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The Wallacean Shortfall and the role of historical distribution records in the conservation assessment of an elusive Neotropical snake in a threatened landscape

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A B S T R A C T

Documenting species distribution is essential to extinction risk asessments and subsequent conservation actions. Historical records are thus essential to understand how species are distributed and how their range has changed over time. However, using historical records might contribute to overestimating the species current range and misrepresent their conservation status. Here, we illustrate the pitfalls of this approach using a widespread but elusive Neotropical snake species, *Philodryas livida* (Dipsadidae Bonaparte, 1838). We mapped occurrences of this species over time and calculated its Extent of Occurrence and Area of Habitat. Our results show that due to the intense, widespread anthropic land-use transformation since the discovery of *P. livida* in 1920, most historical localities are now likely unsuitable for its occurrence and both its current Extent of Occurrence and Area of Habitat become remarkably smaller (5.7% and 19.1% remaining, respectively) if only localities from the last 30 years are considered. Apart from the natural elusiveness of the species, intense habitat loss and fragmentation may also explain the low number of recent records of *P. livida,* all concentrated within or near protected areas, indicating a putative decline in range relevant to its conservation status. We thus highlight how failing to consider the date of records and the associated land-use change over time might underestimate species range reduction and thus threat status. We strongly encourage the inclusion of the date of each occurrence record in conservation assessments, as suggested by the IUCN's mapping standards, such that historical records are carefully considered, especially in highly dynamic and threatened biomes such as the Cerrado savannas in Brazil.

1. Introduction

Detailed knowledge of the geographical distributions of species is fundamental to render accurate biogeographical interpretations and conservation strategies, especially in megadiverse and poorly sampled countries or regions (Ficetola et al., 2014, Nogueira et al., 2019). The need for accurate occurrence records dates from early biogeographers (Wallace, 1852) and the lack of detailed data on species distributions is is the "Wallacean Shortfall" on behalf of the father of biogeography (Lomolino, 2004). Every new distribution record increases our knowledge of species ranges and is likely a contribution to mitigating the Wallacean Shortfall. However, not every existing distribution record is available to the scientific community, either because it is not made public through scientific publishing and taxonomic revisions or because voucher specimens are not deposited in biological collections were not verified in terms of current taxonomy and correct diagnosis (Nogueira et al., 2019). Despite that, the recent increase in digital availability of occurrence records from museums and herbaria is providing useful data for a primary understanding of many species' geographic distribution (e.g., GBIF - https://www.gbif.org; see Gaul et al., 2020). Nonetheless, the accuracy of such data has been questioned, and relevant limitations to the use of this information have become evident (Ficetola et al., 2014; Gaul et al., 2020; Zizka et al., 2020).

The range size of a species is one of the primary criteria considered to

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estimate its extinction risk IUCN (2012), and is widely used in species conservation assessments. However, occurrence data for a great number of species is still sparse, inaccurate, or nonexistent (Nogueira et al., 2019), resulting in incomplete information about species distributions that preclude ecological and mechanistic interpretations (Gaul et al., 2020). Furthermore, even though habitat loss is the most important factor behind the current biodiversity crisis (Schipper et al., 2008; Powers & Jetz, 2019; Cox et al., 2022), its impacts are not homogeneously distributed around the globe. While long-occupied (e. g., Europe), inhospitable (e. g., the Great Australian Desert) or very remote regions (e. g., portions of the Amazon forest) have remained mostly unchanged in the last century (Sanderson et al., 2002; Kaplan, Krumhardt, & Zimmermann, 2009; Myers, Mittermeier, Mittermeier, Da Fonseca, & Kent, 2000; Moutinho, Guerra, Azevedo-Ramos, Kapuscinski, & Frumhoff, 2016; Williams et al., 2020, but see Mataveli, Chaves, Brunsell, & Aragão, 2021), other landscapes are currently experiencing a high degree of human-induced transformation (e. g., the Cerrado savannas; Strassburg et al., 2017; Pacheco et al., 2021). Similarly, accounting for habitat loss on a finer scale reveals that particular areas are unequally prone to suffer from distinct aspects of land-use conversion (Strassburg et al., 2017; Grande, Aguiar, & Machado, 2020; Pacheco et al., 2021). Recent rates of land-use conversion also lead to rapid losses of landscape connectivity which hampers population viability, resulting in local extinctions (Thompson, Rayfield, & Gonzalez, 2017; Grande et al., 2020).

Although the complexity and time-wise dependency of geographical range limits have been long recognized, “time” has mostly been considered in a geological timescale framework (Upchurch & Hunn, 2002; Gaston, 2003). While small-scale local habitat aspects have been encouraged to be incorporated into conservation assessments (Brooks et al., 2019; Serrano, Vieira-Alencar, dos, Díaz-Ricaurte, & Nogueira, 2020), the changes of species distributions in ecological time remain largely unexplored. This is especially troublesome regarding rare (naturally scarce) and/or elusive (rarely detected) species (see Rabinowitz, 1981) that have wide distributions because new occasional or inaccurate records might significantly further increase the area of its range. Furthermore, the assessed area of distribution of elusive but widespread species might vary from a large continuous area (maximizing false positives) to disjunct small patches (minimizing false positives), depending on how the current range is interpreted. Similarly, older records without any recent confirmation by nearby faunal inventories may introduce a similar bias, potentially influencing extinction risk assessments. Historical distribution records, for instance, often present inaccuracies about their geographical locations and are sometimes disregarded in fine-scale studies on species distribution modeling (Franklin, 2010). Additionally, if historical records are not supported by recent sightings of a species in the same general location – provided there was enough sampling effort to detect the species – they may inflate the estimated range. On the other hand, historical records are increasingly relevant since they provide a general overview of a species distribution, contributing to the understanding of large-scale biogeographical processes (Raxworthy et al., 2003). Thus, systematically identifying historical distribution records that may currently correspond to unsuitable areas for a given species known from just a few localities may improve our ability to properly assess its conservation status, as suggested by the IUCN (with parts of the species range being classified as Possibly Extinct) (IUCN, 2012), and by the recently proposed Area of Habitat (AoH) approach (Brooks et al., 2019). Herein, we use a potentially widespread but elusive Neotropical snake species, *Philodryas livida*, as a case study to highlight how using historical distributional information without accounting for the date of each record may lead to inaccuracies that are especially pervasive regarding extinction risk assessments.

