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PROPONDO ÁREAS DE CONSERVAÇÃO PARA A ONÇA-PINTADA NO ESTADO DE SANTA CATARINA, BRASIL.

ARAQUARI/SC

2023

MAURO ANDERSON DA SILVA BOSSI

PROPOSING A CONSERVATION AREA FOR THE JAGUAR IN SANTA CATARINE STATE, BRAZIL.

Dissertação apresentada ao curso de tecnologia e meio ambiente do Instituto Federal Catarinense como requisito parcial à obtenção do título de Mestre em 2023.

Orientador: Prof. Dr. Maiko Rafael SPiesss

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“Dedico esse trabalho a minha filha Margô Vieira Bossi”.

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RESUMO

A fragmentação de habitats naturais é um problema crescente na conservação de espécies. Este problema afeta a distribuição das populações e provoca mudanças no nicho das espécies. Os modelos de distribuição de espécies (SDMs) apresentam áreas potenciais na formação de seu nicho fundamental. Uma estratégia conservacionista é utilizar o conceito de espécie guarda-chuva, que necessita de grandes extensões de áreas conservadas para estabelecer seu nicho. Portanto, a onça-pintada (*Panthera onca*) foi selecionada como espécie-alvo deste trabalho, bem como suas três principais presas indicadas pela literatura: a capivara (*Hydrochoerus hydrochaeris*), o cateto (*Dicotyles tajacu*) e o queixada (*Tayassu pecari*). A sobreposição de nicho entre predador e presa foi analisada usando o método de densidade Kernel. A sobreposição não foi significativa, porém a similaridade entre cada presa e o nicho do predador foi alta (> 0,90). Os SDMs gerados utilizaram camadas ambientais disponíveis no banco de dados WorldClim e dados de presença das plataformas Gbif, ICMbio e SpeciesLink. Oito algoritmos diferentes (Bioclim; Domain; Mahalanobis; Support Machine e Maxent) compõem os modelos. A validação interna depende de dois conjuntos de pseudo-ausência: 25% dos dados do predador e incremento com as presas. A validação externa foi realizada por AUC (Area Under the Curve) e TSS (Trusted Smart Statistics). O mapa de consenso avaliou se as áreas com maior aptidão de presa representam as áreas mais adequadas para o predador na região da Mata Atlântica. O melhor modelo foi com Capivara usando o algoritmo maxent com validação via AUC (0,64). Nossos resultados reforçam as áreas de corredores sugeridas para a espécie na literatura e delimitam regiões de futuro interesse de conservação para a região. Assim, o uso de uma abordagem ecotrófica melhorou a análise de nicho desse predador de ponta.

ABSTRACT

The fragmentation of natural habitats is a growing problem in species conservation. This problem affects the distribution of populations and causes changes in the niche of species. Species distribution models (SDMs) present potential areas in the formation of their fundamental niche. A conservationist strategy is to use the concept of umbrella species, which need large extensions of conserved areas to establish their niche. Therefore, the jaguar (*Panthera onca*) was selected as the target species of this work, as well as its three main prey indicated by the literature: the Capybara (*Hydrochoerus hydrochaeris*), the Collared peccary (*Dicotyles tajacu*) and the White-lipped peccary (*Tayassu pecari*). Niche overlap between predator and prey was analyzed using the Kernel density method. The overlap was not significant, however the similarity between each prey and predator niche was high (> 0.90). The generated SDMs used environmental layers available at WorldClim database and presence data from the Gbif, ICMbio e SpeciesLink platforms. Eight different algorithms (Bioclim; Domain; Mahalanobis; Support Machine and Maxent) compose the models. Internal validation relies on two sets of pseudo-absence: 25% of predator data and increment with preys. External validation was performed by AUC (Area Under the Curve) and TSS (Trusted Smart Statistics). The consensus map assessed whether the areas with the highest prey aptitude represent the most suitable areas for the predator in the Atlantic Forest region. The best model was with Capivara using the maxent algorithm with validation via AUC (0.64). Our results reinforce the corridor areas suggested for the species in the literature and delimit regions of future conservation interest for the region. Thus, the use of an ecotrophic approach improved the niche analysis of this apex predator.

Palavras-chave: Atlantic Forest; diet; niche overlap; species distribution models; *Panthera onca*.

