UNIVERSIDADE FEDERAL DE SÃO CARLOS
FUNDAÇÃO PARQUE ZOOLÓGICO DE SÃO PAULO
PROGRAMA DE PÓS-GRADUAÇÃO EM CONSERVAÇÃO DA FAUNA

SÓSTENES JOSÉ SOUZA PELEGRINI

Considerando alterações climáticas na escolha de áreas para conservação de serpentes na Região Hidrográfica Tocantins-Araguaia

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Dissertação apresentada ao Programa de Pós-Graduação em Conservação da Fauna, para obtenção do título de mestre profissional em Conservação da Fauna.

Orientador: Prof. Dr. Vinícius de Avelar São Pedro

Co-orientadora: Profa. Dr. Priscila Lemes

SÃO CARLOS
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Folha de Aprovação

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Certifico que a defesa realizou-se com a participação à distância do(s) membro(s) Tiago da Silveira Vasconcelos e, depois das arguições e deliberações realizadas, o(s) participante(s) à distância está(ao) de acordo com o conteúdo do parecer da banca examinadora redigido neste relatório de defesa.

Prof. Dr. Vinícius de Avelar São Pedro

Dedico esta dissertação a minha avó Benedita, um exemplo para mim, sem dúvidas uma das melhores pessoas que conheci.

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Prefácio

Esta dissertação é composta por um único capítulo em formato de artigo. Nele investigamos as áreas potencialmente mais adequadas para a ocorrência de serpentes dentro da região hidrográfica do Araguaia-Tocantins. Com base na modelagem de nicho climático das espécies conhecidas para esta região, identificamos áreas que serão mais estáveis nas próximas décadas de acordo com o clima atual e as projeções climáticas para o futuro, considerando um cenário mais otimista (com menores emissões de CO2) e um cenário mais pessimista (com maiores emissões de CO2). Finalmente, indicamos as melhores áreas para a conservação de serpentes através da sobreposição entre os modelos de nicho ecológico, a distribuição atual das unidades de conservação e o uso do solo na região.

Resumo

Uma das formas mais efetivas de preservar a biodiversidade *in situ* é por meio da criação de áreas protegidas. A expansão da rede de áreas protegidas é crucial para que os esforços de conservação da biodiversidade sejam otimizados em áreas adequadas. Para tanto, é importante que as novas áreas sejam escolhidas com critérios claros – por exemplo, elevada diversidade e nível de endemismo. É cada vez mais importante considerar as mudanças climáticas globais em curso, já que há evidências que muitas espécies alterem sua área de distribuição atual em resposta às novas condições climáticas. Aqui, buscamos indicar quais são as melhores áreas para a conservação de serpentes da Região Hidrográfica Tocantins-Araguaia, uma área com grande importância biológica, mas também cada vez mais ameaçada por atividades antrópicas. Nós consideramos dois cenários de mudanças climáticas, um otimista e um pessimista (RCP 45 e RCP85) e geramos modelos de nicho ecológico para toda a comunidade de serpentes da região. Finalmente, utilizando os modelos gerados, a rede de unidades de conservação existentes e a porcentagem de vegetação nativa obtida mediante o MAPBIOMAS apontamos as áreas climaticamente mais estáveis como as mais indicadas para a conservação das serpentes nessa bacia. Para tanto utilizamos o software Zonation. Em nossos resultados observamos que a maior parte dessas áreas se concentram ao sul da região de estudo, coincidindo com a maior lacuna atual de áreas protegidas nesta bacia.

Palavras Chave: Amazônia, Áreas Protegidas, Cerrado, Modelagem de Nicho, Zonation.

Abstract

One of the most effective ways to preserve biodiversity *in situ* is through the creation of protected areas. The expansion of the network of protected areas is crucial for efforts to conserve biodiversity to be optimized in suitable areas. To this end, it is important that new areas are chosen with clear criteria - for example, high diversity and level of endemism. It is increasingly important to consider the current global climate changes, as there is evidence that many species change their current range in response to new climatic conditions. Here, we seek to indicate which are the best areas for the conservation of snakes in the Tocantins-Araguaia Hydrographic Region, an area of great biological importance, but also increasingly threatened by human activities. We considered two climate change scenarios, an optimistic and a pessimistic one (RCP 45 and RCP85) and generated ecological niche models for the entire snake community in the region. Finally, using the generated models, the network of existing conservation units and the percentage of native vegetation obtained through MAPBIOMAS, we point out the most climatically stable areas as the most suitable for the conservation of snakes in this basin. For this we use the Zonation software. In our results, we observed that most of these areas are concentrated south of the study region, coinciding with the largest current gap in protected areas in this basin.

Keywords: Amazon, Cerrado, Protected Areas, Niche Models, Zonation.

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Lista de Abreviaturas

CCSM4: Community Climate System Model Version 4.

ENMs: Ecological Niche Models.

GBIF: Global Biodiversity Information Facility.

GIS: Geographic Information System.

GO: Goiás.

HadGEM2-ES: Hadley Global Environment Model 2 - Earth System.

MA: Maranhão.

MIROC5: Model for Interdisciplinary Research On Climate.

MT: Mato Grosso.

MZUSP: Museu de Zoologia da Universidade de São Paulo.

PA: Pará.

RCP: Representative Concentration Pathway.

TAHR: Tocantins-Araguaia Hydrographic Region.

TO: Tocantins.

Sumário

Introduction

Human actions are reducing natural resources faster than ever seen (FODEN et al., 2013; CEBALLOS et al., 2015; PACIFICI et al., 2015). Habitat loss and fragmentation, introduction of alien species, and global climate change are some of the main threats with devastating effects on nature (WILSON et al., 2016; TILMAN et. al., 2017). As a result, several species and populations may disappear in the coming years (BARNOSKY et al., 2011; CEBALLOS et al., 2015). Among these threats the climate change is particularly worrying as its impacts can cause irreversible damages on a global scale, affecting organisms in different ways (ROOT & SCHNEIDER, 2006). Its effects on species are related to alterations in reproductive periods (DUNN & MØLLER, 2019), geographic distribution (CATEN et al., 2017), and local or global extinctions (MCLAUGHLIN et. al., 2002; CEBALLOS et al., 2015). In addition, fragmentation will act in synergy with climate change inhibiting species from dispersing towards more suitable habitats (ROOT & SCHNEIDER, 2006).

