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Ecologia espaço-temporal de populações de *Leopardus wiedii* (Schinz, 1821) em áreas do sul da Mata Atlântica

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À biodiversidade da Mata Atlântica, que mesmo ameaçada não perde seus tantos encantos.

(Dedico)

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Resumo

O gato-maracajá (*Leopardus wiedii*) é um pequeno felídeo neotropical arborícola que parece ser dependente de florestas. Esta espécie está distribuída, em grande parte, no bioma Mata Atlântica, e possui características ecológicas ainda pouco conhecidas. Neste estudo, estimamos a densidade populacional e investigamos os padrões deatividade de populações de gato-maracajá em áreas com diferentes tipos de habitats e perturbações antrópicas no extremo sul do bioma Mata Atlântica. Nossa hipótese é que os padrões de densidade e atividade irão diferir entre as áreas em resposta a diferenças na cobertura florestal e perturbação antrópica.Entre os anos de 2017 e 2019, coletamos os dados em seis áreas, através de armadilhamento fotográfico.Nós empregamos o mesmo esforço (dois meses) e arranjo amostral (20 estações, constituídas por duas armadilhas fotográficas cada,não-iscadas e instaladas até 1 km de distância) em cada uma das áreas. Como resultado, obtivemos 66 registros de gato-marcajá, duas áreas foram removidas das análises devido aos poucos registros obtidos (n=2 para ambas). Avaliamos os potenciaisefeitos de fatores ambientais, incluindo os antrópicos, sobre as populações do gato-maracajácomparando nove modelos de captura-recaptura espacial relativos àdensidade, taxa de detecção e uso espacial. As estimativas de densidade domelhor modelo variaram de 9.6±6.4 indivíduos/100km², em uma área de maior perturbação humana, até 37.4±15.1 indivíduos/100km² em uma área mais preservada. Este modelo também indicou umainfluência positiva esignificativa da cobertura vegetalsobre densidade da espécie, reforçando a hipótese da sua dependência florestal. O padrão de atividade do gato-maracajá foi significativamente noturno para todas as áreas. Sua atividade foi sobreposta com espécies relacionadas a atividades humanas e com jaguatirica, *Leopardus pardalis*; encontramos um coeficiente moderado de sobreposição temporal com animais domésticos (cães domésticos e gatos) possivelmente associado à maior perturbação humana. Este representa o primeiro estudo de densidade e padrão de atividade de gato-maracajá realizado em multi-áreas no extremo sul da Mata Atlântica, destacando a importância da cobertura vegetal para esta espécie e revelando que algumas áreas antropizadas também são relevantes para a implementação de ações de conservação da espécie.

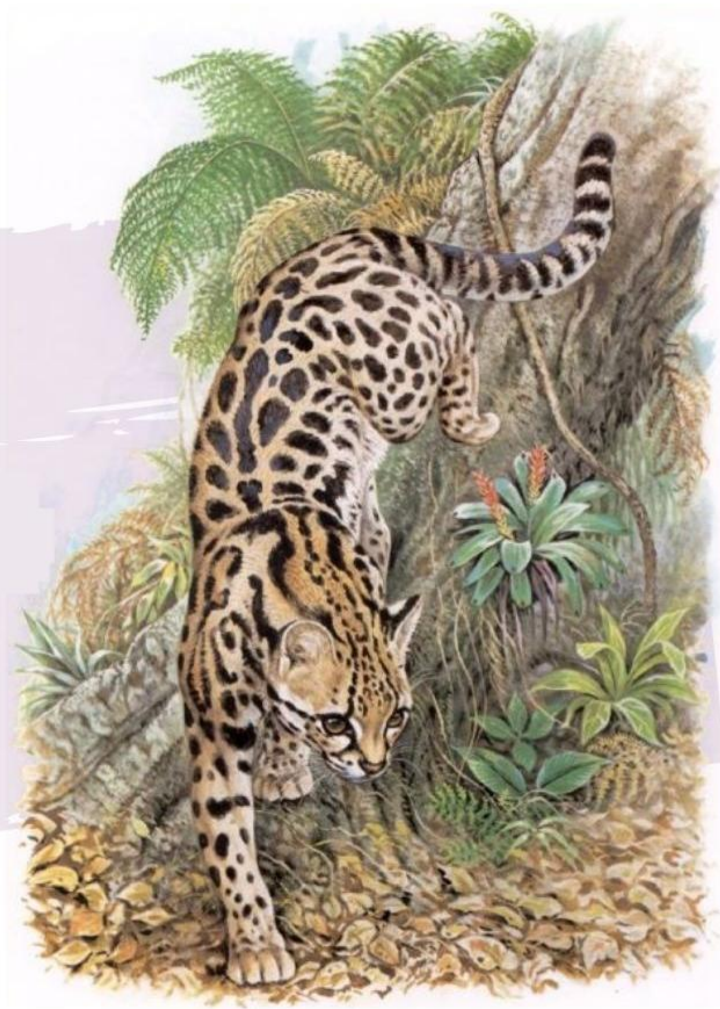
Palavras chave: armadilhamento fotográfico, captura-recaptura espacial, densidade populacional, gato-maracajá, padrão de atividade.