2. Material and methods

2.1. Study species

Philodryas livida (Amaral, 1923) has a potentially wide distribution in Central South America, being considered endemic to the Cerrado savannas of South America (Nogueira, Ribeiro, Costa, & Colli, 2011; Nogueira et al., 2019) in Brazil and northeastern Paraguay (Nogueira et al., 2019). Little is known about its natural history since it is rare in scientific collections, but it has been observed in the wild exclusively in grassland areas at intermediate to high elevations (133–928 m; N = 30 records in literature and museums; see Nogueira et al., 2019; Supp. Mat. 1). It is currently listed as Vulnerable under criteria A2c by the IUCN (Scott, Cacciali, Silveira, & da Prudente, 2020).

2.2. Data collection and mapping

We compiled distribution point locality records for *P. livida* from the literature (e. g., Thomas & Fernandes, 1996; Valdujo et al., 2009; Nogueira et al., 2019) and matched these records with the available collecting information at the herpetological collection of Instituto Butantan to complement our dataset with the approximate date of collection of each known specimen. Part of the available records were obtained by the authors in the field, during snake surveys in Emas National Park (citar aqui Valdujo et al., 2009), a large protected area of Cerrado in central Brazil. Apart from the records in Laguna Blanca Reserve, Paraguay, these are the only available field records for this species. Furthermore, we also gathered point occurrences from the Global Biodiversity Information Facility (GBIF; https://www.gbif.org), using only vouchered records with collection date, coordinates and a location precision of less than 5 km, since non-filtered datasets might bias conservation assessments (Zizka et al., 2020). We mapped the evolution of its known range from the first collected specimen until the present by subsequently adding the records reported in the following decades (progressive approach). We used a Minimum Convex Polygon (MCP) formed by the species records (cf. Extent of occurrence, EOO; IUCN (2012)) to illustrate how knowledge on the species range evolved over time. We then departed from the current known range of the species and subsequently removed the oldest records by decades (regressive approach). Importantly, if a given locality had specimens from different decades, we kept the records in the map up to the most recent decade when the species was captured in that locality.

Additionally, to assess if *P. livida* might have gone undetected in recent years due to sampling bias or low sampling effort, we reviewed published surveys both in localities where it had been previously reported and within its EOO formed by all known records. For the localities where the species has been previously detected, we searched for a combination of the terms “herpeto* OR [locality] OR inventory OR checklist OR snake OR reptile” in Google Scholar, where [locality] corresponded to the name of the municipality of known records. For localities within its reported range, we searched for “herpeto* AND cerrado AND inventory AND checklist AND snake AND reptile” and considered only surveys inside a buffer of 150 km around *P. livida*’s EOO, to minimize potential omission errors. For every survey, we recorded the last sampled year, duration of sampling, sampling effort (in days), sampling method, coordinates, type of habitat and whether *P. livida* or other species of the genus *Philodryas* had been recorded (Supp. Mat. 2). We confirmed species identification when photos of the reported individuals were available. For example, even though *Philodryas livida* has broad similarities with sympatric closely-related species such as *P. patagoniensis* or *P. agassizii*, it has as a distinct dorsal coloration (lighter and less homogeneous than *P. patagoniensis* yet darker but less clearly striped than *P. agassizii*). Furthermore, voucher specimens can be identified since they also differ in hemipenial morphology and number of dorsal rows (17-17-15 in P. livida, 19-19-15 in *P. patagoniensis* and 13-13-13 in *P. agassizii*).

2.3. Estimation of EOO, AoH and AOO

We used the MCP formed by the full dataset (i.e. with all known records) to estimate the current extent of occurrence (EOO), and the Area of Habitat (AoH, *sensu* Brooks et al., 2019) of *P. livida*. The EOO represents a measure of area by only considering the MCP and thus the overall extent of a species range (IUCN, 2012; Serrano et al., 2020), while AoH is an alternative to the estimation of AOO (area of occupancy) that takes into account the total area of the preferred habitat of the species, limited by the elevational range of the species (Brooks et al., 2019). Even though the original methodology to calculate AoH suggests using IUCN range polygons, this procedure does not allow estimating the evolution of AoH over time since it is based on all records. Thus, even though we also calculate the AoH using the IUCN polygon, we chose the EOO to illustrate how historical records may affect this parameter. We calculated the AoH of *P. livida* as the total area occupied by grasslands (preferred habitat of the species; Nogueira et al., 2019; CCN and PHV *personal observation*) occurring between 200 and 900 m above the sea level, and restricted to the limits of the Brazilian Cerrado as proposed by Dinerstein et al. (2017). This elevation range takes into account the elevation of the most recent specimens collected (last three decades, see Results and Supp. Mat. 1) because old records are more likely to present inaccuracies than the most recent ones (e.g. Zizka et al., 2020), and older records from Instituto Butantan were often reported from railway stations near the actual capture localities (see Discussion). We used land-use data provided by the MapBiomas initiative for the year of 2020 (collection 6; the most recent release; MapBiomas, 2022), but excluded the 3.6% of the total EOO of *Philodryas livida* corresponding to Paraguayan records since data for the Cerrado is restricted to the political borders of Brazil. We used QGIS 3.24 (QGIS Development Team, 2022) to estimate the EOO, and Google Earth Engine (Gorelick, Hancher, Dixon, Ilyushchenko, Thau, & Moore, 2017) to estimate the AoH. Additionally, we calculated the AOO through time with the regressive approach using GeoCAT (Bachman, Moat, Hill, De La Torre, & Scott, 2011) as it is one of IUCN's assessment criteria (Brooks et al., 2019).

3. Results

Since its description in 1923, a total of 30 vouchered specimens of *Philodryas livida* have been collected in 14 localities (Fig. 1, Table 1). Georeferenced information was not available for two records (IB3681 and IB40953; Supp. Mat. 1). Most records were obtained before the late 1970s, with gaps of records in the 1960s, and 1980s. From the 1990s to the 2000s, the calculated EOO for *P. livida* increased from 72,918 (since the 1970s) to 215,901 km^2, when six individuals were collected at Emas National Park and surroundings, Mineiros municipality, Goiás state, Brazil, between 1997 and 2001 (Valdujo et al., 2009, Table 2). Additionally, a new record revealed the persistence of the species in the municipality of Itirapina, state of São Paulo, in the same decade. Since then, the species has been recorded only twice, in 2011 and 2013, at the Reserva Natural Laguna Blanca in Paraguay (Smith et al., 2014), which expanded its range to the current known extent (Fig. 2, Table 2: "Full") while also representing the first record outside Brazil. With our regressive approach, considering only records from the last three decades (n = 5 in three localities), the EOO and AoH of *P. livida* decreased 94.3% and 77.0%, respectively, (Fig. 3) in relation to those parameters for the full dataset. Estimates of AoH using the IUCN Red List range and the EOO with all records were similar, albeit the former was 5% larger (2401.0 km^2 and 2,295 km^2, respectively). Regarding the species' AOO, it ranged from 84 km^2 with the full dataset to 32 km^2 if only the last three decades were considered, a reduction of 61% (Supp. Mat. 3). These values of AOO would correspond to IUCN Red List categories of "Endangered" for the full dataset and of "Critically Endangered" if using records from only the last decade, according to the GeoCAT assessment. Remarkably, all recent records were reported from within or in the surroundings of protected areas (Fig. 1). In the last three decades *P. livida* has been detected in only three out of the 14 localities where it had been known to occur. Remarkably, two of these records are from the last ten years while the remaining is from at least 20 years from the present.