LISTA DE ILUSTRAÇÕES

lista de tabelas

LISTA DE ABREVIATURAS E SIGLAS

SDMs	Special Distribution Models (Modelos de distribuição espacial)
AUC	Área sobre a Curva
TSS	True Skill Statistic (Estática de habilidade Verdadeira)
NT	Near Threatened (Quase ameaçada)
VU	Vulnerable (Vulnerável)
US	Estados Unidos da América
S	Sul
W	Norte
FO	Frequência de Ocorrência
PO	Porcentagem de Ocorrência
PCA	Analise de componentes Principais
PMDO's	Modelos com a pseudo-ausência baseada nas presas.
svm	Vetor suporte de Maquina
m	Maxent
MDP	multiplicação do modelo de previsão
ns	não significativo
s	significativo
Fgd	Distribuição geográfica favorável

LISTA DE SÍMBOLOS

>	Maior que
%	Porcento
°	Graus decimais
Km^2	Quilômetro quadrado
x	Número de vezes
*	baseado no estudo de Broennimann *et al.* (2012)
Km	Quilômetro
=	Igual
±	mais ou menos
/	dividido
&	Conjunção “e”
-	hífen

SUMÁRIO

1 INTRODUCTION

Determining the geographic distribution of a species is a challenge that involves quantifying the distribution area (ecological niche) and its delimiting influences (Colwell & Rangel, 2009); and defining the biotic (predation, competition, parasitism) and abiotic (temperature, luminosity, slope) interactions responsible for the formation of its niche (Gaston, 2003). With wide geographical distribution the jaguar (*Panthera onca*) (Rabinowitz & Zeller, 2010; Hunter, 2015) can occupy different types of environments (De Angelo, Paviolo & Di Bitetti, 2011; Rodriguez-Soto et al., 2011), it difficult to define is distribution.

The jaguar is the world 's third largest cat and the Latin´s America largest carnivore. The species has been extirpated from an estimated 49% of its historical range and is extinct in El Salvador, the US and Uruguay. The remaining populations occur from northern Mexico to northern Argentina (Hunter, 2015). The species has been listed as Near Threatened (NT) in the globally assessment for The IUCN Red List of Threatened Species (Quigley et al., 2017) and as Vulnerable (VU) in the Brazilian official red list of threatened species (Brasil, 2022). In the coastal region of Brazil, it is apparently extinct in the southern (Pampas) and northern extremes (Morato et al., 2013).

The Brazilian Atlantic Forest is considered one of the most threatened ecosystems in the world, with approximately 11% of its original coverage (Ribeiro et al., 2009). Only 10.32% of Atlantic Forest is predicted as suitable for jaguar occurrence, and the effective population size to be less than 250 individuals (Ferraz et al., 2012a; Morato et al., 2013). The Dense Ombrophilous Forest covers a coast strip where most of these Brazilian populations concentrate. But even in those remnants considered as the best habitat for them the jaguar have become uncommon as a result of habitat modification (Mazzolli, 2008).

Although subsisting on a wide variety of animals, with at least 85 recorded prey species (Sunquist & Sunquist, 2002; Hunter & Barrett, 2018), jaguars concentrate their feeding on a small number of common large-bodied prey (Garla, Setz & Gobbi, 2001). Mammals predominate in its diet, with Capybara (*Hydrochoerus hydrochaeris*) and Collared and White-lipped Peccaries (*Dicotyles tajacu* and *Tayassu pecari*) being frequently the most important prey species where they occur (De Azevedo, 2008).

A variety of metrics is used to measure niche overlap (Pianka, 1980). Species distribution models are normally used to quantify the environmental niche (Guisan & Thuiller, 2005). In this work, we estimate the niche of species through projection with grids (each cell represents a value) in environmental layers. This technique overcomes current deficiencies in niche quantification by: i) considering the biases introduced by spatial resolution; ii) idealize the geographical and environmental space; iii) and correct the density of occurrence in each region as a function of space (Broennimann et al., 2012).

Modeling species distribution is a promising field of research and species distribution models (SDMs) have become a useful tool to improve our knowledge about endangered populations and species-environment relationships (Guisan & Zimmermann, 2000; Ferraz et al., 2012a). There is an increasing use of these models for environmental applications in conservation planning by highlighting areas where the species might occur and identifying key areas for potential corridors linking protected areas (Ferraz et al., 2012b). Their capacity to predict species occurrence can be used in the assessment of habitat suitability, climate change landscape management impact, and site selection for species reintroduction for example (Pearson et al., 2007).

Technically, these SDMs are supported by three main pillars: (i) species occurrence data, (ii) environmental variables and (iii) analytical methods (Lima-Ribeiro & Diniz-Filho, 2012). Yet, according to Trainor et al. (2014), for more effective conservation strategies reliant on understanding species interactions, models that accurately project species distributions should include species interactions as well as biophysical conditions. Thus, the distribution models of the three main jaguar prey items were incorporated into the analysis. Our hypothesis is that the areas of higher suitability for the jaguar 's main prey species are also the most suitable for this top predator in the Atlantic Forest region. We also hypothesize that this top predator has niche overlap with its prey.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The Atlantic Forest encompasses 17 Brazilian states, subdivided into the formations of Dense, Mixed and Open Ombrophilous Forests, Deciduous and Semi-deciduous Seasonal Forests, as well as Mangroves, sandbank formations, and fields at high altitudes in mountainous environments, based on the defined in Brazilian legislation (Brasil, 2006).

