphibia/index.php) (Hoffmann et al., 2010; IUCN, 2015).

Altogether, only ~40% of described reptile species have been assessed by the IUCN (IUCN, 2015), including those considered in Böhm et al. (2013). Furthermore, most species have been categorized based on range size (i.e. Category B criteria). Why have reptiles, the largest class of tetrapods, been neglected? Potential explanations include the lower level of research that has been conducted on reptiles (Bonnet et al., 2002), their more secretive behaviour (Doody et al., 2013), adverse public perception (Kellert, 1993), and high rates of cryptic species diversity (Oliver et al., 2009; Rosauer et al., 2016–in this issue).

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Whatever the cause, reptiles are still being discovered and described at an astronomical rate (~200 species are being added per year) (Uetz and Hosek, 2015). Thus, despite their recent efforts through the Global Reptile Assessment (GRA; http://www.iucnredlistassessments.org/the-global-reptile-assessment/), the IUCN struggles to keep up with these additions, and to update assessments that are necessitated by this taxonomic activity (e.g., splitting of existing species into several taxa). The relatively recent description of many species (>1800 in the 21st Century so far — and many more revalidations of synonyms and elevation of subspecies to species rank, Uetz and Hosek, 2015) has resulted in an incomplete knowledge of reptilian biogeography, population density, ecology and life history (Meiri, accepted for publication).

Few assessments of reptile extinction risk were completed prior to Böhm et al. (2013), and those that were focused on specific taxonomic groups (elapid snakes, Reed and Shine, 2002; lacertid lizards, Siliceo and Diaz, 2010; New Zealand lizards, Tingley et al., 2013a). However, since the publication of Böhm et al. (2013) there has been a flurry of analyses based on species assessed by the IUCN (Böhm et al., 2016–in this issue; Tomovic et al., 2015; Tolley et al., 2016–in this issue; Roll et al., 2016–in this issue; Bland and Böhm, 2016–in this issue; Tolley et al., 2016–in this issue; Maritz et al., 2016–in this issue). But how representative of the broader reptile fauna are the subset of species that have been assessed? And do distributional, ecological, life-history or taxonomic biases exist in the reptile species that have been assessed by the IUCN? The existence of biases in the assessed reptile species could potentially influence the generality of some key findings of Böhm et al. (2013), namely: i) 19% of reptile species being threatened with extinction, ii) 21% of species being Data Deficient, iii) threat status being higher in freshwater environments, tropical regions and oceanic islands, and iv) Data Deficient species occurring more frequently in tropical areas (Central Africa, South-East Asia) and among fossorial species.

Here we investigate whether biases in distribution, ecology, life-history and taxonomy exist in the lizard species that have been assessed to date by the IUCN. Lizards represent 60% of reptile diversity (6304 valid species to date of which 36% are assessed; Table 1), but have lower levels of assessment compared to snakes (51% of 3567 species assessed), turtles (67% of 341 species), crocodiles (92% of 25 species), and the tuatara (100% of 1 species) (IUCN, 2015; Uetz and Hosek, 2015). Lizards (here including the squamate suborders Sauria and Amphisbaenia) are highly diverse and nearly cosmopolitan, with a plethora of life styles, reproductive characteristics, sizes, shapes and colours- and threats (Pianka and Vitt, 2003). Knowledge of potential biases in the traits of species that have been assessed will act to inform conservation and focus efforts towards the taxa and regions that are in the greatest need of investigation and determination of their conservation status. We predicted that assessed species were more likely to occur in areas of high levels of research activity (i.e. Northern Hemisphere regions; e.g., Europe, northern North America), have wide ranges, wide elevational ranges, occur at lower elevations in temperate biomes (that have been better studied than the tropics and desert regions), and in continental (rather than oceanic) regions. Furthermore, we predicted that species that were more obvious and easier to study (e.g., large, long-lived, viviparous, diurnal, surface active, limbed species), and have been known for longer (i.e. described earlier), would have higher rates of assessment. Due to deep phylogenetic divergences in the distribution, biology and ecology of lizard lineages and families (Vitt et al., 2003; Vitt and Pianka, 2005), we predicted any biases would manifest themselves as different levels of assessment among lizard taxonomic groupings.