To serve as a counter-example, we also preliminarily use as comparison the locally-abundant and commonly-found *P. patagoniensis*, a phylogenetically-related species (Arredondo et al., 2020) that is sympatric with *P. livida* and widely distributed across open habitats in South America (López & Giraudo, 2008; Nogueira et al., 2019). We gathered point occurrences from the Global Biodiversity Information Facility (GBIF; https://www.gbif.org), using only vouchered records with collection date, coordinates and a location precision of less than 5 km, since non-filtered datasets might bias conservation assessments (Zizka

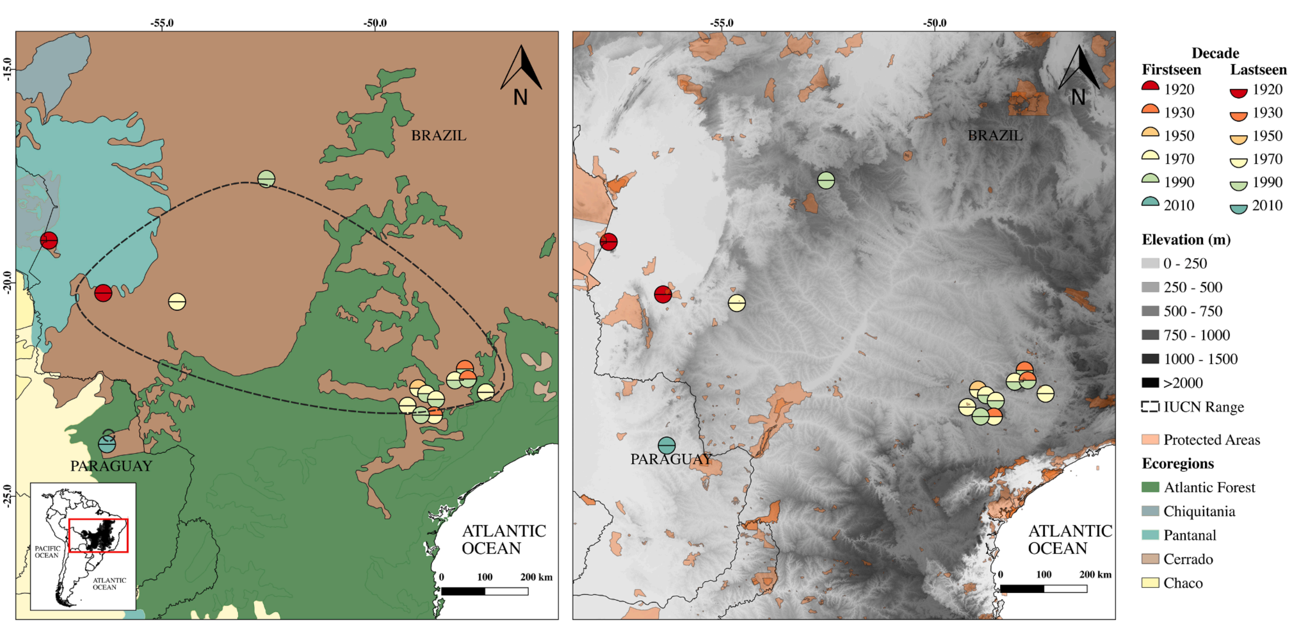

Fig. 1. Distribution records (colored according to first and last seen decade) of *Philodryas livida*, with ecoregions (left) and elevational variation (right). Records from Parque Nacional das Emas are represented by a single locality to aid visualization. The area within the dotted line corresponds to the species current range polygon according to IUCN. Protected areas are from the World Database on Protected Areas (IUCN & UNEP-WCMC, 2015).

Table 1
Number of individuals of *Philodryas livida* reported for each locality and each decade.

Locality	1920	1930	1950	1960	1970	1980	1990	2000	2010
Corumbá	1							0	
Miranda	2								
São Carlos		3							
Itatinga		1							
Itirapina		2					1		0
Avaré			1						
Agudos			1		1				0
Fazenda Santa Bárbara*					1				
Brotas					1				
Campo Grande					1				
Lençóis Paulista					3				0
São Manuel					1				
Limeira					1				
Mineiros							5		
Santa Bárbara/PY**									2
Total	3	6	2	0	9	0	6	0	2

* denotes a record which has been erroneously perpetuated in scientific literature.
** refers to a locality in Paraguay, the only record outside of Brazil. The original reported location is "Fazenda Santa Bárbara" with no details on municipality or state but several papers have wrongfully attributed this record to "Águas de Santa Bárbara, state of São Paulo". This is another potentially pervasive consequence of historical records, as often their exact location is less accurate or uncertain.

Table 2
Extent of occurrence (EOO) and Area of Habitat (AoH, *sensu* Brooks et al., 2019) of *Philodryas livida* in square kilometers (km^2) in two different scenarios (see main text for details). The EOOs and AoH are illustrated in Fig. 2 and Fig. 3 for the progressive and regressive approaches, respectively.

Progressive approach			Regressive approach			
Dataset	EOO	AoH	Dataset	EOO	AoH	EOO %
1920–1930	60,445	309	Full	392,075	2,295	100.0
1920–1950	61,422	326	1930–2010	310,352	2,109	79.2
1920–1970	72,918	377	1950–2010	300,246	2,077	76.6
1920–1990	215,901	1,439	1970–2010	292,768	2,060	74.7
1920–2000	230,724	1,693	1990–2010	270,927	1,978	69.1
Full	392,075	2,295	2000–2010	22,350	539	5.7

et al., 2020). We recorded 795 dated occurrences of *P. patagoniensis* in the same time period as reported for *P. livida* (out of 1594 total occurrences; 165 from the herpetological collection of the Instituto Butantan and 630 from GBIF), with 115 records (14.5% of total records) within the range of *P. livida* (Supp. Mat. 4). Similarly to *P. livida*, the progressive approach also shows a steady increase in species range size over time. Our regressive approach showed a constant decrease in range size only when regarding collection records after the 1960s. When considering only points from the last 30 years, there was a decrease of 66.3% of EOO (Supp. Mat. 4).