The study area was defined as the southern Brazilian state of Santa Catarina, located between latitudes 26° and 29° S and between longitudes 48° and 53° W and with an area of 95,346 km². The coast of Santa Catarina state is formed by Dense Ombrophilous Forest (IBGE, 2019) with moderate to severe fragmentation (Rosot et al., 2021) and predominance of secondary stage of regeneration dominated by species from disturbed areas (Lingner et al., 2015). Predominant in areas with altitudes greater than 500 meters, the majority of forest fragments of Mixed Ombrophilous Forests are highly impacted and impoverished due to intensive human impact (Vibrans et al., 2011).

On the other hand, Santa Catarina is the 4th Brazilian state with the highest native coverage, with 46% of the territory with a predominance of forest remnants, especially in the coastal and mountain ranges (Weber et al., 2021).

2.2 SPECIES OCCURRENCE DATA

Records of the jaguar and its most important prey species were obtained from the online data sets SpeciesLink, Global Biodiversity (Chamberlain & Boettiger, 2017) and ICMBio database. To avoid inconsistencies, we excluded records of type specimens, synonyms, those taken before 1900, and dubious registers. To assess the most important prey we reviewed papers published between 1996 and 2022 on jaguars diet. Because it is a generalist predator (Sunquist & Sunquist, 2002; Hunter & Barrett, 2018), we assessed frequency of occurrence (FO) and percentage of occurrence (PO), the most commonly applied techniques.

2.3 NICHE OVERLAP

The limiting distribution was calculated using the occurrence records (maximum latitude W; minimum latitude N) and the bioclimatic layers (bioclimatic envelopes) available by the online WorldClim database. Envelopes have a spatial resolution of 0.0833° degrees (arc 5) in pixel size. Species distribution was estimated using convex polygons with a 100-meter buffer. The bioclimatic information of the envelopes were vectorized by Principal Component Analysis (PCA) for each species (Villegas et al., 2021). The niche overlap analysis measures the intersection levels between the gaps of two species; niche equivalence measures whether niche overlap is constant by reallocating occurrences of both species randomly between their two ranges; and niche similarity indicates whether the niche of one species can predict the occurrence of the other (Villegas et al., 2021) .

The significance of niche overlap was estimated by the metric D (Broennimann et al., 2012) with a range of 0 - 1 (where 0 represents no overlap). Density (number of occurrences in cell) was based on Kernel (Worton, 1989). We verified the capacity of the model of one species to predict the occurrence of another through similarity (Warren, Glor, & Turell, 2008). And finally, the similarity between niches of the species was compared. The generated script is an adaptation of the complementary material available at the Website macroecology.netlify.app. Among the adaptations are: 1) the latitudinal division; 2) the formation of two comparative groups for niche overlap (Prey and Predator) and 3) similar resampling between groups (prey x predator).

2.4 SPECIES DISTRIBUTION MODELS (SDM)

To construct the models we used 19 bioclimatic variables taken from the WorldClim database (Fick & Hijmans, 2017) at a spatial resolution of 10 km using the WGS84 reference system (Hijmans, 2019). Statistical analyses were conducted in “R”, version 4.2.2 (R Core Team, 2020) using the packages ‘rgbif’ (Chamberlain et al., 2017). For the internal validation of the model, we used the PMDO's as a test in specific algorithms. The grid size has been increased by 20x to better fit the distribution points. Two distribution models were used: Models of distribution of each target species (MDO's), and models with the pseudo-absence of the predator based on prey (PMDO's).

The algorithms are based on presence data (Bioclim, Domain e Mahalanobis), machine learning (Suporte Machine Vector) and classifications by Maxent (Pecchi et al., 2019). In Supporting Machine Vectors (svm) the dimensional space changes by different Kernel (RBF). In svm1 the linear and vector Kernel was adopted, the Kernel only linear composed the svm2 and the Kernel optimized by the gamma parameter svm3 was created (Kumar et al., 1994). Maxent variations (m1, m2, m3) were linked to changes in Pearson's correlation.

The external validation of the MDO's and PMDO's occurred by: 1) Area under the Curve (AUC) and 2) True Skill Statistic (TSS) with a threshold of 20 repetitions. The classifications adopted take into account the standards established by Elith et al. (2006) and Allouche, Tsoar & Kadmon (2006).

