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Conservation priority sites for reptiles in the Sierra Madre del Sur with a perspective for the future

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ABSTRACT

Introduction: Reptiles are often overlooked when planning for conservation, as they are typically perceived as a persistent or tolerant group. Nonetheless, recent studies have shown their vulnerability. Identifying priority areas is crucial, and spatial prioritization is an essential analysis to optimize the scarce available resources for conservation. Furthermore, it is of the utmost importance to establish protected area networks that would keep their usefulness in the future, especially considering the enormous environmental changes that are currently occurring.
Objectives: To evaluate the performance of the current protected area network (PA) and to identify potential areas for expansion, considering their persistence in time.
Methods: We estimated species distributions for 177 reptiles on the Sierra Madre del Sur in Southeastern Mexico. The species were weighed according to their international conservation status, and future land use scenarios were incorporated to identify priority areas with Zonation software.
Results: We found coincidences between priority areas for reptiles and zones previously identified for other groups. However, most regions with top priority rankings remain unprotected, considering the current established PA. Federal PA protects the highest percentage of priority areas, followed by areas voluntarily dedicated to conservation and state PA. We emphasize conserving natural land uses since they are the only ones that constitute the highest priority zones for reptiles.
Conclusions: Our prioritization for reptile conservation entails efficient outcomes in terms of temporal permanence, amount of area to be protected, and coverage of species distribution, especially for small percentages of expansions to the current network of PA, making it an affordable proposal for implementation. Nonetheless, it is crucial to recognize that it is also important to consider social factors, possible conflicts of interest, and to evaluate the effectiveness of PA over time.

Key words: land use, Mexico, protected areas, spatial conservation, species distribution models, Zonation.

RESUMEN

Prioridad de sitios de conservación para reptiles en Sierra Madre del Sur con una perspectiva hacia el futuro

Introducción: Los reptiles suelen ser olvidados cuando se planifica la conservación, ya que son considerados un grupo persistente o tolerante. Sin embargo, estudios recientes han demostrado su vulnerabilidad. Identificar áreas prioritarias es crucial, y la priorización espacial es un análisis esencial para optimizar los escasos recursos disponibles para la conservación. Además, es de suma importancia establecer redes de áreas protegidas que mantengan su funcionalidad en el futuro, especialmente considerando los enormes cambios ambientales que se están presentando en la actualidad.

Objetivos: Evaluar el desempeño de la red actual de áreas protegidas (AP) e identificar áreas potenciales de expansión contemplando su persistencia en el tiempo.

Métodos: Estimamos la distribución de 177 especies de reptiles en la Sierra Madre del Sur, en el sur de México. Las especies fueron ponderadas según su estado de conservación nacional e internacional, y se incorporaron escenarios futuros de uso del suelo para identificar áreas prioritarias con el software Zonation.

Resultados: Encontramos coincidencias entre áreas prioritarias para reptiles y zonas previamente identificadas para otros grupos. Sin embargo, la mayoría de las regiones con clasificación de máxima prioridad siguen desprotegidas considerando las AP actualmente establecidas. Las AP federales protegen el mayor porcentaje de áreas prioritarias, seguidas por las áreas dedicadas voluntariamente a la conservación y las AP estatales. Hacemos énfasis en conservar los usos naturales del suelo ya que son los únicos que constituyen las zonas de mayor prioridad para los reptiles.

Conclusiones: Nuestra priorización para la conservación de reptiles implica resultados eficientes en términos de permanencia temporal, cantidad de área a proteger y cobertura de distribución de especies, especialmente para pequeños porcentajes de expansiones de la red actual de AP, lo que la convierte en una propuesta asequible para su implementación. Es crucial reconocer que también es importante considerar factores sociales, posibles conflictos de intereses y evaluar la efectividad de las AP a lo largo del tiempo.

Palabras clave: uso del suelo, México, áreas protegidas, conservación espacial, modelos de distribución de especies, Zonation.

INTRODUCTION

Reptiles are usually forgotten when planning for conservation as they are normally seen as a persistent or tolerant group (Vitt & Caldwell, 2014). Nonetheless, recent studies have shown their vulnerability not only to climate change (Sinervo et al., 2010) but also to land use change (Cox et al., 2022). Reptiles are considered to be the second most abundant vertebrate group in tropical environments after amphibians (de Miranda, 2017). Therefore, given their ecological importance in the ecosystems (e.g., nutrient cycling, seed dispersal, energy flow; Cortés-Gomez et al., 2015), it is of crucial importance to conserve them (de Miranda, 2017).