In our review we found three snake surveys in previously recorded localities of *P. livida*, but all failed to record the species. The elapsed time between the last vouchered individual of the species and surveys in these localities ranged from 12 years in Itirapina (São Paulo, Brazil) to 83 years in Corumbá (Mato Grosso do Sul, Brazil). The total sampling effort was 544 days among studies (average of 181.3 ± 231.5 days), consisting

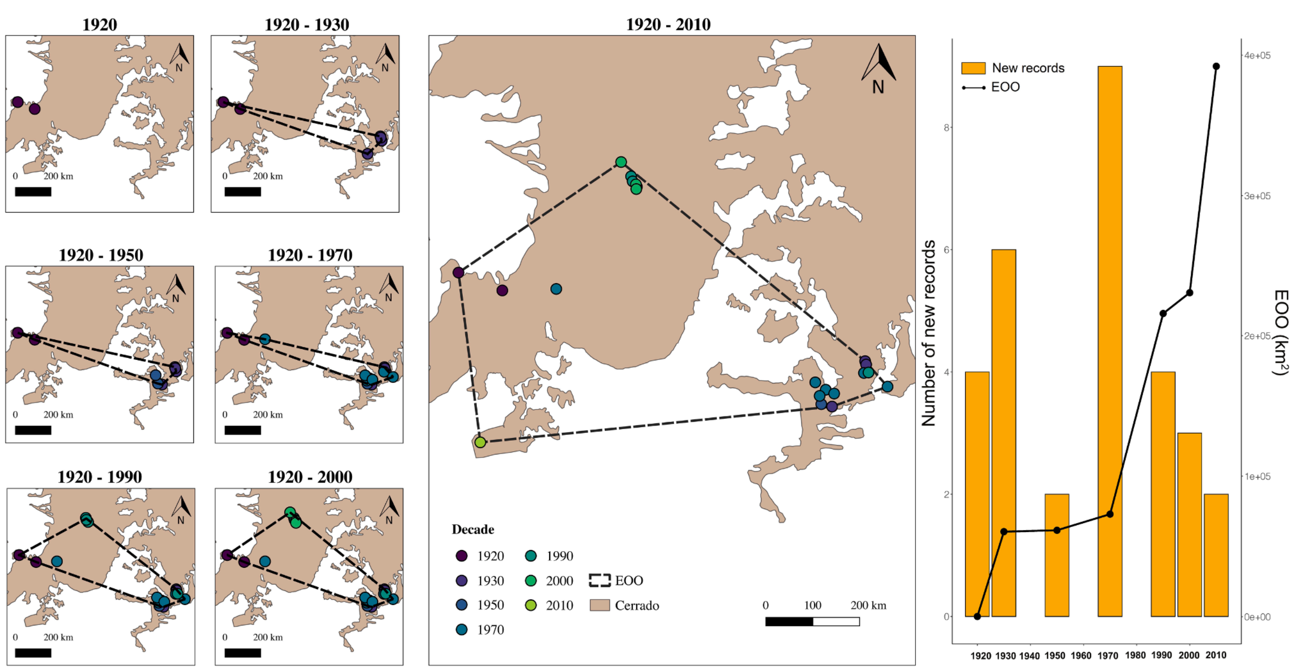

Fig. 2. Progressive approach showing how *Philodryas livida*'s EOO evolved over time by iteratively adding localities from subsequent decades. The graph (left) shows how many new records were reported and the corresponding increase in EOO.

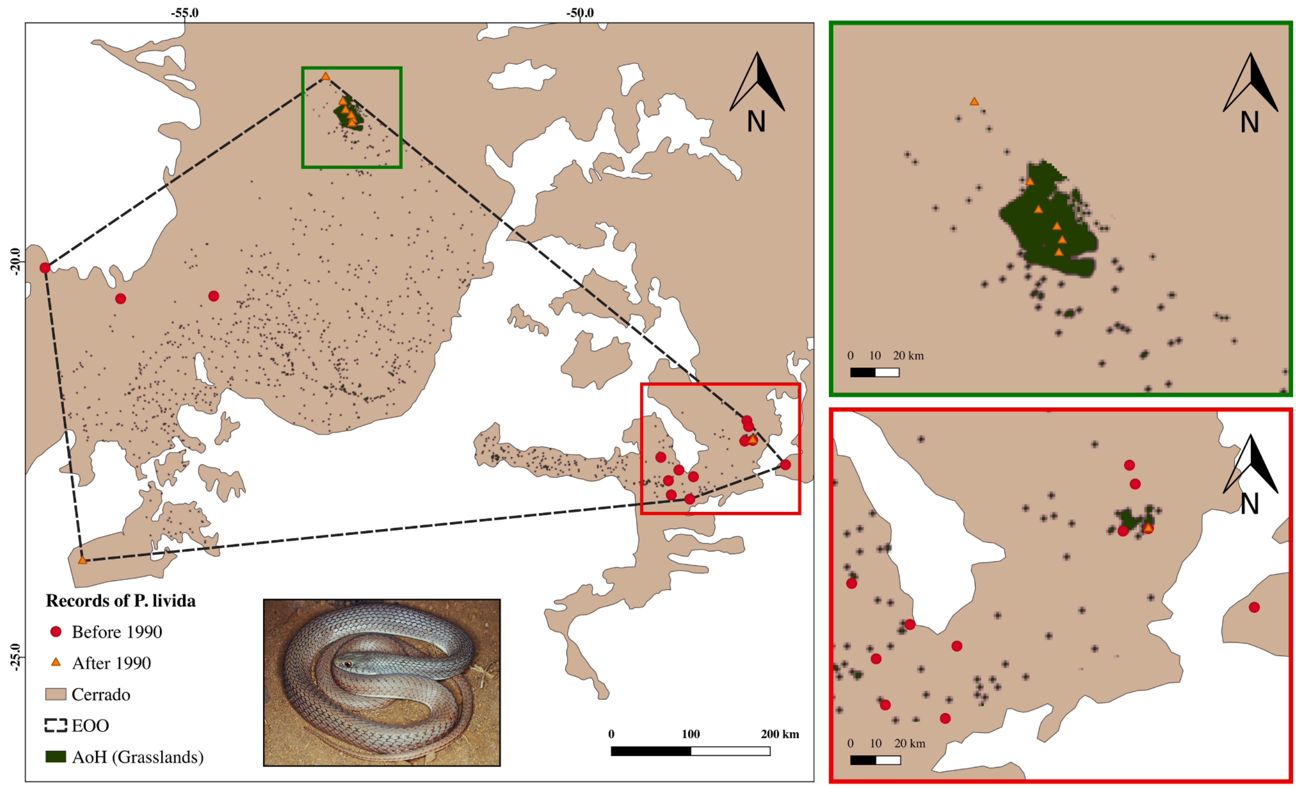

Fig. 3. EOO and AoH of *P. livida* with records prior to and after 1990, with insets showing remaining areas of continuous suitable habitat (top right; Parque Nacional das Emas, Goiás state, Brazil) and areas under strong land-use change (bottom right; São Paulo state, Brazil).