Abstract

The margay (*Leopardus wiedii*) is a small neotropical arboreal wild cat that seems to be forest-dependent, although few studies have evaluated the relation of spatio-temporal aspects of its ecology with landscape characteristics. We aim to estimate density and activity patterns of margay populations in six areas with different habitat types and anthropogenic disturbance levels in the southernmost Atlantic Forest of Brazil. Our hypothesis is that density and activity patterns will differ between areas in response to differences in forest cover and anthropogenic disturbance. Margay records were obtained in the six areas through camera trapping, during spring and summer from 2017 to 2019. We used the same camera trap grid size and effort for every area (20 stations, each with paired cameras, un-baited, placed 1km apart). We obtained 66 margay records, but we excluded two areas from the statistical analyses due to the small number of records. Potential effects of environmental, including anthropogenic, factors on margay density, rate of detection and space use were assessed by comparing nine candidate spatial capture-recapture (SCR) models. The density estimated through the top-ranked model varied from 9.6±6.4 individuals/100km² in an area of higher human disturbance to 37.4±15.1 individuals/100km² in a more preserved area. This model also indicated that margay densities respond positively to vegetation cover, reinforcing the thesis of forest dependence by the species. Margay revealed to be mostly nocturnal, aswere its potential preys, small rodents and marsupials. Activity of margay overlapped with that of the ocelot, *Leopardus pardalis*, and with mammals associated to human presence(wild boar, cattle, dogs, cats, and humans themselves). We provide the first multi-area study on patterns of density and activity of the margay in the southernmost Atlantic Forest, highlighting the importance of vegetation cover for the species and revealing that some areas of human use should also be the focus of conservation actions towards the margay cat.

Key words: activity patterns, camera-trapping, margay cat, population density, spatial capture-recapture.

CAPÍTULO I



Introdução Geral

Felídeos e a linhagem da jaguatirica

A América do Sul possui uma grande diversidade de mamíferos carnívoros (Mammalia:Carnivora), representando aproximadamente 16% da diversidade mundial [1,2]; dentre as espécies que compõem esta ordem encontram-se os felídeos [3]. Os felídeos constituem a família Felidae, atualmente dividida em 11 gêneros e 38 espécies [4]. As espécies dessa família são hipercarnívoras, atuando como reguladoras de populações de outros vertebrados, principalmente mamíferos, sendo importantes componentes da estrutura e dinâmica das comunidades ecológicas, suas ausências podem ocasionar perda de biodiversidade a nível local [5]. O gênero *Leopardus*, que pertence à Linhagem da Jaguatirica, apresenta seis espécies com ocorrência no Brasil: *Leopardus guttulus*(gato-do-mato-pequeno-do-sul), *Leopardus tigrinus* (gato-do-mato-pequeno), *Leopardus geoffroyi* (gato-do-mato-grande), *Leopardus colocola*(gato-palheiro), *Leopardus pardalis*(jaguatirica) e *Leopardus wiedii* (gato-maracajá). O gato-maracajá, *L. wiedii*, é um felídeo de pequeno porte que se assemelha fenotipicamente à sua espécie irmã, *L. pardalis*[8], porém de tamanho e peso menores[9,10].

Biologia e ecologia do gato-maracajá, *Leopardus wiedii*

Leopardus wiedii caracteriza-se por apresentar olhos grandes e protuberantes, focinho saliente e uma cauda longa [9–11]. Sua pelagem apresenta coloração entre amarelo-acizentado e castanho-ócreo e apresenta rosetas largas, completas e espaçadas nas laterais [9,12]. O gato-maracajá possui hábito arborícola, sendo um escalador extremamente ágil [9,13]. A espécie é possivelmente a mais arborícola de todos os felídeos neotropicais, possuindo adaptações morfológicas que facilitam sua escalada, como sua cauda longa para manter o equilíbrio e tornozelos capazes de rodar 180º[11]. O gato-maracajá é categorizado como "Quase ameaçado" a nível global [12]. No entanto, são necessários dados adicionais sobre sua ecologia, demografia, e história natural [12], para uma avaliação mais precisa sobre o grau de ameaça da espécie a nível global.