Mexico is the second country with the highest reptile species richness in the world after Australia, with 1 073 species, and has high levels of reptile endemism, since above 50 % of the species are endemic (558 species; Suazo-Ortuño et al., 2023). Curiously it also has been shown, that are least for Mexico, reptile species have smaller distribution ranges than amphibians (Koleff et al., 2008) and that mountains harbor the highest reptile richness in the country (Ochoa-Ochoa et al., 2014). The latter is not a new concept since, for a long time, mountainous regions have been considered as reservoirs for biodiversity not only for reptiles but in general for all terrestrial organisms, probably due to their topographic and environmental heterogeneity (Perrigo et al., 2020; Rahbek et al., 2019). The Sierra Madre del Sur (SMS) is a complex mountainous region in the Southeast portion of the country, and it is expected to have up to 280 species of reptiles, with approximately 211 being endemic to Mexico (Flores-Villela & Ochoa-Ochoa, 2016; Johnson et al., 2017; García-Padilla et al., 2020; Ríos-Solís et al., 2022; Ramírez-Arce et al., *under review*; see SMT1 and SMT2). This region, nevertheless, has been affected by land use change and it is expected to have large deforestation rates in the near future, with reptiles being highly vulnerable to these changes (Mendoza-Ponce et al., 2020).

In terms of species diversity, geographical-temporal knowledge of the species is still scarce (Hortal et al., 2015), and in the SMS the knowledge is particularly scarce as can be seen in the locality records that exist for the zone and the few studies listing species list or inventories in the region (SMT1 and SMT2). Therefore, a large part of the SMS area does not have any biological records, or it is under-sampled (i.e., has very few, and in general, opportunistic records). For this reason, the estimation of distribution areas is a fundamental resource to fill existing information gaps particularly when developing conservation plans (see for example Camarena-Hérnandez et al., 2023). Therefore, species distribution modeling (SDM) has been widely used to account for the lack of sampling in order to estimate species distribution, since its beginnings in the mid-1980s (Peterson et al., 2011).

The modeling process has been accompanied by the development of ecological niche theory and methodological strategies (Peterson & Soberón, 2012; Soberón et al., 2017) to try to reproduce the complex interactions (e.g., biological, historical) that actually shape the species distribution areas. Several algorithms have been developed trying to reproduce those interactions (Elith & Graham, 2009; Elith & Leathwick, 2009). In this sense, the SDM generation process consists of the association of ecological variables to the records of the species and their projection in geographical space to recognize where the conditions are suitable for them (Ochoa-Ochoa & Ríos-Muñoz, 2019; Ríos-Muñoz & Espinosa-Martínez, 2019). It is important to stress that there is no consensus, to our knowledge, of which is the best algorithm or the best procedure to generate an SDM. However, to explore potential areas for conservation it is essential to fill those distributional gaps.

In the year 2000, the National Commission of Protected Natural Areas (Comisión Nacional de Áreas Naturales Protegidas, CONANP) was created, as an institution aimed at consolidating protected areas (PA) (Comisión Nacional de Áreas Naturales Protegidas, [CONANP], 2018). In Mexico, as in many other countries, there are different categories of PA, governmental and private PA. The first ones include Federal, State, and Municipal PA whose characteristic is that they are established by the government (hence their name) and, in general, there is a hierarchy not only in terms of area but also in terms of assigned resources, with the federal ones being the largest and with the most resources. The private areas are named Areas Voluntarily Designated for Conservation (AVDC), in this case any landowner can declare and register her or his land to be under protection, however, these areas do not receive government funds. It is worth emphasizing that all the PAs are acknowledged by CONANP.

The establishment of the Aichi 2011-2020 goals of the Convention on Biological Diversity (Convention on Biological Diversity, [CBD], 2010; CBD, 2021) highlighted PA as a fundamental mechanism in conservation (CONANP, 2018). Although, in recent years, a significant number of PA have still been decreed, the paradigms that underlie their application and management face new socioeconomic contexts. The SMS is no exception and despite the enormous biological diversity and endemic species it has, there are few established PA, with only eight (CONANP, 2024) with a coverage percentage of less than 10 %, although it is also important to highlight that there has recently been decreed another large PA, Sierra de Tecuani. Nevertheless, not only is it essential to establish new protected areas to conserve biodiversity in the long term but also to assess the value, as tools for conservation, of the current PA, particularly when facing enormous environmental changes that are currently occurring and will continue to occur in the near future (IPCC., 2023).