Climate change can affect species in physiological, behavioral and ecological aspects (SCHMITZ & BARTON, 2014) Ectothermic animals are some of the most vulnerable organisms to climate change (DILLON et al., 2010; FODEN et al., 2013). This is especially true for tropical amphibians and reptiles since their thermal safety margins are relatively narrow, and even small increases in temperatures can lead to large biological changes (MORLEY et al., 2019). A large number of reptile species are highly sensitive to climate change, especially due to habitat specialization (BÖHM et al., 2016). Recently, Diele-Viegas et al. (2018) observed that Amazonian reptiles can suffer from increased temperatures, especially the forest dwelling species. Studies with snakes indicate that, despite having a relatively good ability to adapt to temperature increases (within a certain limit) these animals may not be able to adapt to constant and high changes (AUBRET & SHINE, 2010; READING et al., 2010). For Neotropical snakes, the consequence of climate change can be a severe contraction in their original distribution ranges that will not be prevented by the current protected areas (LOURENÇO-DE-MORAES et al., 2019).

Considering this picture, urgent conservation actions are necessary, such as the designation of new protected areas (TILMAN et al., 2017). However, it is a worldwide concern that the existing protected areas may be not efficient to safeguard biodiversity (RUTHERFORD et al., 1999; ARAÚJO, et al., 2011; BUTT et al., 2016; QU et al., 2018; WILLIAMS et al., 2019; JACOBS et al., 2019).

Different approaches aim to identify areas of fauna and flora distribution for the choice of conservation areas (correlative, mechanistic, based on characteristics and combined) (PACIFIC, 2015). The correlative approach considers data on the presence and absence of species in a given geographical area (PETERSON et al., 2011). The mechanistic approach is based on biological characteristics, such as interspecific relationships and adaptability to climate change, there is still the possibility of combining the two approaches (PACIFIC, 2015).

Ecological Niche Modeling (ENM) is a strategy based on correlative approaches (SIQUEIRA et. Al., 2007; SILVANO, 2011; SILVA, 2014; ANACLETO & OLIVEIRA, 2014). The ENM uses different types of environmental variables to predict the distribution of species, such as climatic data, relief and soil conditions (PETERSON et al., 2011). The ENM has been used for several purposes, such as contributing to the conservation of rare or threatened species (ENGLER et al., 2004; GIOVANELLI et al., 2008), and to infer the impacts of climate change on biota (ARAÚJO et al., 2006; ARAÚJO et al., 2008).

The Zonation software was developed to solve problems related to the allocation of space conservation resources and is able to prioritize space conservation in large areas (MOILANEN et al., 2009; MOILANEN et al., 2014). The software makes a priority classification from a complete scenario and gradually removes the least valuable cells (some common species), while the most important cells for biodiversity (high species richness and occurrence of unique species) are maintained until the end (DI MININ et al., 2014).

In Brazil, the Tocantins-Araguaia Hydrographic Region (TAHR) is located in a very special region for biodiversity that coincides with the ecotone between two highly diverse morphoclimatic zones – the Amazon and the Cerrado (Brazilian Savanna) (ANA, 2009). Despite of this, the region is currently subjected to several anthropic impacts, such as deforestation for livestock, agriculture, road construction and hydroelectric powerplant (SILVA JUNIOR *et al.*, 2005; ANA, 2019). Government conservation-related actions in the TAHR are scarce but include existing protected areas, which currently cover only 9% of the basin (ANA, 2009). Other priority areas for conservation in the region, considered by the Brazilian Federal government, were selected based on biological and social criteria but does not take into account the impacts of climatic changes (MMA, 2018).

Brazilian Government efforts for the conservation of reptiles are mostly based on the National Conservation Action Plans, which are basically documents of public policies that identify the main threats to biodiversity and present a guide of priority conservation actions (ICMBIO, 2018a). There is no specific plan for the conservation of snakes, but the National Action Plan for the Extinction of Ichthyofauna, Herpetofauna and Primates of the Cerrado and Pantanal considers TAHR in its assessments. Although these plans indicate the main threats in this region, such as fragmentation, there is no mention of the potential impacts of climate change (ICMBIO, 2018b). Thus, our main objective is to identify the most suitable areas for snakes conservation in the Tocantins and Araguaia River Basins, based on methods of ecological niche models and considering land use and the prognosis of climate change.

Methods

Study area

Our study was focused on the Tocantins-Araguaia Hydrographic Region (TAHR) that is located in the north-central Brazil, across the states of Pará (PA), Tocantins (TO), Goiás (GO), Mato Grosso (MT) and Maranhão (MA) (Figure 1). It comprises the Tocantins and Araguaia river basins with a total of 918,822 km^2 (11% of the Brazilian territory) (ANA, 2009). This region corresponds to a transitional area between Amazon and Cerrado, two South American morphoclimatic zones severely threatened by farming activities (OLIVEIRA et al., 2008; ARRAES et al., 2012; ESCOBAR, 2019).