A distribuição geográfica da espécie compreende desde o norte do México até ao Uruguai e norte da Argentina [9,13]. No Brasil, e também no estado do Rio Grande do Sul (RS), o *status* de conservação da espécie consta como "Vulnerável" [14,15]. No RS, a espécie distribui-se pelo bioma altamente fragmentado da Mata Atlântica [14], um *hotspot* de biodiversidade mundial [16]. Atualmente, devido ao longo e intenso histórico de desmatamento desde a colonização europeia, a Mata Atlântica está restrita a pequenos fragmentos florestais em uma matriz de paisagem antrópica, com muitos ambientes de florestas naturais convertidos em áreas agrícolas, decriação de gado e em áreas urbanas[17]. Como o gato-maracajá apresenta hábitos arborícolas, isso o torna, teoricamente, mais dependente dos habitats florestais, portanto, potencialmente mais sensível ao desmatamento [13]. Estima-se que o tamanho populacional efetivo de *L. wiedii* no Brasil corresponda a cerca de 4.700 indivíduos, com perspectivas de declínio em 10% nos próximos anos devido a efeitos de perda e fragmentação de habitat; suas populações são intrinsecamente pequenas, semelhante ao que ocorre em outras espécies de felídeos de pequeno-médio porte do Brasil [14].

Lacunas e possibilidades no estudo de felídeos neotropicais

Os felídeos, em geral, apresentam hábitos solitários e noturnos, o que dificulta observações em campo para obtenção de informações a respeito de sua biologia. Por isto, pesquisas de campo tornam-se importantes na tentativa de suprir essas lacunas de conhecimento [9]. Apesar dos felídeos representarem um grupo modelo interessante para se avaliar os efeitos de perda e fragmentação de habitat, devido à sua vulnerabilidade e importante papel na estrutura das comunidades, muitas espécies ainda não possuem informações disponíveis sobre sua ecologia e como a perda e a fragmentação de habitat afetam suas populações [18]. Em particular, as espécies de médio e pequeno porte presentes na América do Sul representam algumas das espécies menos estudadas mundialmente, sendo que o gato-maracajá é uma das espécies com menor número de estudos publicados dentro do gênero *Leopardus* [5]. Espécies de felídeos que ocorrem em ambientes florestais, como o gato-maracajá, tendem a ser menos estudadas considerando as dificuldades logísticas de trabalho e de visualização dos indivíduos [5].

O armadilhamento fotográfico é um método muito utilizado atualmente por pesquisadores que trabalham com espécies raras e de difícil observação. Esse método se popularizou por ser não-invasivo e por produzir uma variedade de tipos de dados possibilitando diferentes análises como densidades populacionais [11]e padrão de atividade [19],tornando-se uma importante ferramenta para avaliar características ecológicas espaço-temporais de espécies raras e de difícil observação direta[20].

Objetivos

Informações sobre a densidade de populações são requisitos básicos no âmbito da conservação de espécies [21] e estudos de padrão de atividade melhoram nosso entendimento sobre aspectos comportamentais e ecológicos [22]. Neste contexto, o presente estudo pretende estimar a densidade populacional e o padrão de atividade do gato-maracajá em áreas distintas do bioma Mata Atlântica no sul do Brasil e analisar os potenciais efeitos da perturbação humana sobre a ecologia dessa espécie aparentemente tão dependente da floresta. Para tal, foram utilizados modelos espacialmente explícitos de captura-recaptura [21,23] para as análises de densidade populacional e o padrão de atividade foi estimado a partir dos registros horários de ocorrência da espécie, testando a uniformidade de sua atividade nas 24h; além disso, foi calculada a sobreposição temporal entre o gato-maracajá e outras espécies que possam afetar seu padrão de atividade [24].

Estrutura da dissertação

A dissertação está organizada em três capítulos: capítulo introdutório, capítulo principal e capítulo conclusivo. A primeira parte apresenta uma introdução geral. O segundo capítulo está em formato de manuscrito em inglês a ser submetido para a revista científica PLOS ONE. Por último é apresentada uma conclusão geral. A formatação da dissertação seguiu as regras de formatação do periódico a ser submetido o artigo, disponíveis em:https://journals.plos.org/plosone/s/submission-guidelines. Visando facilitar a leitura, figuras e gráficos foram apresentados ao longo do manuscrito, na sequência de sua citação no texto.