Spatial prioritization for species diversity conservation is the most important objective within systematic conservation planning (SCP), because the allocation of resources must be truly efficient (Margules & Pressey, 2000). SCP can also assist in locating other land uses, based on computational tools, but the key aspect is that such prioritization must be ecologically informed (Pressey et al., 2007). SPC methods have evolved to organize various cost factors and increase ecological reality by implementing methods to address species-specific connectivity and uncertainty, and also by implementing more complex computer programs that can address larger landscapes and a wide variety of data types (Kukkala & Moilanen, 2013), as well as the possibility of including the permanence over time of selected areas given a projection of change, whether climatic or coupled with land use changes (Moilanen et al., 2022).

In this work we set out to find the most priority sites for reptile conservation within the SMS taking into account the current established network of protected areas and establishing a network of priority conservation sites using different threat layers as costs, therefore penalizing areas with many threats, and taking also into account land use change models to project possible scenarios into the future with different socioeconomic pathways trajectories. Finally, we evaluated the coincidence of the priority sites with the protected areas in Mexico by performing a gap analysis. Since priority analysis is based on species richness and rarity, we hypothesize that priority sites will occur in the areas with the highest reptile species occurrence.

MATERIAL AND METHODS

Estimation of species distribution areas and conservation status. A list of reptile species was compiled through a bibliographic database search (SMT1 and SMT2). All species names were taxonomically refined to avoid counting twice the same species that have been classified in different ways in the literature consulted and in biological collections. This depuration consisted of updating the taxonomy of each species according to the criteria of Uetz et al. (2024). Additionally, we classified species according to their IUCN conservation category (IUCN, 2023) as follows: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least concern (LC), Data Deficient (DD), and Not Evaluated (NE); and by its conservation category according to the Norma Oficial Mexicana NOM-059-SEMARNAT-2010 (SMT1).

Maxent algorithm (Phillips et al., 2006) was used to generate the SDM, and only those species with at least 10 presence data were taken into account in the models (Guisan et al., 2017). The data was divided into training data (70 %) and internal validation data (30 %) (Beck et al., 2014). The kuenm R package (Cobos et al., 2019) was used, which generates several candidate models using all the possible parameterizations from different sets of environmental variables, different regularization multipliers, and different combinations of features such as linear, quadratic, and product, among others. We used the 19 bioclimatic variables from CHELSA (Karger et al., 2017) between the period of 1979 and 2013 at a resolution of ~1 km 2 as predictor variables, and from these, three data sets were used: 1) variables chosen from correlation analysis, 2) variables chosen from VIF analysis, and 3) variables presenting a cumulative importance value of 95 % from an initial model run with default settings in Maxent using all 19 bioclimatic variables (Sillero et al., 2021; Simões et al., 2020). Eight regularization values: 0.1, 0.4, 0.7, 1, 2, 3, 4, 5; and five combinations of features were used, using only linear, quadratic and hinge, because most species had less than 80 presence data (Elith et al., 2011; González-Fernández et al., 2018; Merow et al., 2013): linear, quadratic, hinge, linear x quadratic, and linear x quadratic x hinge. This generated a total of 120 candidate models per species. The choice of the best model was made using the following criteria: 1) significant models (using partial ROC) with omission rates ≤ 5 %, and 2) models with ΔAICc values ≤ 2 (Cobos et al., 2019). The best models for some species were significant, but with an omission rate > 5 %, therefore best models used were those with the lower omission rate and ΔAICc ≤ 2, acknowledging that the latter metric is not the most reliable (Velasco & González-Salazar, 2019).

The final models were built with the parameterization of the best model, using logistic output for better interpretation. From the suitability maps obtained with the final models, binary presence/absence maps were obtained to use them in subsequent analyses. For this, a convergence threshold of 10-5 and

500 iterations for each species was used (Phillips et al., 2006), and the 'Maximum training sensitivity plus specificity' was used as a convergence rule since it is a convergence threshold suitable when only presence data is available (Liu et al., 2013, Liu et al., 2016). All models were generated in R 3.5.0 (R Core Team, 2018).

Spatial prioritization. To select priority conservation areas, the Zonation 5 software was used as the most updated version of the software (Moilanen et al., 2022). This software produces a balanced and complementary categorization of areas, maximizing the occurrence of species and considering different "penalty" variables (Di Minin & Moilanen, 2014). Zonation 5 produces a hierarchical prioritization of the landscape, as it iteratively classifies and eliminates cells according to the presence of species, connectivity, and complementarity of areas (Moilanen et al., 2022). The prioritization was made considering the entire SMS area to evaluate the performance of PAs in protecting reptiles. The marginal loss rule, Core Area Zonation 2 (CAZ2), was used, which emphasizes the high average cover of species, tending to improve the cover of species with the worst performance (Moilanen et al., 2022).