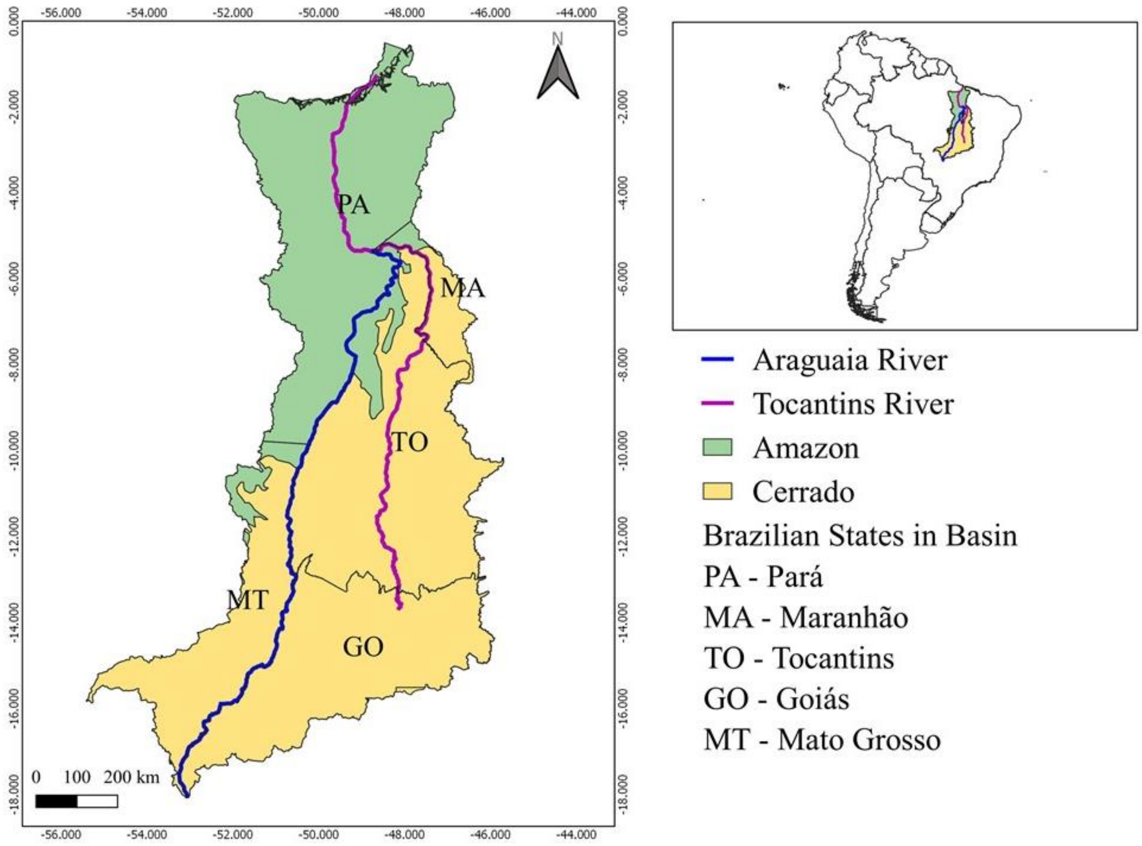

Figure 1. Geographical location of the Tocantins-Araguaia Hydrographic Region (TAHR).

Occurrence Points

We gathered snakes occurrence localities from different sources: herpetological collections (MZUSP), literature (papers, books and theses), online databases (GBIF, SpeciesLink and Portal da Biodiversidade) and personal field records. This information was collected by August 7, 2019. After collecting species information, we selected snake data based on taxonomic validation according to Costa & Bérnils (2018). Filtered and excluded inaccurate taxonomic information, identified problematic or inaccurate locality records, and compared the spatial distribution of records obtained with species ranges according to Nogueira et al. (2019). This resulted in 162 species occurring for the watershed (Appendix).

Ecological niche models

We used the environmental climatic variables available on the Worldclim website (http://worldclim.org/version2), with 2,5 minutes spatial resolution (this is about 4.5 km at the equator). For the future projections, we used these same climatic variables, considering three scenarios (CCSM4, HadGEM2-ES e MIROC5) projected to 2070. These models are widely used in niche modeling studies and two of them (HadGEM2-ES and MIROC5) were specifically studied for our target region (DE SOUSA et al., 2019). The variables consider an optimist future (RCP 4.5) and a pessimist future scenario (RCP 8.5) of climate change.

To avoid redundant variables, we submitted them to a correlation analyses by organizing a matrix with Spearman coefficient values for each pair of variables (GUISAN & ZIMMERMANN, 2000). Pairs with a value greater than 0.75 were considered strongly correlated (BUENO, 2012). At the end, the selected variables were: Temperature Annual Range (BIO7), Mean Temperature of Warmest Quarter (BIO10), Annual Precipitation (BIO12), Precipitation of Wettest Month (BIO13) and Precipitation of Warmest Quarter (BIO18).

We used four algorithms to build the ENMs: Bioclim (NIX, 1986), the Domain (or Gower distance) (CARPENTER et al., 1993), Support vector machines (SVM) (TAX & DUIN, 2004) and MaxEnt (PHILLIPS et al., 2006). We used an ensemble forecasting framework of species distribution (ARAUJO & NEW, 2007) to reduce the uncertainty of predictions. For each species, we used a subset of 75% of the occurrence points for training the models and 25% for testing them. Each process of modeling was repeated randomly for 10 times, varying the points of training and testing each time (PETERSON et al., 2011).

To avoid unreliable models, we discard species with less than 10 points of occurrence, but it is important to mention that we use all known points in South America for the species used in this study (PETERSON et al., 2011), We choose one threshold independent [area under the receiver operating characteristic (ROC) curve – AUC] and one threshold dependent [true skill statistic (TSS)] (see Peterson et al 2011, for details) to cover possible applications of snakes' spatial distribution. The AUC is obtained by plotting sensitivity versus (1 – specificity) for a range of increasing predictive threshold values. High performance models are indicated by large areas under the ROC curves and high AUC scores (MANEL et al., 1999). Usually AUC values of 0.5–0.7 indicates low accuracy, values of 0.7–0.9 indicates useful applications and values higher than 0.9 indicate high accuracy (SWETS, 1988).

After elaborating the ENM, we discard the models with AUC (Area Under the Curve) values smaller than 0.8 (Figure 2). AUC varies from 0 to 1 and the greater the value the greater is the prediction power of the model (PETERSON et al., 2011). This resulted in a total of 122 species with AUC equal to or greater than 0.8. All this process and the dates generated were analyzed by programming language R, with specifics packages as "sp", "corrr", "raster", "dismo", "kernlab", "vegan", "rgdal" e "rJava" (HIJMANS & ELITH, 2013).