Table 1
Levels of lizard assessment among different realms numbers are species numbers. Percentages are from the realm totals.

Realm	Total	Non-assessed	Assessed		
			Total assessed	Assessed, not DD	Assessed, but not in Böhm et al. (2013)
Afrotropic	959	587 (61%)	372 (39%)	306 (32%)	243 (25%)
Australia	747	638 (85%)	109 (15%)	104 (14%)	22 (3%)
Madagascar	292	11 (4%)	281 (96%)	252 (86%)	234 (80%)
Nearctic	189	41 (22%)	148 (78%)	146 (77%)	113 (60%)
Neotropic	1972	1426 (72%)	546 (28%)	440 (22%)	282 (14%)
Oceania	507	284 (56%)	223 (44%)	186 (37%)	155 (31%)
Oriental	1065	772 (72%)	293 (28%)	206 (19%)	158 (15%)
Palearctic	573	245 (43%)	328 (57%)	301 (53%)	243 (42%)
Overall	6304	4004 (64%)	2300 (36%)	1941 (31%)	1450 (23%)

2. Methods

IUCN lizard assessments were downloaded from the IUCN website (http://www.iucnredlist.org/) on the 24th June 2015. Binomials were compared to the March 2015 version of the reptile database (http://www.reptile-database.org/; downloaded on the 2nd April 2015) — we consider only species included in this dataset, or described since (surprisingly many: 41 species at the time of analyses). We updated the names in the IUCN database according to the reptile database taxonomy, but only included data where there was a one-to-one fit between a reptile database name and an IUCN one (i.e., entities considered species by the IUCN, but subspecies, or populations within larger species by the reptile database were omitted). We restricted our analyses to lizards and amphisbaenians (henceforth "lizards") because they are less well assessed than other reptilian taxa. We treated data on the lizards assessed by the Institute of Zoology (IOZ; Böhm et al., 2013) in a similar manner to which we treated IUCN data. Four species included in Böhm et al. (2013): *Basiliscus vittatus*, *Gonatodes albogularis*, *Microlophus albemarlensis*, and *Sphaerodactylus argus* (all considered Least Concern by Böhm et al.) are listed as having no IUCN assessments. We treat them as assessed (and not DD) in subsequent analyses (see below). *Leiolopisma fasciolare* — a dubious species from an unknown locality and with no ecological data (not assessed by the IUCN) was omitted.

We collected data on lizard traits from the literature, and in a few cases, in the field (see Meiri, 2008; Meiri et al., 2012, 2013, 2014; Scharf et al., 2015 for details). The following categories of traits were recorded:

- Distribution: *Geographic range* data (including *range size* [log transformed] and *latitudinal centroids*) for all lizards were obtained from the GARD (Global Assessment of Reptile Distributions) working group (http://www.gardinitiative.org). A lizard was considered to inhabit the *biogeographic realm* (according to the realm definition in Wallace 1876) and *biome* (biome data obtained from the WWF, https://www.worldwildlife.org/biome-categories/terrestrial-ecoregions) where the largest part of its range resides in order to consider each species only once. An alternative approach is to consider a species as present at all the realms or biomes it inhabits (or in which a substantial part of its range is found). Given that most lizards are endemic to a single realm or biome, however (e.g., 91.2% of species inhabit just one realm, 92.6% have >90% of their distribution in one realm), such an approach is unlikely to change the results of our analysis. We grouped the "tropical and subtropical" biomes of the IUCN designation ("Tropical and subtropical moist broadleaf forests", "Tropical and subtropical dry broadleaf forests", "Tropical and subtropical coniferous forests" and "Tropical and subtropical grasslands, savannas and shrublands") into one "tropical" biome, and similarly grouped the "Temperate broadleaf and mixed forests", "Temperate Coniferous Forest", "Boreal forests/Taiga" (the latter with one species, *Zootoca vivipara*) and "Temperate grasslands, savannas and shrublands" biomes into one "Temperate" biome. We did not analyse the "Flooded grasslands and savannas" biome because too few species inhabit this biome for meaningful analyses. Species were considered *insular endemics* if they inhabit no continent (i.e., if they only inhabit landmasses smaller than Australia). *Elevation* data were directly recorded from the literature and not derived from range maps.