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CAPÍTULO II

Density estimates using spatial variation models and activity patterns of margay (*Leopardus wiedii*) in the southernmost Atlantic Forest

Introduction

The establishment of appropriate conservation strategies depends the population density information among other aspects[1]. The knowledge of populations size in different areas and time allows to identify: declining population; geographic range size and fragmentation; small or very small population size, restricted distribution populations, etc.[2]Those topics are some of the criteria used to evaluate if a taxon belongs in a threatened category in IUCN Red List[2]. Thus it is crucial to have studies that applied population analyses to assess information of population trends [3], population viabilities[4], or populations status [5]. Another relevant characteristics that should be considerate to determine conservation actions is the ecology and behavioral features [2]. Activity pattern studies, for example, can provide investigation concerning niche segregation between intra-guild species coexistence [6–9], predator-prey species interactions[10], temperature preferences and responses to the seasonal variations[11], relationships among activity pattern and environmental variables(*e.g.*lunar or artificial lights [12–14] andanthropogenic disturbances [15–17]). In this sense, the knowledge about daily activity patterns should improve our understanding of behavioral and ecological aspects of species.

Small and medium-sized South American cats are amongst the least studied felids worldwide[18]. The margay (*Leopardus wiedii*), a small solitary species, is one of the least studied Neotropical felids, although its distribution ranges from northern Mexico to Uruguay and northern Argentina[19–21]. Margays are possibly the most arboreal of all felids, and thus seem to be strongly dependent on forested habitats [22,23]. Indeed, margays has morphological adaptations that make them excellent climbers, such as long tails that they use for maintaining balance and ankles that rotate up to 180º [21,24]. This particular ecological trait suggests that margays could be more threatened by deforestation than non-arboreal species. However, the species' ecology is poorly known, especially in the Atlantic Forest biodiversity hotspot [25], although it seems to be one of the areas of highest habitat suitability for the species [23].

Nowadays, the Atlantic Forest is restricted to small forest fragments in a matrix of human-dominated landscape, occupying less than 12% of its original area [26]. This situation suggests that species strongly dependent on the forested nature of the biome, as the margay, may be facing regional extinction in the short term. This may be even more problematic in the southernmost range of the biome, which represents the southern distribution limit of the margay [27], where it should present naturally lower densities.

However, density estimates for the margay across its distribution range are few explored, when compared to other felid species. Studies carried out in forested areas of México, estimated density changing between12 to 81individuals/100km²[28,29]. According IUCN [9], there are estimates from Brazil ranging from one to five individuals/km²and up to 15 to 25 individuals/ 100 km², however it was not possible to access the specific location of studies [27,30,31]. For the Atlantic Forest, the density estimates was 22 individuals/100 km² (T. Oliveira, pers. comm.).The studies, however, used traditional capture-recapture models, which fail to assess the spatial structure of the ecological processes[1]. Spatial capture-recapture (SCR) models should be able overcome this limitation by incorporating spatial information from the individual detections[1,32,33].Opposing to density estimates, a much greater number of studies has described activity patterns of margay across its range, suggesting that, overall, the species is nocturnal [6,8,17,28,29,34–37], though in some areas it may show a cathemeral pattern [38].

The Brazilian National Action Plan for the Conservation of Small Cats (CENAP/ICMBio) has seven specific objectives, where one is to conduct studies that assess how different natural and anthropogenic processes influence the small feline populations [39]. Therefore, here we aim to estimate population density of margay using spatial capture-recapture models; and to describe its activity patterns across a range of areas with different levels of human disturbance in the southernmost limit of the Atlantic Forest. We created two hypotheses: i) density differs across study areas; ii)activity patterns is crepuscular/nocturnal, but it can changes in each study area. We expect margay densities to respond positively to forest cover and negatively to human disturbance and ocelot presence. Besides their dependence on forest cover, margays also seem to respond to the presence of other felids. In fact, Oliveira et al. (2010) reported an 'ocelot effect', suggesting that the presence of the ocelot, *Leopardus pardalis*, negatively impacts densities of margay, as well as those of the remaining smaller spotted cats [30].

Additionally, *L. wiedii* populations should present more nocturnal activity in areas of highest levels of anthropogenic modification (with more occurrence of domestic and exotic species)[15]. Ultimately, we aim at generating subsidies for the definition of management actions towards margay conservation in the southern extreme of its distribution, where it should be particularly sensitive to population fluctuations.

Material and Methods

Study area

We carried out the study in six areas in Rio Grande do Sul, southern Brazil(Fig 1). This region comprises the southern portion of the species distribution [27] and the southernmost limit of the Atlantic Forest biome. The Atlantic Forest falls out the tropical climate, and semi-deciduous and ombrophylus mixed forests (*Araucaria* forests) replace the ombrophylus dense forests typical of the lower latitudes [40–42]. This region also includes the ecotone between the Atlantic Forest and the Brazilian Pampa, which increases the structural and compositional landscape complexity, with changes in climate, elevation, vegetation and, consequently, beta diversity [43–45]. Only12 % of the original area of the Atlantic Forest subsists, with the remaining area almost completely replaced by croplands [26]. Indeed, due to habitat loss and fragmentation [27,46] the margay is categorized as "Vulnerable" in Rio Grande do Sul [46,47].