Selection of Conservation Areas

To select the most suitable areas for the conservation of snakes, we used the software and algorithm Zonation v.4.0 (MOILANEN et al., 2009; MOILANEN et al., 2014), that classifies areas based on species distribution, land use, and existing conservation areas (MOILANEN et al., 2009; LEHTOMÄKI & MOILANEN, 2013). As result, two important outputs are generated: a priority map and a performance curve, indicating which areas have higher importance for the conservation (LEHTOMÄKI & MOILANEN, 2013).

Because our main conservation objective was the existing reserve network expansion under climate change scenarios, we firstly used the ENMs both current and future climate predictions after we included the, the current protected areas indifference whether sustainable use or strictly protected areas (MMA, 2020). Also, we include, the native vegetation cover that is available on the MapBiomas project (PROJETO MAPBIOMAS, 2018; https://mapbiomas.org/). Following the recommendations of Di Minin et al. (2014) we assigned equal weights for species and for the input file of native vegetation until the sum of the total weight is 100. And the existing conservation units were used as a mask layer in the Zonation software.

We selected the top 17% of the study area, that is in accordance with 11th Aichi Target of the Strategic Plan for Biodiversity established by the Convention on Biological Diversity (UNEP, 2010). All this process of editing and overlaying maps was carried out with the QGIS 3.6.0 software (QGIS, 2020).

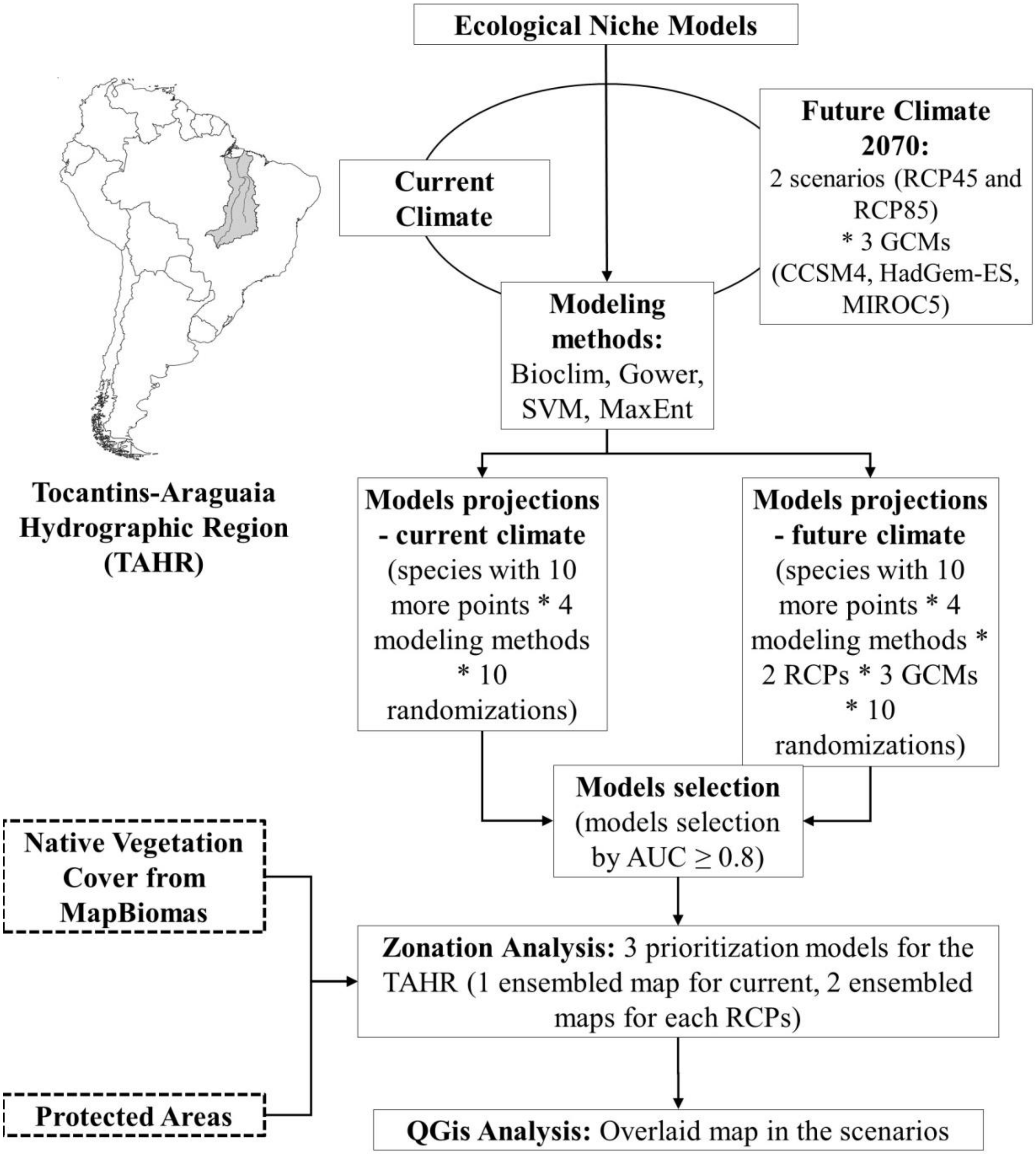

Figure 2. Flowchart with the steps of data entry and prioritization of the choice of areas for conservation.

Results

We generated 20,570 maps with AUC ≥ 0.8, which 2,890 are for the current climatic conditions and 17,680 for the future (8,730 for RCP 4.5 and 8,950 for RCP 8.5). Thus, we generated three consensus maps of climatic suitability, one for the current conditions, one for the future optimistic scenario (RCP 4.5) and another one for the pessimistic future scenario (RCP 8.5) (Figure 3).