For prioritization analyses, 177 reptile species, and a 2016 land use cover layer (1:250 000) (INEGI, 2016), were included. To ensure the persistence over time of the priority areas, we also incorporated three models of land use change projected for 2060: "Business As Usual" (BAU), the green, and the worst-case scenario. The BAU scenario uses Shared Socioeconomic Pathway 2 (SSP2) assumptions defined as 'middle of the road', in which social, economic, and technological trends do not change markedly from historical patterns, and climate data from gas concentration path 4.5 (RCP4.5); the green scenario considers a sustainable path and uses socioeconomic data from SSP1 and climate variables RCP4.5 and RCP2.6. Finally, the worst scenario, considering the highest historical deforestation rates, as well as consumerist and unequal social trends, combines the data from SSP3 and RCP8.5 (Mendoza-Ponce et al., 2018). Land use layers were reclassified into two classes, natural and anthropogenic. Anthropogenic land use layers were negatively weighed to remove those cells first in the prioritization process while allowing those sites to still be considered during the planning process. We simultaneously use the current land use layer and the three future scenarios to obtain a conservative priority area estimation. In other words, we wanted to ensure that in any given scenario of land use change or socioeconomic pathway, the selected priority areas were supposed to persist, therefore if a site is selected in the prioritization, it is due that in any scenario (BAU, green or worse) said area will remain with a natural land use, ensuring reptile diversity conservation in the long-term.

Species layers were weighted according to their IUCN category (IUCN, 2023) as follows: CR, 5; EN, 4; VU, 3; NT, 2; LC, 0; DD, 1; and NE, 1. We used only the IUCN categorization as most species were not included in the Norma Official Mexicana NOM-059-SEMARNAT-2010 (SMT1). Weight values were assigned so that the sum of the negative and positive weights equals zero, allowing a balanced solution for prioritization (Moilanen et al., 2011; Ramírez-Albores et al., 2016). A priority map and performance curves were made (Fig. 1 and Fig. 2, respectively), to explore the results.

Protected areas network evaluation. For the evaluation of the PAs, we estimated the proportion of the highest priority areas that are under current protection (Table 1). We also calculated the prevalence of land use types present in the highest priority areas accounting for different scenarios (Table 2). This was done to identify important land uses for the conservation of reptiles within the SMS. We considered 17 % of Aichi goal 11 (CBD, 2010) given that within the SMS, several PAs are still far from that goal. We also considered 30 % to reduce threats to biodiversity by 2030 (CBD, 2021) because these targets must be seen to increase areas towards a higher long-term global target (Larsen et al., 2015), and because Mexico is a signatory country of those agreements.