We collected data from 120 sites in six areas spanning a range of habitat types and human land-use intensity, the six areas were:

I) Serra Geral National Park (SGNP)(29°08'2''S, 49°59'40''W), a federal conservation unit of strict protection, constituted by a mosaic of natural landscapes of different vegetation formations, such as araucaria forests [48], the park portion sampled in this study was in expropriation area with cattle in some patches;

II)Banhado dos Pachecos Wildlife Refuge (BPWR) (30º06'22''S, 50º52'11''W),a protected area located close to large urban centers(ca. 28km from capital city, Porto Alegre), this area is composed of large areas of plains[27,49]and forests fragments between roads and residences; two camera-trap stations ended up being installed outside of the protected area closest to human settlements, due the standard distancebetween the stations kept in the field sampling. This study area is located within an eco-tone zone between the Atlantic Rain Forest and Pampas biome[50].

III) Center for Research and Conservation of NaturePró-Mata (PROMATA) (29º28'54''S, 50º10'35''W) is a private natural heritage reserve, the largest privately protected area in the state[51]; previously occupied by small farms and agropastoral activities, this area is under natural regeneration per more than 20 years[52];

IV)Turvo State Park (TUSP) (27°08’44’’S, 53°53’10’’W), an integral protected area created in 1954, this park is one of the largest conservation units in the state[53] and the most intact area in this study;

V)a rural area close to the city of Teutônia (TEUT)in the central region of the state (29º26’36’’S, 51º47’57’’W),a non-protected area, it is a matrix of private small properties non-protected with different agricultural activities (corn and soy crops) and livestock (chicken, pigs, dairy cattle), and, in high hills of the region, there are fragments of native and exotic forests that consist in functionally forest fragments connected each other;

VI) Passo Fundo National Forest (PFNF) in the (28°18’47’’S, 52°10’55’’W), is a protected area with sustainable land use, predominantly composed by plantednative trees forest, created from the purchase of agricultural land for the implantation of an experimental plant for planting native trees[54,55].