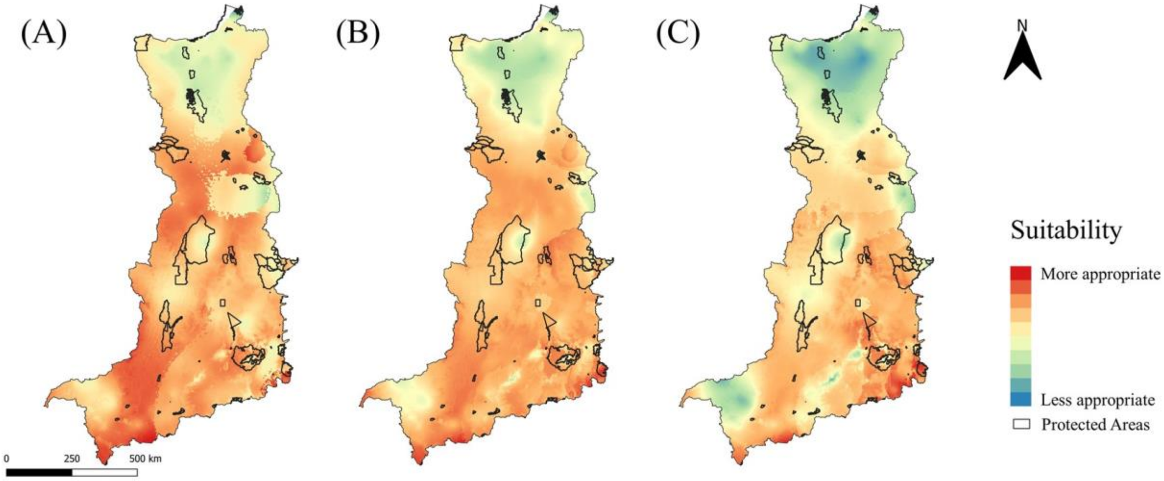

Figure 3. Consensus areas of climatic suitability for snakes in the TAHR according to (A) current conditions, (B) optimistic future conditions (RCP 4.5), and (C) pessimistic future conditions (RCP 8.5).

If we consider areas with more than 50% suitability (warm colors on the map) as adequate for conservation, these areas will decrease in the future. For the two future scenarios, there is a contraction of the most appropriate areas, where in the pessimistic future (figure 3 - B) these areas decrease significantly, mainly in the north of the hydrographic region, but also in the south and, to a lesser extent, in the central and eastern. Currently, suitable areas represent 87.4% of the hydrographic region areas, while they represent 82.1% in the optimistic future and only 59.6% in the pessimistic scenario. The best areas for the snakes conservation along the hydrographic region varies among the different scenarios (Figure 4), but the overlaid maps found consensus mainly in the south of the hydrographic region, with an exception of a small area in the center-north (Figure 5).

Analyzing the effectiveness of existing protected areas, and still considering the threshold of 50% adequacy as stable climatic areas, we note that 82.4% of the areas are currently climatically adequate. This number increases to 85.6% in the most optimistic climate change scenario and drops to 74.9% in the pessimistic one. In all scenarios, the northernmost units of TAHR, that are located in Amazonian area, are less suitable. Most of them are not strictly protected areas, such as Extractive Reserves and the Environmental Protection Areas. Some of the most protected areas in the south and in center of the basin, which is predominantly covered by the Cerrado, are predicted to lose suitable areas for snakes.

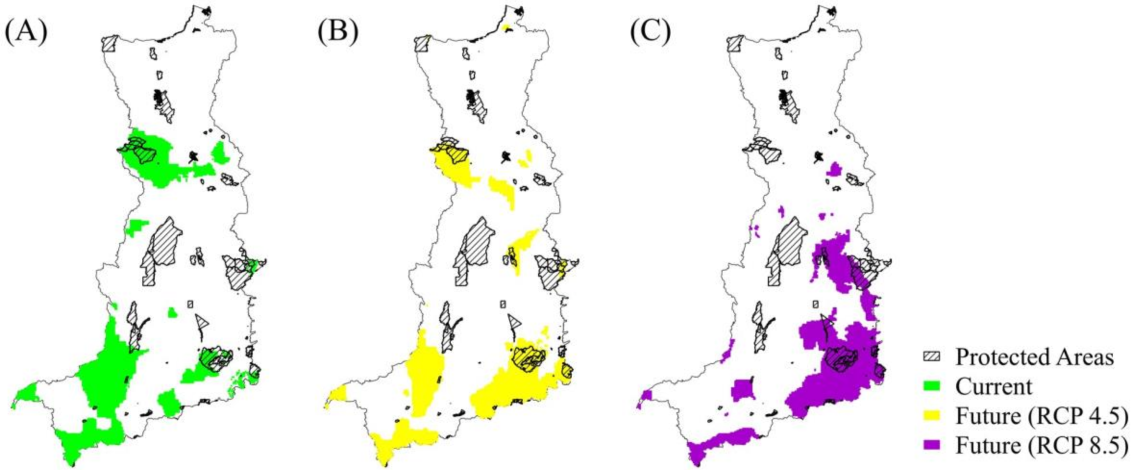

Figure 4. Priority areas showing the 17% of the most climatically suitable areas for the conservation of snakes in the TAHR for each climatic scenario, where A is the current, B is the optimistic future (RCP 4.5), C is the pessimistic future (RCP 8.5) and protected areas

(striped).

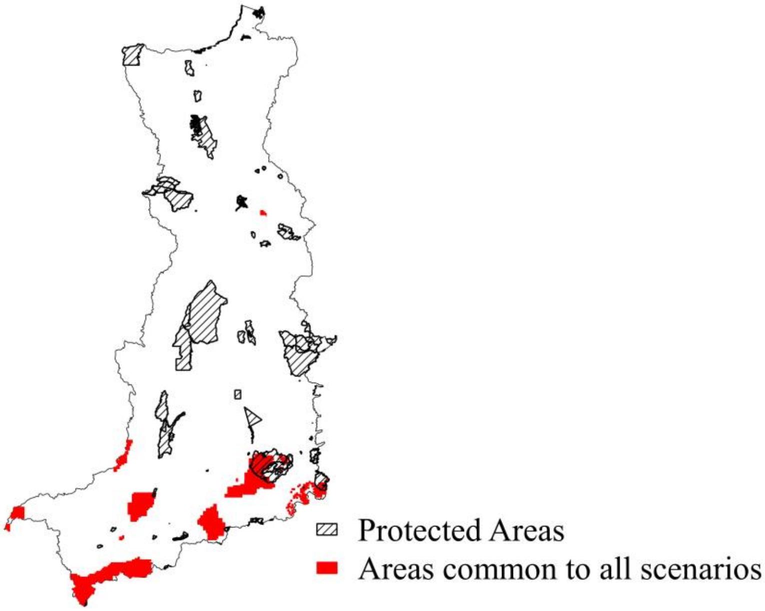

Figure 5. Overlaid areas in the climatic scenarios (red) plus the existing protected areas (striped) in the TAHR.