Environmental suitability was estimated using an Ensemble with 60 trees, and three algorithms with 20 replications. The multiplication of prediction models (MDP) generated a consensus on the distribution of species. The data were normalized (Han, et al., 2011) by the Min and Max factors, by the formula z=x- min (x)max(x)- min(x), where: x is the value corresponding to the pixel of the forecast map.

3 RESULTS

We reviewed seven published papers of dietary analyses on jaguar diet. The three most important prey species with described distribution in the Atlantic Forest were the white-lipped peccary (*Tayassu pecari*), the collared peccary (*Dicotyles tajacu*), and the capybara (*Hydrochoerus hydrochaeris*) (Table 1).

Table 1: Bibliographic survey of the main food items in the diet of jaguar (*Panthera onca*). The values correspond to frequency of occurrence (FO) and percentage of occurrence (PO).

Prey species	**FO%**	**PO%**
Tayassu pecari	(56.1)[4], (6)[5], (16.4)[6]	(15)[2]; (35.4)[4]
Dicotyles tajacu	(35.8)[3], (22)[4], (3)[7]	(7.8)[2], (24)[3], (13.8)[4]
Hydrochoerus hydrochaeris	(20)[1], (2)[3], (4.9)[4], (1)[5], (2)[6]	(1.3)[3], (3.1)[4]

[1]Souza & Azevedo (2020); [2]Garla, Setz & Gobbi, N. (2001); [3]De Azevedo (2008); [4]McBride, Giordano & Ballard (2010); [5]Sollmann et al. (2013); [6]Prado (2010); [7]Facure & Giaretta (1996).

We obtained 2568 records of jaguar, 96 location records for white-lipped peccary, 886 for collared peccary and 883 for capybara in the Atlantic Forest biome. When we evaluated the niche overlap by the D parameter, the species with the lowest representativeness was the white-lipped peccary (0.140), while the capybara showed the best results (0.521) followed by the collared peccary (0.439). No species showed significant equivalence (ns) with 500 replicates. The Niche similarity was high among all models >0.9 with 1000 replicates (Table 2).

Table 2: Niche overlap, Equivalency and niche similarity between jaguar and its main prey species.

Species pairwise comparison	**Metrics of niche overlap (variables with 5 arc minutes)***			
Panthera onca X.	Niche overlap Schoener's D	Equivalency (*P*-value) (nreps = 500)[1]	Similarity [2] (*P*-value): predator-prey (nreps = 1000)[3]	Similarity [2] (*P*-value): prey-predator (nreps = 1000)[3]
T. pecari	0.140	ns	0.912	0.907
H. hydrochaeris	0.521	ns	0.989	0.988
D. tajacu	0.439	ns	0.968	0.971

[1] Equivalency: ns = non-significant, the hypothesis of niche equivalency is rejected; s = significant, niche equivalency cannot be rejected.
[2] Similarity: if $P < 0.05$, hypothesis of niche similarity is rejected; if $P > 0.05$, niche similarity cannot be rejected.
[3] Arrows mean the direction to which the range of one species is overlaid on the other range.
* based on the study of Broennimann et al. (2012)

Jaguar modeling demonstrates greater suitability in the west and extreme north of the Santa Catarina state (Figure 1). The white-lipped peccary also demonstrates suitability restricted to the extreme north of the coast of the state, in addition to a patch in the eastern region and scattered areas in the extreme east close to the border with Argentina (Figure 2).

The capybara suitability demonstrates high value throughout the coast of Santa Catarina. However, its validation demonstrates low values (0.4 - 0.6) and its potential distribution excluding the border with Rio Grande do Sul in the western region (Figure 3). The entire state of Santa Catarina demonstrates low adequacy in the occurrence of collared peccary, where validation demonstrates median results in AUC with m3 (0.64) and svm2 for TSS (0.61). Its use in PMDO's did not influence the predicted distribution of the predator (Figure 4).

Figure 1: Environmental suitability of *Panthera onca* in the state of Santa Catarina based on bioclimatic envelopes. The model was run with 18 different algorithms and internally validated by pseudo-absence and "bootStrap" resampling (80 replicates) in external validation through AUC (Area Under the Curve) and TSS.