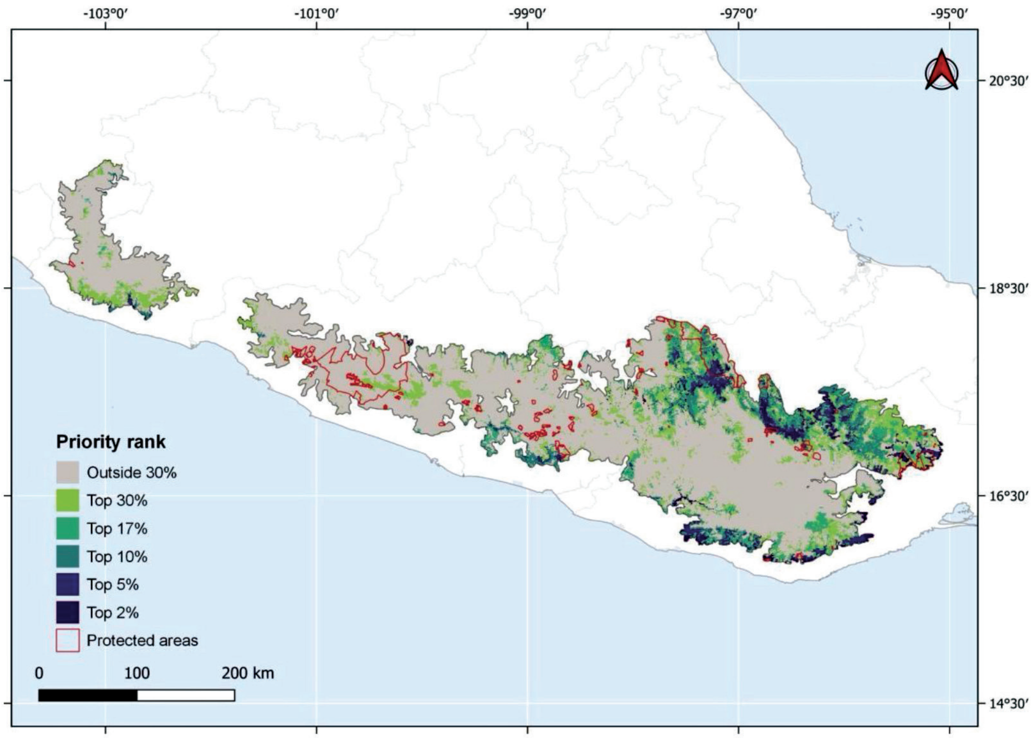

Fig. 1. Priority rank map for reptile conservation. The map is the result of one Zonation run with CAZ2 as a marginal loss rule considering the entire area of the SMS. The current PA have red borders to visualize their coincidence with the most important priority areas for reptiles.

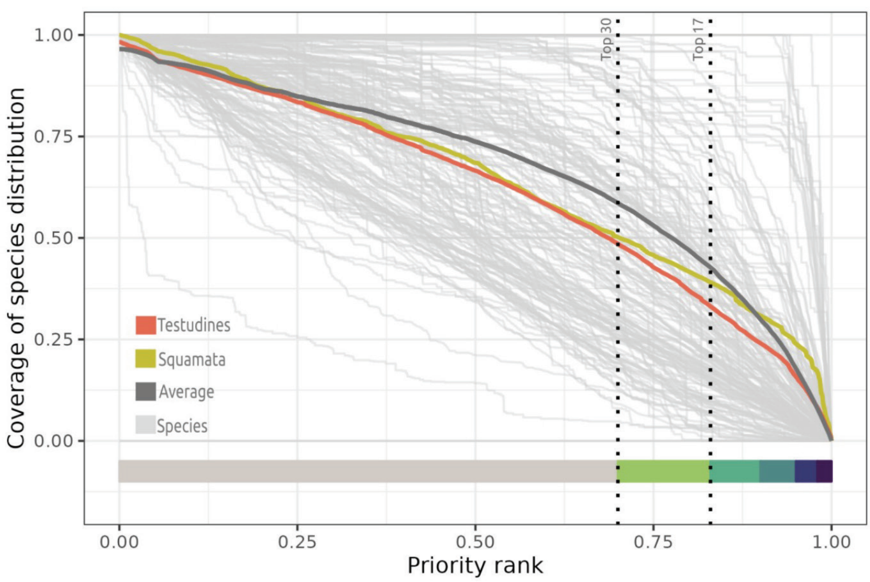

Fig. 2. Zonation performance curves illustrate the relationship between the loss of priority rank areas across the landscape (x-axis) and the corresponding decrease in species distribution coverage (y-axis).

Table 1
Protected Area network evaluation. Percentages of areas under protection are shown for each priority range.

Top Priority (%)	Total area (km^2)	Area inside FPAs (km^2)	Area inside SPAs (km^2)	Area inside AVDCs (km^2)	Area under protection (km^2)	Percentage inside FPAs (%)	Percentage inside SPAs (%)	Percentage inside AVDCs (%)	Total percentage under protection (%)
2	875	87.6	2.4	52.2	142.2	10	0.3	5.9	16.2
5	2 204.1	281.2	3.2	149.4	433.9	12.7	0.1	6.7	19.6
10	4 466.1	503.8	8.8	216.1	728.8	11.2	0.2	4.8	16.3
17	7 741.4	757.7	15.2	226.6	999.6	9.7	0.2	2.9	12.9
30	1 4214.8	1225.4	17.6	331.06	1574.1	8.6	0.1	2.3	11.07
50	25 489.5	2217.8	23.3	646.05	2887.1	8.7	0.09	2.5	11.3
80	48 106.4	4084.4	54.6	940.9	5080	8.4	0.1	1.9	10.5
100	87 024.1	6490.3	106.06	1 436.7	8 033.1	7.4	0.1	1.6	9.2

A distinction is made between Federal Protected Areas (FPAs), State Protected Areas (SPAs) and Areas Voluntarily Designated for Conservation (AVDC).

Table 2
Land use in top priority areas. Percentages by vegetation types are shown for each priority range.

Land use	Top 30 % percentage	Top 17 % percentage	Top 10 % percentage	Top 5 % percentage	Top 2 % percentage
Temperate forest	52.3	51.5	57	59.2	36.3
Cloud forest	12.8	0	0	0	0
Tropical Dry Forest	26	33.6	29.8	40.7	63.6
Other natural vegetation	0.5	0.2	0	0	0
Pasture	4.2	7.2	7.5	0	0
Seasonal Agriculture	3.9	7.2	5.7	0	0
Irrigated Agriculture	0.08	0.2	0	0	0

Land use classification follows Mendoza-Ponce et al. (2018).