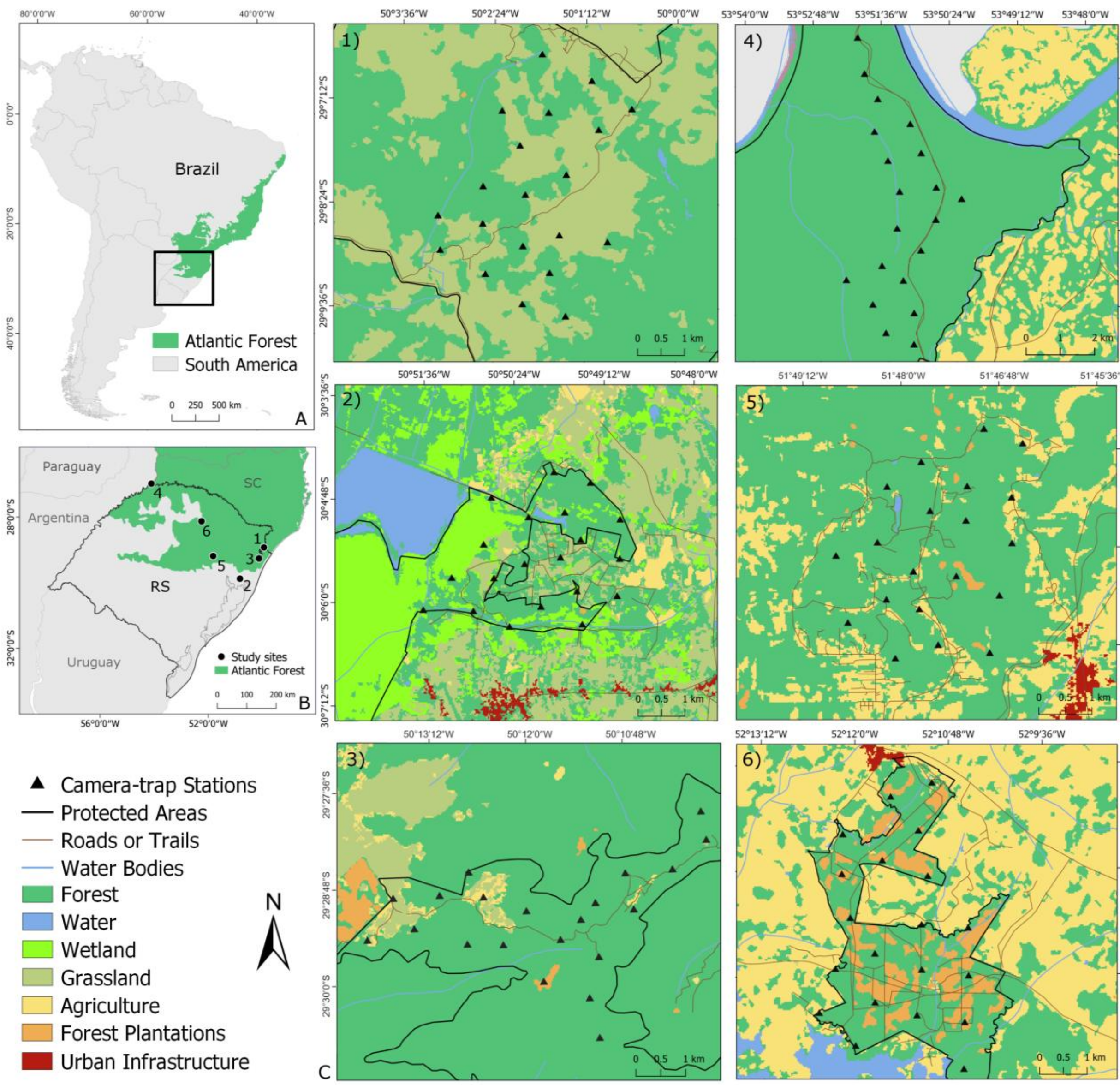

Fig 1. Study area. A) Location of the study areain the southernmost Atlantic Forest at Brazil (in black). B) Location of the six areas at Rio Grande do Sul state (black points)sampled between 2017 and 2019. C) Location of the 20 camera-trap stationsper area (1km apart):1) Serra Geral National Park(SGNP), 2) Banhado dos Pachecos Wildlife Refuge (BPWR), 3) Pró-Mata Center for Research and Conservation of Nature (PROMATA), 4) Turvo State Park (TUSP), 5) Teutônia (TEUT), 6) Passo Fundo National Forest (PFNF).

Field sampling

We collected margay records between 2017 and 2019, during summer and spring, averaging 60-sampling days (56 to 62 days) per area, to assume closed margay populations

[56]. In each area we installed 20 camera-trap stations placed ca.1 km apart(Fig 1C). This layout was defined based on the diameter of small home range estimated for the species (<1km^2)[27]. Each sampling station was composed of two passive infrared digital camera-traps, one at each side of a wildlife trail or road, totaling 40 camera-traps per sampling area. Pairing the cameras allowed recording the two flanks of the detected animals for individual identification through of the individual-specific pelage pattern[57].

We set up the camera traps, unbaited, at 30-40 cm above the ground. We programmed the cameras in video mode (10 s, with a 5 s motion triggered delay), to remain active 24 h per day, recording date and time. We used several camera models and brands: Bushnell Trophy Cam™ and NatureView® (Bushnell Outdoor Products, Overland Park, Kansas), Digital Game Camera Moultrie (Moultrie Products, LLC, Birmingham, Alabama), Browning® Trail Cameras (Prometheus Group, LLC, Birmingham, Alabama) and ScoutGuard Infrared Digital Scouting Camera (Boly Media Communications Co. Ltd., Shenzhen, China).

Density and detection covariates

Based on literature and previous knowledge of biology of margay, we defined a set of environmental covariates, including anthropogenic-related, as predictor variables for the species spatial scale, density and rate of detections. We used the individuals sex covariate for investigate the spatial scale, eight covariates for fitting models for rate of detection, and five covariates for modeling the density; we evaluate if the tree parameter differs between the areas using the covariate session for all parameters (Table 1). We excluded highly collinear predictors using the variance inflation factor (VIF), excluding variables with VIF > 6 [58](S1 Table).

Table 1. Selected covariates and respective predicted effects on spatial-scale, on density and rate of detection of margay cat.