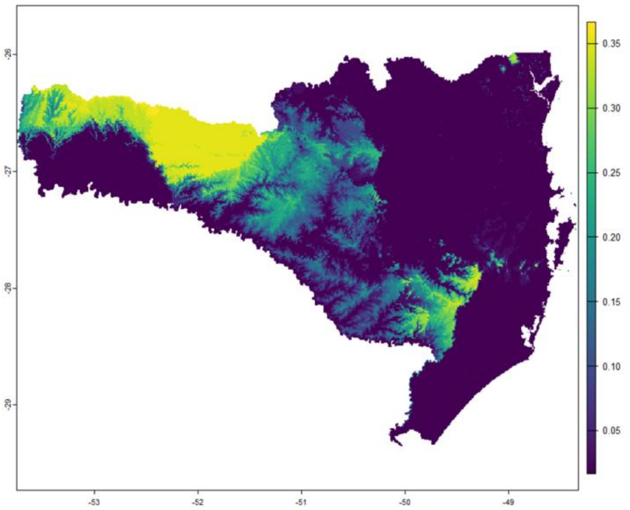


Figure 2: Environmental suitability of the *Panthera onca* (top left) together with the environmental suitability of *Tayassu pecari* (bottom left). On the right is the predicted suitability for *P. onca* with internal validation using *T. pecari* data for pseudo-absences.

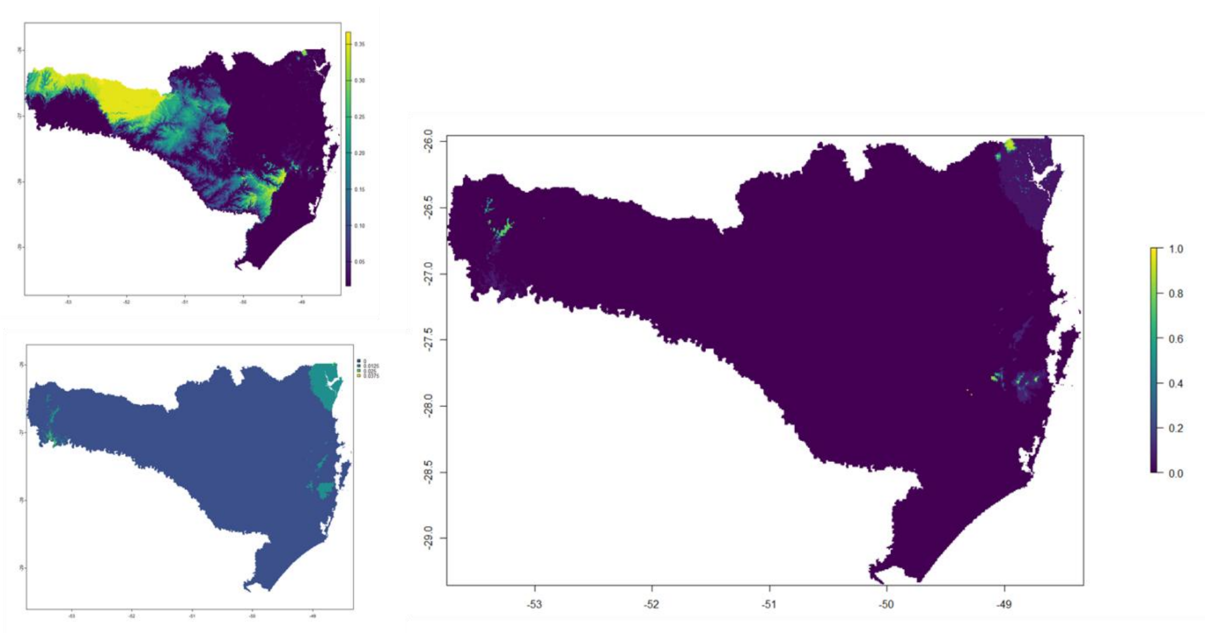


Figure 3: Environmental suitability of the *Panthera onca* (top left) together with the environmental suitability of *Hydrochoerus hydrochaeris* (bottom left). On the right is the predicted suitability for *P. onca* with internal validation using *H. hydrochaeris* data for pseudo-absences.