The first four correspond to natural land use types and the last three to anthropized environments.

RESULTS

Estimation of species distribution areas and conservation status. We generated binary maps of 177 species from two orders: four Testudines and 173 Squamata. Regarding the risk status of the species, according to the IUCN, 21 species are classified as Threatened (VU = 6, EN = 3, CR = 12), only two as Near Threatened (NT), 148 as Least Concern (LC) and 5 as Data Deficient (DD).

Spatial prioritization. The priority rank map (Fig. 1) displays the following top priority areas: 30, 17, 10, 5, and 2. The latter were selected through CAZ2 as a marginal loss rule, allowing for the identification of areas that better account for reptile conservation, emphasizing high average coverage of all species even with the worst-off ones (Moilanen et al., 2022). The top priority areas are in or near the following mountain chains: Sierra de Ixtlán, Sierra de Tlaxiaco, Sierra de Coalcomán, and Sierra de Valadez. The Northeast, Southeast (Oaxaca), and a small fraction of the Southwest (Jalisco) of the SMS also stand out. Interestingly, most of

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the top priority areas are found near the limits of the SMS.

Performance curves summarize the conservation coverage achieved in each top priority fraction (Fig. 2) from the priority rank maps. Specifically, mean performance curves allow an overall evaluation of prioritization, while order-level curves enable the detection of the detailed prioritization behavior by retaining taxonomic resolution. When considering average performance, the top 30 areas cover 58 % of the average reptile species distribution. Protecting the top 17 areas covers over 40 %, while the top 10 covers more than 29 %, and the top 5 covers more than 17 %. Notably, the top 2 areas are the most efficient, covering 8 % of the species distribution with the smallest area to be protected. If we focus on reptile orders separately, it is possible to observe that overall performance curves were slightly better for turtles. For example, if we consider the top 5 in terms of protection, for testudines, 23 % of species distribution would be covered, while for lizards, it would be only 15 %.

Finally, at the species level, *Salvadora lemniscata* demonstrated the best performance curve in prioritization, requiring the least amount of protected landscape area to cover its distribution. Conversely, *Aspidocels communis* showed the poorest performance, requiring most areas to be protected to cover its distribution.

Protected areas network evaluation. Comparing the prioritization areas and the current PA network (Table 1) revealed that less than 10 % of the total area of the SMS is currently protected. Surprisingly the current PA network protects only 11 % of the top 30 % priority areas, the equivalent of 1 574 km^2 out of the entire 87 024.1 km^2. In contrast, if we consider increasingly less inclusive top areas, we can see that the protection percentage increases. For example, in the top 17, almost 13 % of the area is protected, for the top 10, more than 16 % is protected, and for the top 5, almost 20 % is protected. On the other hand, this trend is not maintained for the top 2, where 16.2 % of the area is protected. Generally, we can see that the percentages of PA across the different areas top are low, with the top 5 being the best protected in proportion. This indicates a mismatch between the current PA network and the priority areas for reptiles in the SMS, leaving many areas unprotected, which may lead to negative consequences for the conservation of this group.

If we take into account the efficiency of each type of protected area, it can be observed that their contribution varies for each priority range of areas, with federal PA protecting the greatest amount of area, followed by AVDC, and lastly by state PA. For example, for the top 5 priority sites, the federal PA keeps 12.7 %, the state PA only 0.1 %, and the AVDC 6.7 %. Federal PAs contribute the most to the protection of reptiles, which implies that the organisms are under the application of the PA management plans and the administration of CONANP. On the other hand, we highlight the importance of the AVDCs in the protection of reptiles, since it indicates that the people will have a greater impact on the protection of these areas than that of the state PA.

From quantifying the proportion of land use into each priority top area, we can observe that most of the priority areas are occupied by natural use types (Table 2). Across almost all priority thresholds (top 17 to top 2), temperate forests stand out as the most prevalent land use, accounting for more than 50 % of coverage, followed by tropical dry forests ranging from 29.8 to 63.6 % and pasture and seasonal agriculture covering < 10 %. If we focus on the top 30, we can see that the cloud forest emerges as the third most important land use. In general, zones with natural land uses are more prevalent in priority areas, with the lone exception of pasture and seasonal agriculture but, as mentioned before, with a very low percentage. We highlight that the top 5 and 2 have only natural land uses, temperate and tropical dry forests.