Covariate (units)	Code	Description/ Source	Prediction
Density			
Vegetation cover (1km²)	ndvi	Normalized Difference Vegetation Index Values range from 0 (non-forest) to 1 (dense forest cover) MODIS Product generated by the Land Processes Distributed Active Center (LP-DAAC)[59]	Density will be higher in areas with higher vegetation cover
Distance to water (1km²)	diswater	Euclidean distance raster created in ArcGis based on shapefile of water bodies of the Regional Executive Organization for Environmental Protection [60] Values range from 0 to 10km	Density will be higher closer to natural water bodies
Human population density (1km²)	popdens	Estimate of human population density (it ranges from 0 to 10000 people per square kilometer) Socioeconomic Data and Applications Center; Gridded Population of the World, Version 4 (GPWv4) for2015 [61]	Density will decrease with increasing human densities
Distance to roads (1km²)	disroads	Euclidean distance raster created in ArcGis based on shapefile of water bodies of the Regional Executive Organization for Environmental Protection[60]; missing roads included manually through own observations Values range from 0 to 10km	Density will be higher furthest from roads(paved roads, unpaved roads and trails)
Rate of Detection			
Small mammals (per hour)	smam	Number of independent detections (>1 h apart) of small mammals (small rodents and marsupials) per site-by-occasion	Rate of detection will increase with the presence of small mammals, potential prey of the species
Small birds (per hour)	sbirds	Number of independent detections (>1 h apart) of small birds (Passeriformes) per site-by-occasion	Rate of detection will increase with the presence of small birds, potential prey of the species
Ocelot (per hour)	ocelot	Number of independent detections (>1 h apart) of ocelots (*Leopardus pardalis*) per site-by-occasion	Rate of detection will decrease with the presence of ocelot, potential competitor or intraguild predator
Dogs (per hour)	dogs	Number of independent detections (>1 h apart) of dogs (*Canis familiaris*) per site-by-occasion	Rate of detection will decrease with the presence of dogs, potential predators of margay

Cats (per hour)	cats	Number of independent detections (>1 h apart) of cats (*Felis catus)* per site-by-occasion	Rate of detection will decrease with the presence of cats, potential competitors of margay
Trigger time (seconds)	trigger	Trigger speed of each camera-trap brand/model, and time delay necessary for the camera to shoot a picture once an animal has interrupted the infrared beam within the camera's detection zone (from the instruction manual[a])	Minor response time will increase the rate of detection of margay
PIR detection range (meters)	pir	Passive Infra-Red (PIR) distance detection range of each camera-trap brand/model (from the instruction manual[a])	Higher PIR detection range values, i.e., larger detection zone, will increase the rate of detection of margay
Spatial-scale			
Sex	sex	Sex of individuals (female, male or undetermined)[62]	Spatial use will differ between the sexes
Sessions[b]	session	Different trapping areas with spatial independence[62]. Which area are consider a session.	The density will differ between the areas

[a] we used the setting best camera-trap model to represent the camera-trap station (site).

[b] we used this covariate for all parameters tested.

Density modeling

We identified individual margays from the videos based on their unique spot patterns (Fig 2) and determined the sex of each individual, whenever possible, through the presence/absence of male gonads. We used spatial capture-recapture(SCR) models[1,63] following the workflow of the package *oSCR* 0.42.0 [62,64] in R 3.6.0[65]with multi-session sex-structure models to investigate the population density (*D*), the rate of detection (*p*) and the space use (σ) for margay in the study areas.

Fig 2.Process of individual margay identification. A and B are photographs of two different individuals. B and C photographs of the same individual recorded in separate occasions. Individual identification is based on the unique coat pattern on the front right leg and neck (white circle).

Each sampling area was considered as harboring a distinct margay population, then each one represents an independent single “session” for the analyses. We removed from the analyses the areas with low records. To create the *oSCR* data object, a single EDF file (encounter data file) with information on the individual encounter history data for all areas(session, individual ID, trap, occasion, sex) was linked with the TDF files (trap deployment file) of each session. The TDF files contained name and coordinates of each site (camera trap station), the trap-by-occasion binary operation data (1 = operational, 0 = not operational) and trap-specific covariates that either varied with occasion (time varying) or were the fixed site covariates(Table 1).The number of occasions was the same among sessions(60 occasions), except for PFNF(56 occasions).An important component of the SCR analysis is the state space (*S*), that in *oSCR* is required for each session [62]. The state space data object (ssDF- state space data frame) was created, by defining a buffer distance around the camera traps and a specific resolution defining the state-space centroids, based on the session-specific trap coordinates. Following Sutherland et al. (2019), we used a buffer distance of ca. four times the space use parameter (σ) estimated and a resolution value of half σ, with the values of 2000m and 250x 250, respectively (Fig 3). We clipped out non-habitat points (e.g. water bodies),categorized using the MapBiomas[66] raster, from the buffers to avoid bias in the density estimates[1,67].