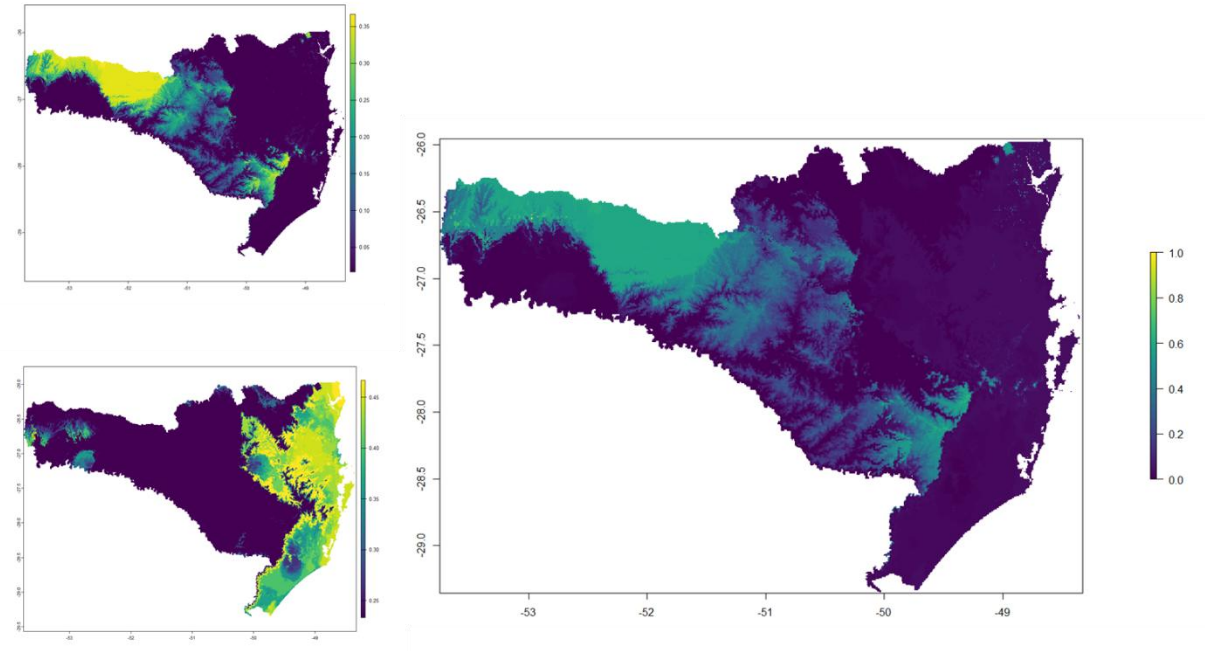
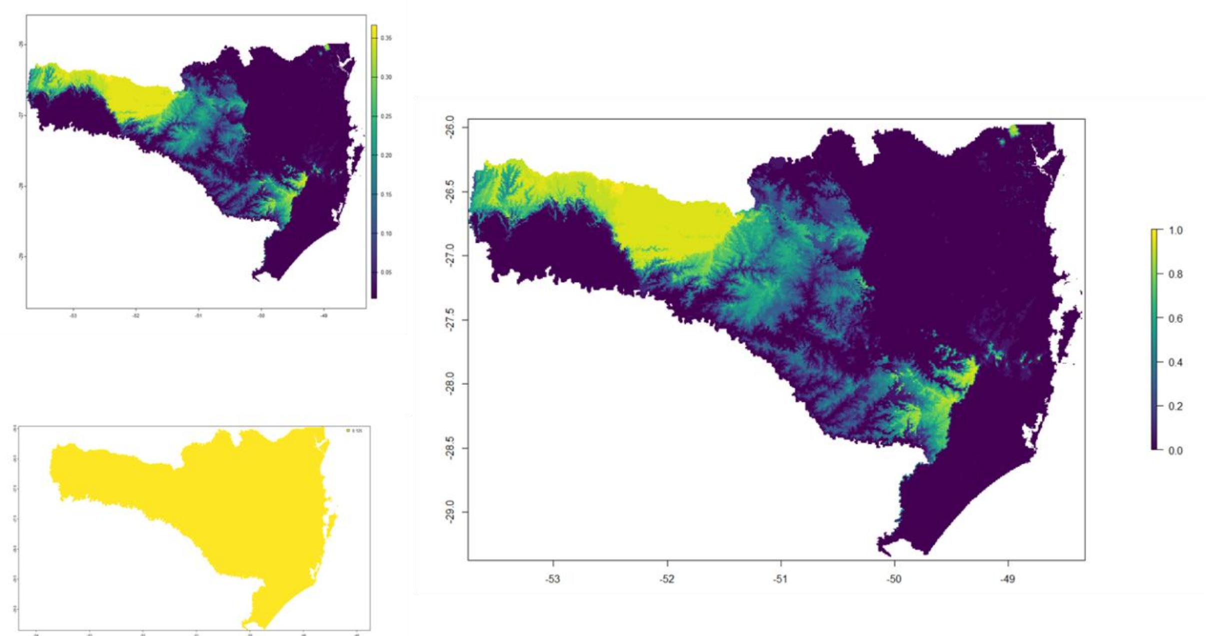
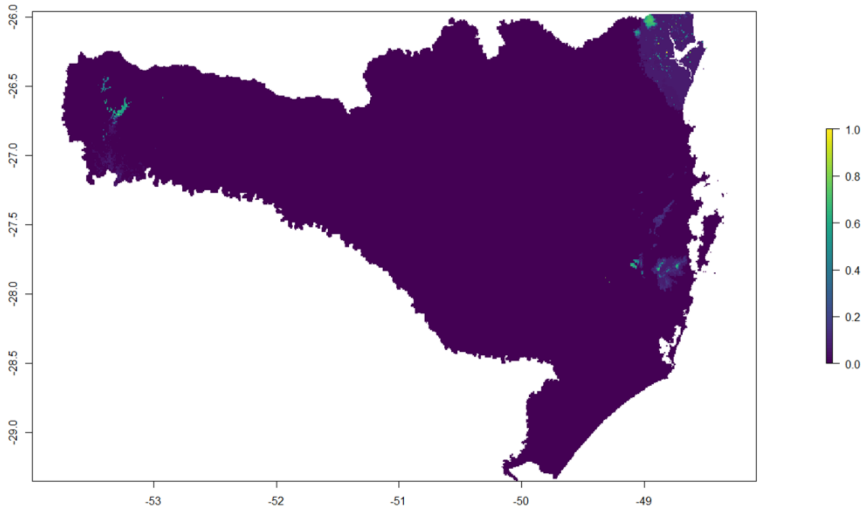