DISCUSSION

Estimation of species distribution areas and conservation status. Our findings show that a large proportion of the reptile species in the SMS are classified as Least Concern, probably maintaining the idea that reptile species are indeed tolerant to environmental changes; however, as mentioned before, this idea is changing particularly when a view to global warming is taken into account (e.g., Sinervo et al., 2010) since the environmental temperature can affect sex-ratio in reptile populations. For example, Sinervo et al. (2024) using ecophysiological models showed that a high proportion of the studied species could be at risk under global warming scenarios but that extinctions may be attenuated in forested sites and by the presence of montane environments in contemporary ranges. Although a study with a wide-range desert lizard *Dipsosaurus dorsalis*, using also ecophysiological models, showed that this lizard, and probably others, are resilient to global warming (Lara-Resendiz et al., 2019). Another aspect that is crucial to take into account is the habitat preferences of reptile species since it is evident when sampling conserved versus modified sites that most reptiles are not generalists (Doherty et al., 2020; Gardner et al., 2007). Therefore, it is important to not generalize on one side or another but also to reconsider all threats within the conservation assessments (Arroyo-Rodríguez et al., 2020; Cordier et al., 2021; Cox et al., 2022). In this sense, many species may be misclassified as Least Concern according to the IUCN, when they may be in a higher category of risk.

Spatial prioritization. It is not surprising to observe that priority sites (Fig. 1) mostly coincide with the areas of greatest reptile richness (Fig. 3), since the algorithm that selects priority sites is based on species number and spatial rarity of those species (Lehtomäki & Moilanen, 2013), thus our hypothesis is partially fulfilled. In the easternmost part of the SMS only the Southern part was included in the top priority sites, probably to minimize the area selected. On the other hand, there is not much congruence between the priority sites for amphibians (Fuentes-de la Rosa et al., 2024) and the ones found for reptiles. This makes sense as both groups may respond differently to climate or land use change (e.g., Cordier et al., 2021) and their diversity distribution may be different along the SMS region (Fuentes-de la Rosa et al., 2024). The few priority sites among amphibians and reptiles in the SMS include from west

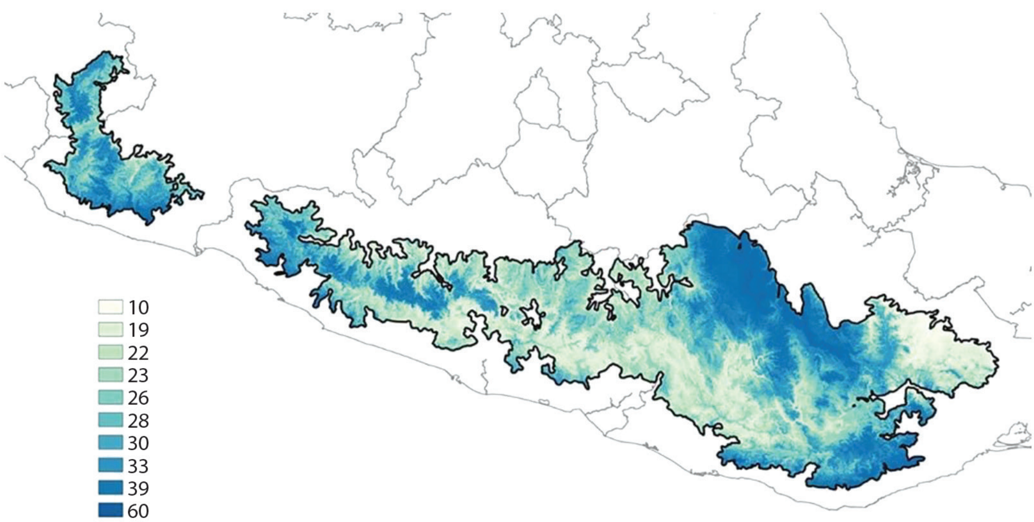

Fig. 3. Reptile richness pattern for Sierra Madre del Sur (SMS) based on Species Distribution Models.

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to East: Sierra de Coalcomán in Michoacán; Sierra de Tecuani in Guerrero; the area around Putla de Villa in the limits of Guerrero and Oaxaca; the area between Sierra de Juárez and Cerro Yatin, North of the city of Oaxaca; the area around Juquila and Pluma Hidalgo; and finally, the area around Santa María Ecatepec and San Lorenzo Jilotepequillo, in the state of Oaxaca. Curiously, the most recently decreed PA Sierra de Tecuani does coincide with the top priority sites found for amphibians (Fuentes-de la Rosa et al., 2024) but barely for reptiles, only a small area belonging to the top 30. Sierra de Juárez has long been considered a special case due to the vast richness and the huge number of range-restricted species that inhabit the area not only for amphibians and reptiles but in several groups (e.g., Hernández-Rojas et al., 2018; Luis-Martínez et al., 2020; Rovito et al., 2012). The unique priority areas found for reptiles are, again from West to East: the area around El Parotal, in Michoacán; the region West Tierra Colorada and the mountain range between Ayutla de los Libres and San Luis Acatlán; and finally, around Tomatepec in Guerrero.