of active search, search by car and pitfall traps, detecting *P. aestiva*, *P. olfersii* and *P. patagoniensis.* We also found nine snake surveys within the *P. livida* buffered MCP, most within or near protected areas, and with an average duration of 8.7 (±6.9) months. The total sampling effort was 299 days (average of 42.7 ± 38.8 days), employing active search and pitfall traps. All these surveys also failed to detect *P. livida* but five of them detected other species of the genus *Philodryas*: *P. agassizi* (n = 1), *P. mattogrossensis* (n = 2), *P. nattereri* (n = 2), *P. olfersii* (n = 3) and *P. patagoniensis* (n = 1).

4. Discussion

Understanding and measuring ranges is of paramount relevance for biodiversity science and conservation assessments (Mace et al., 2008; Rattis, Dobrovolski, Talebi, & Loyola, 2018). Indeed, 83% of the categorizations of threatened snakes in the IUCN Red List (version 2021.1, IUCN 2021) use the criterion B, which includes subcriteria based on thresholds of range size (IUCN, 2012). Our results show that historical records of an elusive species help to understand how distribution changed over time in a highly dynamic and altered landscape. However, this may lead to inadequate conservation assessments if all records (both historical and recent) are considered as evidence of species occurrence. Therefore, instead of carelessly using these records or fully disregarding them, they should be used with caution in appropriate data-informed contexts. Here we assess how the use of historical records can mislead the extinction risk assessment of a species if changes in land-use and suitable habitat are not considered.

Our results indicate that the distribution of *P. livida* was possibly naturally disjunct and has likely changed in recent decades, resulting in an even more rarefied and dicontinuous range over time. This leads to substantial decreases of EOO, AOO and AoH if only the last three decades are considered. Indeed, it is estimated that habitat loss of 44% within its original range may have led to a population decline of 30% (Scott et al., 2020), another important aspect of a species conservation assessment, albeit not evaluated in this work. Furthermore, the IUCN's most recent extinction risk assessment for the species (Scott et al., 2020), is based on a continuous hand-drawn polygon which corresponds to an EOO of 410,216 km^2, which is 18.141 km^2 (4.62 %) larger than our most conservative estimate (progressive approach, Fig. 1) and 387,866 km^2 (1735.42 %) larger than our regressive approach. The AoH calculated with the IUCN's polygon was only 5% larger than our estimate, which validates our method of using the EOO to delimit the AoH with the added benefit of allowing to compare different timeframes. Although *P. livida* may have had a large range originally, it may be a rare species in two other aspects of rarity: it is specialized in an increasingly rare habitat (Cerrado grasslands) and may occur in low abundances (cf. Rabinowitz, 1981), at least in some localities (e. g. Reserva Natural Laguna Blanca). If this is the case, the sampling effort needed to detect it might be higher than that reported here for the recent studies carried out in areas where the species was previously found. However, if the opposite is true, it may have disappeared from most of its original range. Overall, the species has not been recorded in Brazil since the 1997–2001 survey by Valdujo et al. (2009), with its most recent records coming from a highly protected area of pristine Cerrado habitat in Paraguay, where it took over 55 months of sampling to find two individuals (Smith et al., 2016), supporting the idea that *P. livida* may be naturally rare. By contrast, other species of the genus *Philodryas* have been recorded in its range in the same timeframe while sharing some of its ecological attributes such as relatively large body size and diurnal, non-fossorial activity (Feldman, Sabath, Pyron, Mayrose, & Meiri, 2016; Fiorillo, Maciel, & Martins, 2021), although none of these species were found in large numbers (1–3 individuals). Conversely, in Parque Nacional das Emas – a large preserved protected area dominated by extensive Cerrado grasslands – *P. livida* had more than twice the abundance of other *Philodryas* species, which would indicate that this species might have high abundances and/or be easily detected in areas with suitable habitat (Valdujo et al., 2009). Instead, we may interpret its relative rarity in collections not only as a result of its local rarity/elusiveness in suitable sites, but also due to the patchy, disjunct nature of its typical habitat, Cerrado natural grasslands, coupled by the fact that these upland, flat, discontinuous Cerrado grasslands are exactly the first habitat type to be converted to monocultures, as they provide extremely favourable conditions for mechanized agriculture (deep, well drained, flat plateaus, see discussions in Klink & Moreira, 2002. Yet, it is likely that populations of this species are declining, due to its pattern of wide but sparse current distribution which may reflect extinction processes along much of its range (Wilson, Thomas, Fox, Roy, & Kunin, 2004).

Records of *P. livida* from the last 30 years have come exclusively from within or around protected areas, even though less than 1% of this species' range falls within conservation areas (Scott et al., 2020). This may represent a spatial sampling bias because many snake inventories have been extensively conducted in protected areas. This highlights the importance of evaluating new sites for creating new protected areas, especially in the southern Cerrado savannas (Resende et al., 2021), considering that only 6.5% of native Cerrado vegetation is represented within protected areas (Françoso et al., 2015) and that the southern portion of the Cerrado is historically the most affected by land-use conversion (Strassburg et al., 2017). On the other hand, many older distribution records of Brazilian snakes come from third-party collaborators such as local residents and landowners, who used to send snakes to the Butantan Institute and other antivenom producing institutes by railway (Fernandes & Chaves, 2014), resulting in less detailed locality information. Indeed, most records of *P. livida* are from the 1970 s, coinciding with the implementation of the "Pró-Álcool" program, which aimed to increase Brazil's internal production of sugarcane-based ethanol fuel (Rosillo-Calle & Cortez, 1998). This program extensively modified the species habitat but may have increased chance encounters of snakes, but leading to more than tenfold the number of reported individuals of other *Philodryas* species compared to *P. livida*. As As threat assessments based on IUCN criteria often use range size thresholds (under the widely used criterion B), overestimating a species range size by incorporating historical records not supported by recent data not only precludes our ability to assess its actual threat status, but also negatively impacts our efforts to analyze its distribution within an adequate framework of prioritization. For instance, depending on what timeframe we use on the GeoCAT automated assessment, *P. livida* may be considered "Least Concern" or "Critically Endangered" using the EOO or "Near Threatened" to "Critically Endangered" using the AOO. Finally, the proximate cause of not taking into account historical distributional data is the fact that researchers generally do not have access to accurate date of collection of most records for many species, especially in large comprehensive distributions summaries (e. g., Nogueira et al., 2019; but see Serrano et al., 2020), and even in online based distribution records (e. g. only 49.8% of *P. patagoniensis* records were dated in GBIF).