Figure 4: Environmental suitability of the *Panthera onca* (top left) together with the environmental suitability of *Dicotyles tajacu* (bottom left). On the right is the predicted suitability for *P. onca* with internal validation using *D. tajacu* data for pseudo-absences.



Suitability based on jaguar trophic ecology was calculated by normalizing all generated PMDOs (Figure 5). When comparing the MDO's fundamental niche, the greatest similarity in the fundamental niche was between the jaguar and the white-lipped peccary. The maps were converted to the same resolution (0.08333 degrees, or 1km).

Figure 5: Environmental suitability for *Panthera onca* compared to the environmental suitability of its main prey selected in this work (*T. pecari, H. hydrochaereus, D. tajucu*). Suitability models were compared using Normalization.



In the external validation of the eight selected algorithms, three combinations showed sensitivity above 0.6 for prey and predator. Svm2 with TSS validation showed a variation between 0.55 and 0.61. In the M1 model with AUC the sensitivity was close in all species (0.52 - 0.58). Bioclim with AUC validation demonstrated a threshold ranging from 0.52 to 0.55. In models based on M1 there is an inversely proportional relationship in the presence of prey via TSS, and random distribution results in AUC and suitability of 0.06 for the predator. Models based on Domain through AUC were completely random for all species. The best thresholds achieved by species were: AUC with Svm3 algorithm (0.58) for the jaguar; TSS with Svm1 (0.55) for the white-lipped peccary; M1 with the AUC method for the capybara, and AUC for the collared peccary (0.64) (Table 3).

Table 3: Suitability estimation for *Panthera onca* in the state of Santa Catarina with nine different algorithms, in two forms of validation. The first line shows the results for *P. onca* without using prey as pseudo-absences.

Test data		**Models**								
		bioclim	**domain**	**mahal**	**m1**	**m2**	**m3**	**svm1**	**svm2**	**svm3**
P. onca	auc	0.52	0	0.03	0.52	0.004	0.13	0.01	0.42	0.58
	tss	0.06	0.32	0.58	0.006	0.20	0.55	0.48	0.55	0.03
T. pecari	auc	0.54	0	0.05	0.53	0,02	0,21	0	0,11	0,52
	tss	0,03	0,06	0,52	-0,004	0,08	0,55	0,55	0,63	0,04
H. hydrochaeris	auc	0,51	0	0,01	0,55	0,003	0,32	0	0	0,004
	tss	-0,001	-0,18	0,43	-0,04	-0,06	0,5	0,12	0,58	-0,002
D. tajacu	auc	0.55	0	0.22	0.58	0.001	0.64	0.001	0	0.43
	tss	-0.001	-0.28	0.46	-0.003	-0.005	0.45	0.20	0.61	0.003

4 DISCUSSION

The fundamental niche of a species is defined by its favorable geographic distribution (Fgd) and the set of abiotic conditions delimiting it, and the realized niche describes the conditions in which a species actually persists given the presence of competitors or predators (Hutchinson, 1957). Several species' niche concepts have been proposed over time, and no consensus to develop a unified theory has been achieved (Sales, Hayward & Loyola, 2021). In this work we follow the concept that the preferred areas of a species represent its Fgd. MDO's are based on abiotic factors, while when using PMDO's it is possible to approximate the distribution models to the realized niche of the species.

The last known records of jaguars in the southernmost portion of Atlantic Forest dated between decades 1960 and 1990 (Mazzolli, 2008). However, the intensive survey conducted by Fusco-Costa et al. (2022) in the Serra do Mar region in southern Brazil increased the range of jaguar in the Atlantic Forest by 9% and the authors suggested that the forested regions of Santa Catarina state could be an area of potential jaguar occupancy, but more surveys are needed to determine whether the presumed extinction of this species there really represents a case of a false absence.