Protected areas network evaluation. Even including the newly decreed PA Sierra de Tecuani (Diario Oficial de la Federación, 2024), there are few coincidences between PA and the priority areas found for reptiles in the SMS. It has been long known that SMS was not an area of much interest in conservation plans or investment due to various factors such as drug production problems and social conflicts (including intentional abandonment by previous governments, both federal and state), fortunately, this attitude seems to be changing.

The SMS region is still far from achieving international conservation agendas (17.30 % of the territory). However, a small proportion of extra conserved areas targeted through prioritization methods can give more efficient conservation outcomes in terms of resources and species protection. But the most important aspect is that it is affordable for implementation.

Federal protected areas have the greatest contribution to conserving the priority sites found in the analysis, highlighting the recent increase in the protected areas belonging to this category such as the Sierra Tecuani Biosphere Reserve (Diario Oficial de la Federación, 2024). This is not surprising given the size of the federal PA. However, it is notorious and of great importance that private areas or ADVC are in the second place of protected areas. The importance of these areas has been previously noted for amphibians (Ochoa-Ochoa et al., 2009). Nonetheless, this category of PA is tricky since it can be withdrawn as the owner of the land wishes.

Conservation of temperate forests and tropical dry forests is essential to ensure the long-term maintenance of the SMS reptiles since most priority areas were occupied by these land use covers (Table 2). Additionally, a recent study suggests that both types of forests may host high reptile taxonomic and functional diversity in many areas along the SMS, particularly temperate forests (Ramírez-Arce et al., *under review*). On the other hand, grasslands or seasonal crops may seem to be important land uses for some reptiles, as a small percentage of priority areas were occupied by these (Table 2). This may be true for some generalist species that can adapt and take advantage of these disturbed environments (e.g., Berriozabal-Islas et al., 2017; Urbina-Cardona et al., 2006). Additionally, the incorporation of future layers may allow the possibility of regeneration of these environments, which could favor the return and/or permanence of the reptiles. Nevertheless, it is important to take into consideration that SDMs and spatial prioritization were based solely on climatic variables, therefore, some priority areas may be climatically suitable areas, but with land use covers (i.e. perturbed land uses) that are harsh for most species.

Most reptiles tend to be vulnerable to land use change (Cordier et al., 2021; Gardner et al., 2007). For example, several studies at different scales of analysis agree that urbanization and agricultural intensification reduce overall reptile diversity (e.g., Barnagaud et al., 2020; García-Llamas et al., 2019; Leavitt & Fitzgerald, 2013) and that the prevalence of large forested areas is essential for many species, especially those with specialized habits (e.g., arboreal or scansorial; Palmeirim et al., 2021). Land use change also may reduce the number of functional groups, having negative repercussions on ecosystem processes and services (Newbold et al., 2020). Although some studies suggest that reptiles can respond positively to perturbed land uses, this may be true only for some generalist species and for perturbed land uses with greater structural complexity (Mendenhall et al., 2014) and less contrast with the natural land use covers (Deans & Chalcraft, 2017). Therefore, most reptiles are probably not resistant to environmental change and may be at high risk of extinction in several areas of the SMS in the future (for example, Ramírez-Arce et al., *under review*). Given the land use transformation rate occurring within the SMS, reptiles are probably disappearing faster than their incorporation into national conservation agendas without even considering the description of new species. Therefore, conservation of remaining natural land covers along the SMS, such as temperate and tropical dry forests, is essential.

Spatial prioritization for conservation is essential to propose new areas to achieve conservation objectives, especially those acquired as a signatory country of international agreements such as the Aichi goals. However, it is important to consider the limitations of the spatial prioritization proposed here and to explore possible new approaches so that it is ecologically and socially realistic. Particularly, considering that as shown previously there seems to be little overlap among prioritizations with different biological groups, therefore implementing each prioritization would result in unachievable, and second, the grain used here is around one square kilometer, which is a huge area to begin with. Therefore, if it is not possible to protect all priority sites, other kinds of strategies derived from these results could be of great importance like small-scale corridors within the top priority sites. Finally, it is important to recognize this tool as part of a larger framework within Systematic Conservation Planning. That is why proposals for implementation, monitoring, and evaluation must also be considered to achieve conservation objectives.

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See supplementary material
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