In all scenarios, the performance curves indicate that not all species benefited from prioritization in an equivalent manner. However, this varies in relation to the proportion of the protected landscape (Figure 6). 17% of the protected area is equivalent to approximately 10% of the occurrence of species in the three scenarios (black line).

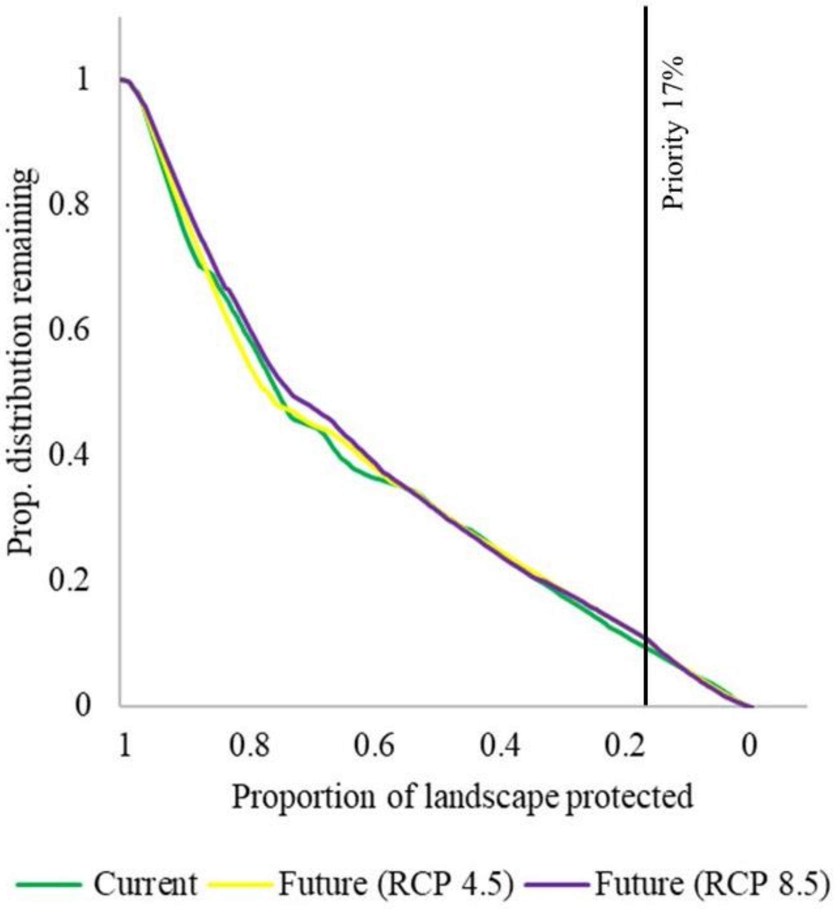

Figure 6. Performance curves of different priority for conservation, each line represents a scenario [green line is the current, yellow line is the optimistic future (RCP 4.5) and purple line is the pessimistic future (RCP 8.5)]. The vertical line (black line) represents the recommended AICHI target (17%).

Discussion

The most suitable areas for the snakes conservation coincides with the major gap of protected areas in the South of TAHR. Current protected areas represent 9.17% of the hydrographic region and areas indicated by the zoning software represent 4.57%. Together the existing areas plus the indicated ones would cover 13.74% of the hydrographic region.

Although this number is still lower than the 17% suggested in the Aichi Biodiversity Targets, focusing the conservation efforts in such strategic areas would be very helpful towards a more desirable scenario.

It is important to note that the south of TAHR is in the Cerrado, a severely threatened Biogeographic region that have only 7.41% of its territory currently under protection (MMA, 2020). The areas indicated in our study represent 2.11% of this savanna, which could increase this amount up to 9.52%. This is especially important considering that most of the current protected areas in southern TAHR are predicted to lose suitable conditions for snakes in the future. Thus, it becomes urgent for snakes conservation to protect the Cerrado, which is the most diverse ecoregion for this taxa in the Neotropics, in both species richness and phylogenetic diversity (GUEDES et al., 2018). Synergistically, our indicated areas match considerably those pointed out by the Brazilian government as having high and extremely high priority for conservation in the same region (MMA, 2018). In addition, our areas also coincide with those indicated for the conservation of lizards according to Fenker et al. (2020).

Currently in Brazil, the choice of conservation areas considers an elaborate planning that usually relies on species inventory and the use of GIS tools based on extensive legislation. Nevertheless, climate change has been completely neglected in the selection of protected areas (TOPPA et al., 2013). Recently, Lapola et al. (2019) assessed whether protected areas in Brazil will be effective in the future considering climate change. They analyzed 993 protected areas and note that 1.7% are highly vulnerable to climate change and 26% are moderately vulnerable. Many of the protected areas at high risk are located in Amazon and western Cerrado (LAPOLA et al. 2019), which is corroborated by our results.

Moura et al. (2016) found that climate is the most important factor that explains species richness patterns for vertebrates in South America. Therefore, climate change must be not be neglected in conservation planning, as many species are expected to alter their distributions due to changes in temperature and precipitation. Lemes & Loyola (2013) noted that many species of anuran amphibians in the Atlantic Forest may have their distribution altered due to climate change, and will be forced to disperse to more suitable areas in the future. Lourenço-de-Moraes et al. (2019) found similar results for snakes also in the Atlantic Forest and highlighted the need to create corridors and areas in suitable climatic locations.