It is about time to look into species distributions regarding short-term changes in their ranges without necessarily disregarding the relevance of historical records to understand historical patterns derived from geological time frames. These two pieces of information reflect different landscape processes and thus should be used in different contexts, which requires clear directives of which records should be used and in which approach. Information on habitat change and likely extinct populations can also be considered in novel approaches such as the Species Threat Abatement and Restoration" (STAR) metric, which evaluates the potential benefit of actions that aim to reduce threats and restore habitat for threatened species such as *P. livida* (Mair et al., 2021). We encourage researchers and conservation practitioners to adopt and stimulate among peers the habit of disclosing the detailed collection date of as many species distribution records as possible, especially in geographical distribution summaries (e. g., Serrano et al., 2020). This might increase our capacity of discussing a species conservation status while incorporating the factors involved in the decision of considering a species absent from a given historical occurrence site, as well as considering the opinion of specialists on how different taxa are expected to be recorded.

We argue that a first step to better assess the contribution of historical records is to have access to the precise date of collection of distribution records. This should be followed by an expert evaluation of what in fact should be considered "historical" in a species or group specific context and how these records have been impacted by land-use changes that may reduce or lead to the disappearance of suitable habitat. For example, an old record from a remote area in Amazonia, where most of the original habitat remains intact, can still be considered valid. In contrast, records from areas that have suffered intense land use change may no longer be valid for calculating current EOO in threat assessments (as in this study). This detailed information and expert knowledge can then be incorporated into IUCN's standard methodology of classifying parts of a species range as 'Possibly Extinct' and to better evaluate the conservation status of the species. We also highlight the importance of thorough identification by taxon specialists, of depositing vouchers in scientific collections and especially of making this information public and widely available to use, in order to better understand how species ranges, in particular rare and/or elusive ones, might change over time. None of this can be achieved unless a considerable change of perspective is considered for both authors and journals dedicated to publishing, for example, distribution summaries. It is necessary to provide at least the basic information that compose a species distribution records: "What, Where and When" (Isaac & Pocock, 2015; Gaul et al., 2020) and to stimulate the publication of checklists even if they are derived from short-term, non-hypothesis driven studies, and especially when they are supported by vouchers deposited in public collections. These changes in the way we deal with distribution records and their use in conservation will help to reduce the Wallacean Shortfall, and result in more accurate threat assessments in an age of rampant biodiversity crisis.

Author contributions

FCS, JPSV-A and JCDR planned the study; FCS, JPSV-A and JCDR collected the data; PHV and CCN collected field data for the studied species, FCS, JPSV-A and JCDR analyzed the data; FCS and JPSV-A led the writing of the manuscript; FCS, JPSV-A and JCDR wrote the original draft; CCN, PV and MM and supervised the manuscript. FCS, JPSV-A and JCDR wrote the final version of manuscript. All authors reviewed and contributed to the manuscript and approved its final version for publication.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Filipe C. Serrano reports financial support was provided by Coordination of Higher Education Personnel Improvement. Joao Paulo dos Santos Vieira-Alencar reports financial support was provided by Coordination of Higher Education Personnel Improvement. Juan C. Diaz-Ricaurte reports financial support was provided by Coordination of Higher Education Personnel Improvement. Marcio Martins reports financial support was provided by State of Sao Paulo Research Foundation.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnc.2023.126350.

References

Bachman, S., Moat, J., Hill, A. W., De La Torre, J., & Scott, B. (2011). Supporting Red List threat assessments with GeoCAT: Geospatial conservation assessment tool. *ZooKeys, 150*, 117.

Brooks, T. M., Pimm, S. L., Akçakaya, H. R., Buchanan, G. M., Butchart, S. H. M., Foden, W., Hilton-Taylor, C., Hoffmann, M., Jenkins, C. N., Joppa, L., Li, B. V., Menon, V., Ocampo-Peñuela, N., & Rondinini, C. (2019). Measuring Terrestrial Area of Habitat (AOH) and Its Utility for the IUCN Red List. *Trends in Ecology and Evolution, 34*(11), 977–986. https://doi.org/10.1016/j.tree.2019.06.009

Cox, N., Young, B. E., Bowles, P., Fernandez, M., Marin, J., Rapacciuolo, G., Böhm, M., Brooks, T. M., Hedges, S. B., Hilton-Taylor, C., Hoffmann, M., Jenkins, R. K. B., Tognelli, M. F., Alexander, G. J., Allison, A., Ananjeva, N. B., Auliya, M., Avila, L. J., Chapple, D. G., Cisneros-Heredia, D. F., Cogger, H. G., Colli, G. R., de Silva, A., Eisemberg, C. C., Els, J., Fong, G. A., Grant, T. D., Hitchmough, R. A., Iskandar, D. T., Kidera, N., Martins, M., Meiri, S., Mitchell, N. J., Molur, S., Nogueira, C. C., Ortiz, J. C., Penner, J., Rhodin, A. G. J., Rivas, G. A., Rödel, M. O., Roll, U., Sanders, K. L., Santos-Barrera, G., Shea, G. M., Spawls, S., Stuart, B. L., Tolley, K. A., Trape, J. F., Vidal, M. A., Wagner, P., Wallace, B. P., & Xie, Y. (2022). A global reptile assessment highlights shared conservation needs of tetrapods. *Nature, 605*, 285–290. https://doi.org/10.1038/s41586-022-04664-7

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., … Saleem, M. (2017). An ecoregion-based approach to protecting half the terrestrial realm. *BioScience, 67*(6), 534–545. https://doi.org/10.1093/biosci/bix014

Ficetola, G. F., Rondinini, C., Bonardi, A., Katariya, V., Padoa-Schioppa, E., & Angulo, A. (2014). An evaluation of the robustness of global amphibian range maps. *Journal of Biogeography, 41*(2), 211–221. https://doi.org/10.1111/jbi.12206

Fiorillo, B. F., Maciel, J. H., & Martins, M. (2021). Composition and natural history of a snake community from the southern Cerrado, southeastern Brazil. *ZooKeys, 1056*, 95–147. https://doi.org/10.3897/zookeys.1056.63733

Feldman, A., Sabath, N., Pyron, R. A., Mayrose, I., & Meiri, S. (2016). Body sizes and diversification rates of lizards, snakes, amphisbaenians and the tuatara. *Global Ecology and Biogeography, 25*(2), 187–197. https://doi.org/10.1111/geb.12398

Fernandes, S. C. G., & Chaves, E. M. L. (2014). Iconografia de um projeto de Vital Brazil: considerações a respeito da Campanha Antiofídica do Instituto Butantan. *Cadernos de História da Ciência, 10*(1), 77–92.