The large biomass of this feline and its high displacement rate (Sunquist & Sunquist, 2002; Hunter & Barrett, 2018) is an issue that must be discussed when accepting models. Biomass is linked to the need for good prey and subsequently to the occupation of a vast area. In addition, the fragmentation process promotes the disappearance of the species in highly modified areas.

Regarding the main prey identified in this study, the white-lipped peccary populations are found in 31,37% of the Atlantic Forest significant remnants. This species is classified as Critically Endangered (CR) (Keuroghlian et al., 2012). Despite being considered Near Threatened ameaçada (NT), the collared peccary also suffers population reduction due to hunting pressure, loss of habitat quality and fragmentation (Desbiez et al., 2012). The collared peccarys are more of a habitat generalist that uses a wide variety of habitats, while white-lipped peccary are more restricted to forested habitats, especially riparian forests (Ferreguetti et al., 2018).

Whitworth et al. (2022) provided the first temporally and spatially replicated assessment of how population crash events of white-lipped peccary alter the structure of vertebrate communities. The authors detected that the jaguar displayed substantial declines in encounter rate following the white-lipped peccary crash, supporting the existence of a strong predator–prey relationship and diet preference regionaly. Despite the authors assumed that the predator's continued presence in the region shows that this species can also avoid local extirpation by consuming other prey, the species' adaptability is limited by its demand for large areas of adequate habitat and a stable prey base (Astete, Sollmann & Silveira, 2008).

The scoping review of Rocha et al. (2023) demonstrated that jaguars may exhibit diverse patterns of prey consumption, which not only depend on prey size but also vary depending on prey availability and the sites where research is conducted. Some large species such as tapirs (*Tapirus terrestris*) and capybaras are almost absent in the jaguar's diet in Atlantic Forest (Astete, Sollmann & Silveira, 2008).

The capybara has wide environmental plasticity, and its semi-aquatic habits provide different occupations in the landscape. This species uses native grassland areas for foraging, watercourses for reproduction and shelter from predators, and forests for resting and the birth of young (Azcarate, 1980, MacDonald, 1981).

Niche overlap was not significant between species, however high similarity was found. The highest niche overlap found was between the jaguar and capybara (0.52) and the lowest between jaguar and white-lipped peccary (0.14). Even with greater overlap, the semi-aquatic life habit of capybaras (MacDonald, 1981) probably makes predation by the jaguar more difficult. The Tayassuids are amongst the most consumed prey by jaguars, which might reflect their niche similarity being greater than 0.90. This similarity may be linked to the wide geographic distribution of these species.

The environmental suitability calculated by the MDO's and PMDO's indicated the probability of occupation of the species. In the Atlantic Forest, collared peccary is completely favored in Santa Catarina state, a pattern already described by Cruz (2017). When externally validating an MDO's via AUC the performance of the models are flawed (0,50 -0,60) with the exception of the PMDO's m3 of Collared peccary (AUC =0,64), a widely consumed prey.

The above average results by the TSS criterion based on machine learning demonstrate a good generalization of the data (Allouche, Tsoar & Kadmon, 2006). This algorithm has sensitivity in the choice of parameter values (Duan, et al., 2003) with the optimization by the gamma parameter (svm2) the classification was effective. The prey with the highest dietary contribution, the white-lipped peccary, presented MOD's similar to that of the predator.

This prey also presents the second best calculated PMOD's (svm2, TSS-= 0,63). Regarding the performance of the models, aspects related to the jaguar's ecology must be taken into account: this species is sensitive to environmental disturbances; as an umbrella species it demonstrates the need for vast distribution areas (Noss et al., 1996; Miller & Rabinowitz, 2002); and its role as a keystone species reflects on the control of prey density and the balance of ecosystems (Miller & Rabinowitz, 2002). Spatial models give us important information for choosing priority areas for the conservation of this predator (Zeller et al., 2013). In their work, Morato et al. (2013) estimated a capacity of 2.22 ± 1.33 individuals/100 km^2 in the Atlantic Forest by capture-mark-recapture. So, the adopted resolution size is able to minimally cover a couple of jaguars.

Refining the fundamental niche of a predator using prey with normalized models is a promising method. Our models demonstrated important areas for the conservation of the jaguar in the north of the coast of Santa Catarina, with possible ecological corridors on the border with Argentina (Rabinowitz & Zeller, 2010). This reinforces the hypothesis of Fusco-Costa et al. (2022) that this northern region could serve as a source of individuals for the coastal forests further south. However, acceptance of suitability was made more flexible as previously mentioned.

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