The creation of protected areas is the most important action for snakes conservation, because it reduces habitat fragmentation, which is the most negative impact for wild snakes (RODRIGUES, 2005). But the creation of protected areas is also important, as it reduces other impacts on wildlife snakes, such as the human-induced killing (MOURA et al., 2010; PANDEY et al., 2016), and road killing (HARTMANN et al., 2011; SECCO et al. 2014). In the models, we did not use species with less than ten occurrence points. However, some of them are species with restricted distribution and may be more prone to extinction. For instance, the species *Epictia clinorostris* Arredondo and Zaher, 2010 is endemic to the central portion of the Cerrado nearby the Araguaia river, and is not recorded in protected areas so far, what would make it very benefited by the creation of protected areas in southern basin (NOGUEIRA et al., 2019).

Although several studies have reported population declines in snakes worldwide (e.g. GIBBONS et al., 2000; READING et al., 2010; LUKOSCHECK et al., 2013), there is still insufficient investigation on the impacts of climate change in this group. The few studies that address this issue in the Neotropic region are punctual and generally focused on a single species (MESQUITA et al., 2013; VASCONCELOS, 2014; COSTA et al., 2016; CATEN et al., 2017). The only study so far to investigate these potential impacts in snakes on a community level exposes the vulnerability of these reptiles in the Atlantic Forest, highlighting the need for similar approaches in other morphoclimatic zones (LOURENÇO-DE -MORAES et al., 2019).

In conclusion, our results indicate that the best conservation areas for snakes in TAHR are located mainly in the south, where protected areas are still scarce. The snake community in TAHR may be at risk, as the most suitable areas will shrink, given global prospects for climate change. And the some current protected areas may not be effective in preserving these reptiles. Therefore, we hope that this work can contribute to future research and conservation planning in a highly biodiverse region in central Brazil.

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Appendix - List of snake species in the TAHR.

Family / *Species*	**Species used in prioritization**
Aniliidae	
Anilius scytale (Linnaeus, 1758)	
Anomalepididae	
Liotyphlops beui (Amaral, 1924)	X
Liotyphlops ternetzii (Boulenger, 1896)	X
Typhlophis squamosus (Schlegel, 1839)	
Boidae	
Boa constrictor Linnaeus, 1758	
Corallus batesii (Gray, 1860)	X
Corallus hortulanus (Linnaeus, 1758)	
Epicrates assisi Machado, 1945	X
Epicrates cenchria (Linnaeus, 1758*)*	
Epicrates crassus Cope, 1862	X
Eunectes murinus (Linnaeus, 1758)	X
Colubridae	
Chironius carinatus (Linnaeus, 1758)	X
Chironius exoletus (Linnaeus, 1758)	X
Chironius flavolineatus (Jan, 1863)	X
Chironius fuscus (Linnaeus, 1758)	X
Chironius multiventris Schmidt & Walker, 1943	X
Chironius quadricarinatus (Boie, 1827)	X
Chironius scurrulus (Wagler in Spix, 1824)	X
Dendrophidion dendrophis (Schlegel, 1837)	X
Drymarchon corais (Boie, 1827)	
Drymoluber brazili (Gomes, 1918)	X
Drymoluber dichrous (Peters, 1863)	X
Leptophis ahaetulla (Linnaeus, 1758)	
Mastigodryas bifossatus (Raddi, 1820)	X
Mastigodryas boddaerti (Sentzen, 1796)	X
Oxybelis aeneus (Wagler in Spix, 1824)	X
Oxybelis fulgidus (Daudin, 1803)	X
Phrynonax polylepis (Peters, 1867)	X
Rhinobothryum lentiginosum (Scopoli, 1785)	X
Simophis rhinostoma (Schlegel, 1837)	X
Spilotes pullatus (Linnaeus, 1758)	X
Spilotes sulphureus (Wagler, 1824)	
Tantilla melanocephala (Linnaeus, 1758)	

Family / *Species*	**Species used in prioritization**
Dipsadidae	
Uromacerina ricardinii (Peracca, 1897)	X
Dipsadidae	
Apostolepis adhara França, Barbo, Silva-Júnior, Silva & Zaher, 2018	
Apostolepis albicollaris Lema, 2002	X
Apostolepis ammodites Ferrarezzi Barbo & Albuquerque, 2005	X
Apostolepis assimilis (Reinhardt, 1861)	X
Apostolepis cearensis Gomes, 1915	X
Apostolepis cerradoensis Lema, 2003	
Apostolepis flavotorquata (Duméril, Bibron & Duméril, 1854)	
Apostolepis longicaudata Gomes in Amaral, 1921	X
Apostolepis nelsonjorgei Lema & Renner, 2004	
Apostolepis nigrolineata (Peters, 1869)	
Apostolepis polylepis Amaral, 1922	
Atractus albuquerquei Cunha & Nascimento, 1983	X
Atractus alphonsehogei Cunha & Nascimento, 1983	
Atractus caxiuana Prudente & Santos-Costa, 2006	
Atractus latifrons (Günther, 1868)	X
Atractus major Boulenger, 1894	X
Atractus pantostictus Fernandes & Puorto, 1994	X
Atractus snethlageae Cunha & Nascimento, 1983	X
Atractus tartarus Passos, Prudente & Lynch, 2016	
Boiruna maculata (Boulenger, 1896)	X
Boiruna sertaneja Zaher, 1996	X
Clelia clelia (Daudin, 1803)	
Clelia plumbea (Wied, 1820)	X
Dipsas bucephala (Shaw, 1802)	X
Dipsas catesbyi (Sentzen, 1796)	X
Dipsas indica Laurenti, 1768	X
Dipsas pavonina Schlegel, 1837	X
Dipsas variegata (Duméril, Bibron & Duméril, 1854)	X
Drepanoides anomalus (Jan, 1863)	X
Erythrolamprus aesculapii (Linnaeus, 1766)	X
Erythrolamprus almadensis (Wagler in Spix, 1824)	X
Erythrolamprus carajasensis (Cunha, Nascimento & Avila-Pires, 1985)	