Françoso, R. D., Brandão, R., Nogueira, C. C., Salmona, Y. B., Machado, R. B., & Colli, G. R. (2015). Habitat loss and the effectiveness of protected areas in the Cerrado Biodiversity Hotspot. *Natureza & conservação, 13*(1), 35–40. https://doi.org/10.1016/j.ncon.2015.04.001

Franklin, J. (2010). *Mapping species distributions Spatial interference and prediction.* Cambridge University Press.

Gaston, K. J. (2003). *The structure and dynamics of geographic ranges*. Oxford University Press.

Gaul, W., Sadykova, D., Roark, E., White, H. J., León-Sánchez, L., Caplat, P., & Yearsley, J. M. (2020). What have biological records ever done for us? A systematic scoping review. *Frontiers of Biogeography, 12*(4), e48607.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment.

Grande, T. O., Aguiar, L. M. S., & Machado, R. B. (2020). Heating a biodiversity hotspot: Connectivity is more important than remaining habitat. *Landscape Ecology, 35*, 639–657. https://doi.org/10.1007/s10980-020-00968-z

Isaac, N. J. B., & Pocock, M. J. O. (2015). Bias and information in biological records. *Biological Journal of the Linnean Society, 115*(3), 522–531. https://doi.org/10.1111/bij.12532

Kaplan, J. O., Krumhardt, K. M., & Zimmermann, N. (2009). The prehistoric and preindustrial deforestation of Europe. *Quaternary Science Reviews, 28*(27–28), 3016–3034. https://doi.org/10.1016/j.quascirev.2009.09.028

Klink, C. A., & Moreira, A. G. (2002). Past and current human occupation and land-use. In P. S. Oliveira, & R. J. Marquis (Eds.), *The Cerrado of Brazil. Ecology and natural history of a neotropical savanna* (pp. 69–88). New York: Columbia University Press.

IUCN (2021). The IUCN Red List of threatened species. Available at: https://www.iucnredlist.org. Accessed in 13-January-2021.

IUCN (2012). IUCN Red List Categories and Criteria: Version 3.1, second edition. Available at: https://portals.iucn.org/library/node/10315. Accessed in 11-January-2021.

IUCN & UNEP-WCMC (2015). The World Database on Protected Areas (WDPA), UNEP-WCMC, Cambridge, U.K. Available at: www.protectedplanet.net. Accessed September 2015.

Lomolino, M.V. (2004) Conservation biogeography. Frontiers of Biogeography: new directions in the geography of nature (ed. by M.V. Lomolino and L.R. Heaney). Sinauer Associates, Sunder- land, Massachusetts.

López, M. S., & Giraudo, A. R. (2008). Ecology of the snake *Philodryas patagoniensis* (Serpentes, Colubridae) from northeast Argentina. *Journal of Herpetology, 42*(3), 474–480. https://doi.org/10.1670/07-087.1

Mace, G. M., Collar, N. J., Gaston, K. J., Hilton-Taylor, C. R. A. I. G., Akçakaya, H. R., Leader-Williams, N. I. G. E. L., … Stuart, S. N. (2008). Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation biology, 22*(6), 1424–1442. https://doi.org/10.1111/j.1523-1739.2008.01044.x

MapBiomas. (2022). Collection of Brazilian land cover and use map annual series v.6.0. https://mapbiomas.org.

Mataveli, G. A., Chaves, M. E., Brunsell, N. A., & Aragão, L. E. (2021). The emergence of a new deforestation hotspot in Amazonia. *Perspectives in Ecology and Conservation, 19*(1), 33–36. https://doi.org/10.1016/j.pecon.2021.01.002

Mair, L., Bennun, L. A., Brooks, T. M., Butchart, S. H., Bolam, F. C., Burgess, N. D., … McGowan, P. J. (2021). A metric for spatially explicit contributions to science-based species targets. *Nature Ecology & Evolution, 5*(6), 836–844. https://doi.org/10.1038/s41559-021-01432-0

Moutinho, P., Guerra, R., Azevedo-Ramos, C., Kapuscinski, A. R., & Frumhoff, P. C. (2016). Achieving zero deforestation in the Brazilian Amazon: What is missing? Zero deforestation in the Brazilian Amazon. *Elementa: Science of the Anthropocene, 4*, Article 000125. https://doi.org/10.12952/journal.elementa.000125

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(6772), 853–858. https://doi.org/10.1038/35002501

Nogueira, C., Ribeiro, S., Costa, G. C., & Colli, G. R. (2011). Vicariance and endemism in a Neotropical savanna hotspot: Distribution patterns of Cerrado squamate reptiles. *Journal of Biogeography, 38*(10), 1907–1922. https://doi.org/10.1111/j.1365-2699.2011.02538.x

Nogueira, C., de, C., Argôlo, A. J. S., Arzamendia, V., Azevedo, J. A. R., Barbo, F. E., Bérnils, R. S., Bolochio, B. E., Borges-Martins, M., Brasil-Godinho, M., Braz, H., Buononato, M. A., Cisneros-Heredia, D. F., Colli, G. R., Costa, H. C., Franco, F. L., Giraudo, A. R., Gonzalez, R. C., Guedes, T. B., Hoogmoed, M. S., & Martins, M. (2019). Atlas of Brazilian Snakes: Verified Point-Locality Maps to Mitigate the Wallacean Shortfall in a Megadiverse Snake Fauna. *South American Journal of Herpetology, 14*(sp1), 1–274. https://doi.org/10.2994/sajh-d-19-00120.1

Pacheco, P., Mo, K., Dudley, N., Shapiro, A., Aguilar-Amuchastegui, N., Ling, P. Y., Anderson, C., & Marx, A. (2021). *Deforestation Fronts: Drivers and Responses in a Changing World*. Gland, Switzerland: WWF.