Family / *Species*	**Species used in prioritization**
Erythrolamprus frenatus (Werner, 1909)	X
Erythrolamprus maryellenae (Dixon, 1985)	
Erythrolamprus miliaris (Linnaeus, 1758)	X
Erythrolamprus oligolepis (Boulenger, 1905)	X
Erythrolamprus poecilogyrus (Wied-Neuwied, 1825)	X
Erythrolamprus reginae (Linnaeus, 1758)	
Erythrolamprus taeniogaster (Jan, 1863)	X
Erythrolamprus typhlus (Linnaeus, 1758)	X
Helicops angulatus (Linnaeus, 1758)	X
Helicops hagmanni Roux, 1910	X
Helicops leopardinus (Schlegel, 1837)	X
Helicops polylepis Günther, 1861	X
Helicops trivittatus (Gray, 1849)	X
Hydrodynastes bicinctus (Herrmann, 1804)	X
Hydrodynastes gigas (Duméril, Bibron & Duméril, 1854)	X
Hydrodynastes melanogigas Franco, Fernandes & Bentin, 2007	
Hydrops martii (Wagler in Spix, 1824)	X
Hydrops triangularis (Wagler in Spix, 1824)	X
Imantodes cenchoa (Linnaeus, 1758)	X
Imantodes lentiferus (Cope, 1894)	X
Leptodeira annulata (Linnaeus, 1758)	
Lygophis meridionalis (Schenkel, 1901)	X
Lygophis paucidens Hoge, 1953	X
Oxyrhopus formosus (Wied, 1820)	X
Oxyrhopus guibei Hoge & Romano, 1978	X
Oxyrhopus melanogenys (Tschudi, 1845)	X
Oxyrhopus petolarius (Linnaeus, 1758)	X
Oxyrhopus rhombifer Duméril, Bibron & Duméril, 1854	X
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	X
Phalotris labiomaculatus Lema, 2002	
Phalotris nasutus (Gomes, 1915)	X
Philodryas aestiva (Duméril, Bibron & Duméril, 1854)	X
Philodryas agassizii (Jan, 1863)	X
Philodryas argentea (Daudin, 1803)	X
Philodryas livida (Amaral, 1923)	
Philodryas nattereri Steindachner, 1870	X
Philodryas olfersii (Liechtenstein, 1823)	X

Family / *Species*	**Species used in prioritization**
Philodryas patagoniensis (Girard, 1858)	X
Philodryas psammophidea Günther, 1872	X
Philodryas viridissima (Linnaeus, 1758)	X
Phimophis guerini (Duméril, Bibron & Duméril, 1854)	X
Pseudoboa coronata Schneider, 1801	X
Pseudoboa neuwiedii (Duméril, Bibron & Duméril, 1854)	X
Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	X
Pseudoeryx plicatilis (Linnaeus, 1758)	X
Psomophis joberti (Sauvage, 1884)	X
Rhachidelus brazili Boulenger, 1908	X
Rodriguesophis iglesiasi (Gomes, 1915)	X
Sibon nebulatus (Linnaeus, 1758)	X
Sibynomorphus mikanii (Schlegel, 1837)	X
Sibynomorphus ventrimaculatus (Boulenger, 1885)	X
Siphlophis cervinus (Laurenti, 1768)	X
Siphlophis compressus (Daudin, 1803)	X
Siphlophis leucocephalus (Günther, 1863)	
Siphlophis worontzowi (Prado, 1940)	X
Taeniophallus brevirostris (Peters, 1863)	X
Taeniophallus occipitalis (Jan, 1863)	X
Thamnodynastes hypoconia (Cope, 1860)	X
Thamnodynastes pallidus (Linnaeus, 1758)	
Thamnodynastes phoenix Franco, Trevine, Montingelli & Zaher, 2017	X
Xenodon merremii (Wagler in Spix, 1824)	X
Xenodon nattereri (Steindachner, 1867)	
Xenodon rabdocephalus (Wied-Neuwied, 1824)	
Xenodon severus (Linnaeus, 1758)	
Xenopholis scalaris (Wucherer, 1861)	X
Xenopholis undulatus (Jensen, 1900)	X
Elapidae	
Micrurus brasiliensis Roze, 1967	X
Micrurus filiformis (Günther, 1859)	X
Micrurus frontalis (Duméril, Bibron & Duméril, 1854)	X
Micrurus hemprichii (Jan, 1858)	X
Micrurus lemniscatus (Linnaeus, 1758)	X
Micrurus paraensis Cunha & Nascimento, 1973	X
Micrurus surinamensis (Cuvier, 1817)	X

Family / *Species*	**Species used in prioritization**
Leptotyphlopidae	
Epictia albifrons (Wagler in Spix, 1824)	X
Epictia clinorostris Arredondo & Zaher, 2010	
Siagonodon acutirostris Pinto & Curcio, 2011	
Siagonodon cupinensis (Bailey & Carvalho, 1946)	
Trilepida brasiliensis (Laurent, 1949)	
Trilepida fuliginosa (Passos, Caramaschi & Pinto, 2006)	
Trilepida koppesi (Amaral, 1955)	X
Trilepida macrolepis (Peters, 1857)	X
Typhlopidae	
Amerotyphlops brongersmianus (Vanzolini, 1976)	X
Amerotyphlops reticulatus (Linnaeus, 1758)	X
Viperidae	
Bothrops atrox (Linnaeus, 1758)	X
Bothrops bilineatus (Wied-Neuwied, 1821)	X
Bothrops brazili Hoge, 1954	X
Bothrops itapetiningae (Boulenger, 1907)	X
Bothrops lutzi (Miranda-Ribeiro, 1915)	
Bothrops marmoratus Silva & Rodrigues, 2008	
Bothrops mattogrossensis Amaral, 1925	X
Bothrops moojeni Hoge, 1966	X
Bothrops neuwiedi Wagler in Spix, 1824	X
Bothrops pauloensis Amaral, 1925	X
Bothrops taeniatus Wagler in Spix, 1824	
Crotalus durissus Linnaeus, 1758	X
Lachesis muta (Linnaeus, 1766)	