Powers, R. P., & Jetz, W. (2019). Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios. *Nature Climate Change, 9*(4), 323–329. https://doi.org/10.1038/s41558-019-0406-z

QGIS Development Team. (2022). *QGIS Geographic Information System*. QGIS Association.

Rabinowitz, D. (1981). Seven forms of rarity. In J. Synge (Ed.), *The Biological Aspects of Rare Plant Conservation* (pp. 205–217). Chichester: Wiley.

Rattis, L., Dobrovolski, R., Talebi, M., & Loyola, R. (2018). Geographic range-scale assessment of species conservation status: A framework linking species and landscape features. *Perspectives in ecology and conservation, 16*(2), 97–104. https://doi.org/10.1016/j.pecon.2018.01.001

Raxworthy, C. J., Martinez-Meyer, E., Horning, N., Nussbaum, R. A., Schneider, G. E., Ortega-Huerta, M. A., & Peterson, A. T. (2003). Predicting distributions of known and unknown reptile species in Madagascar. *Nature, 426*(6968), 837–841. https://doi.org/10.1038/nature02205

Resende, F. M., Cimon-Morin, J., Poulin, M., Meyer, L., Joner, D. C., & Loyola, R. (2021). The importance of protected areas and Indigenous lands in securing ecosystem services and biodiversity in the Cerrado. *Ecosystem Services, 49*, 101282. https://doi.org/10.1016/j.ecoser.2021.101282

Rosillo-Calle, F., & Cortez, L. A. (1998). Towards ProAlcool II—a review of the Brazilian bioethanol programme. *Biomass and Bioenergy, 14*(2), 115–124. https://doi.org/10.1016/S0961-9534(97)10020-4

Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V., & Woolmer, G. (2002). The human footprint and the last of the wild: The human footprint is a global map of human influence on the land surface, which suggests that human beings are stewards of nature, whether we like it or not. *BioScience, 52*(10), 891–904.

Serrano, F. C., Vieira-Alencar, J. P., dos, S., Díaz-Ricaurte, J. C., & Nogueira, C. D. C. (2020). Mapping local and regional distribution of *Lygophis paucidens* Hoge, 1952 (Serpentes, Dipsadidae), an elusive snake from the sandy savannas of Brazil and Paraguay. *Check List, 16*(1), 75–81. https://doi.org/10.15560/16.1.75

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., … Young, B. E. (2008). The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science, 322*(5899), 225–230. https://doi.org/10.1126/science.1165115

Scott, N., Cacciali, P., Silveira, A. L., Prudente, A. L. da C., Argôlo , A. J. S., Abrahão, C. R., Nogueira, C. de C., Barbo, F. E., Costa, G. C., Pontes, G. M. F., Colli, G. R., Zaher, H., Borges-Martins, M., Martins, M. R. C., Oliveira, M. L., Passos, P. G. H., Bérnils, R. S., Sawaya, R. J., Cechin, C. T. Z & da Costa, T. B. G. (2020). *Philodryas livida*. The IUCN Red List of Threatened Species 2020: e.T177436A68236052 Doi: 10.2305/IUCN.UK.2020-3.RLTS.T177436A68236052.en. Downloaded on 17 August 2021.

Smith, P., Atkinson, K., Brouard, J. P., & Pheasey, H. (2016). Reserva Natural Laguna Blanca, departamento San Pedro: Paraguay's first Important Area for the Conservation of Amphibians and Reptiles? *Russian Journal of Herpetology, 23*(1).

Smith, P., Cacciali, P., Scott, N., del Castillo, H., Pheasey, H., & Atkinson, K. (2014). First record of the globally-threatened Cerrado endemic snake Philodryas livida (Amaral, 1923)(Serpentes, Dipsadidae) from Paraguay, and the importance of the Reserva Natural Laguna Blanca to its conservation. *Cuadernos de herpetología, 28*(2), 169–171.

Strassburg, B. B., Brooks, T., Feltran-Barbieri, R., Iribarrem, A., Crouzeilles, R., Loyola, R., … Balmford, A. (2017). Moment of truth for the Cerrado hotspot. *Nature Ecology & Evolution, 1*(4), 1–3. https://doi.org/10.1038/s41559-017-0099

Thomas, R. A., & Fernandes, R. (1996). The systematic status of Platyinion lividum Amaral, 1923 (Serpentes: Colubridae: Xenodontinae). *Herpetologica*, 271–275.

Thompson, P. L., Rayfield, B., & Gonzalez, A. (2017). Loss of habitat and connectivity erodes species diversity, ecosystem functioning, and stability in metacommunity networks. *Ecography, 40*, 98–108. https://doi.org/10.1111/ecog.02558

Upchurch, P., & Hunn, C. A. (2002). "Time": The neglected dimension in cladistic biogeography? *Geobios, 35*, 277–286. https://doi.org/10.1016/S0016-6995(02)00065-7

Valdujo, P. H., Nogueira, C. C., Baumgarten, L., Rodrigues, F. H. G., Brandão, R. A., Eterovic, A., Ramos-Neto, M. B., & Marques, O. A. V. (2009). Squamate reptiles from Parque Nacional das Emas and surroundings. *Cerrado of Central Brazil. Check List, 5* (3), 405–417.

Wallace, A. R. (1852). On the Monkeys of the Amazon. Proceedings of the Zoological Society.

Williams, B. A., Venter, O., Allan, J. R., Atkinson, S. C., Rehbein, J. A., Ward, M., … Watson, J. E. (2020). Change in terrestrial human footprint drives continued loss of intact ecosystems. *One Earth, 3*(3), 371–382. https://doi.org/10.1016/j.oneear.2020.08.009

Wilson, R. J., Thomas, C. D., Fox, R., Roy, D. B., & Kunin, W. E. (2004). Spatial patterns in species distributions reveal biodiversity change. *Nature, 432*(7015), 393–396.

Zizka, A., Antunes Carvalho, F., Calvente, A., Rocio Baez-Lizarazo, M., Cabral, A., Coelho, J. F. R., Colli-Silva, M., Fantinati, M. R., Fernandes, M. F., Ferreira-Araújo, T., Gondim Lambert Moreira, F., Santos, N. M. C., Santos, T. A. B., dos Santos-Costa, R. C., Serrano, F. C., Alves da Silva, A. P., de Souza, S. A., Cavalcante de Souza, P. G., Calisto Tomaz, E., Vale, V. F., Vieira, T. L., & Antonelli, A. (2020). No one-size-fits-all solution to clean GBIF. *PeerJ, 8*, e9916.