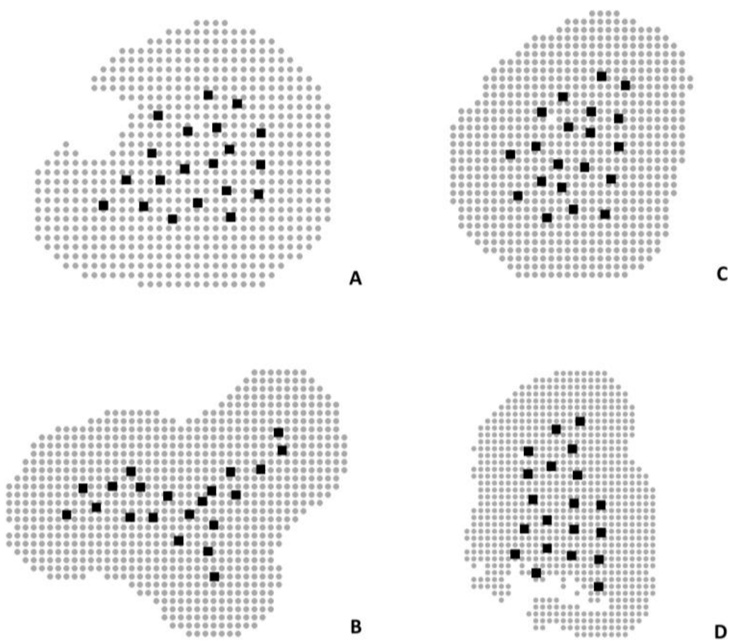

Fig 3.State spaces created for the sampled areas. The black squares are the locations of the camera-trap stations and grey points are the pixel centroids of the state space representing the sampling area. A) Banhado dos Pachecos Wildlife Refuge (BPWR), B) Center for Research and Conservation of Nature Pró-Mata (PROMATA), C) Teutônia (TEUT), D) Passo Fundo National Forest (PFNF). Note the water coordinates removed in A and D.

We used a three-step approach for modelling density of margay: 1) first we analysed the space used by the individuals, fitting the σ parameter models with covariates, as the sex (female or male) and the sessions. In this models we allowed *D* and *p* parameters to be constant *D*~1; *p*~1,σ[covariate]; 2) in the second step we investigated potential effects of covariates in the rate of detection (*p*)of margay, including sex, session, and constant or time-varying trap-level covariates[62]. In this step the σ parameter was set accordingly to the best model on resulting from step 1, while the *D* parameter continued to be set as constant (*D*~1)(D~1,p[covariate], σ[first step]); 3)in this final step we allowed the *D* parameter to vary as a function of a single covariate or of a additive combination of two (D~[covariate], p[second step], σ[first step]). The models built in all steps represent our biological hypotheses regarding the effects of covariates on margay density (*D*), rate of detection (*p*) and spatial scale (σ).We ranked the models using the Akaike Information Criterion (AIC) [68], considering equally fitted models those with ΔAIC ≤ 2[68]. The covariates present in the top model or models were considered as possible determinants of species density, rate of detection and spatial use.

Activity patterns

Activity pattern of margay was evaluated using date and time of the camera-trap records. To maintain temporal independence between the records and avoid autocorrelation, we only considered those with at least a 1-hour gap[10,69]. We applied the same approach to all the other species predicted to affect the activity pattern of the margay, including possible preys (small mammals and small birds), and possible wild competitors, the ocelot, and exotic/domesticated species as domestic dog, cat, cattle and boar records.

Using the package *circular*0.4-93[70] in R, we applied the Watson's Two-Sample Test of Homogeneity to compare pairwise the distribution of activity of margay, small mammals, and small birds throughout time between the studied areas. Because there were no significant differences in margay and small mammals patterns among the sampling areas, we merged the record data for the whole region and tested for uniformity of activity over 24 hours using Rao's Spacing test for each. However, for small birds tests were significant, and then we only estimated the activities of this group per study area (see Table 5).

We compared activity of margay with that of the other species estimating the coefficient of overlapping (Δ) per area. We used the package *overlap* 0.3.2[71]in R [72]. The coefficient of overlapping (Δ) ranges from 0 (no overlap) to 1 (complete overlap), which describes graphically through a kernel density curve [71,73]. We used the threshold proposed by[7]to classify the degree of overlap between species. We adopted the estimator $\Delta_{1,}$ for small samples(n>75)[71,73] and performed smoothed bootstraps, with 1000 resamples,to obtain confidence intervals of the Δ_1 estimator [73].

Ethics statement

Research permits to all conservation units were obtained from Brazilian Ministry of the Environment (permits SISBIO-49050 and SISBIO-64647-1); and from Environment Secretary of Rio Grande do Sul state (permit SEMARS-588), as well as directly from the landowners in private land. During this study no animals were captured or handled, and thus no additional permits or protocols were required by the Brazilian law.

Results

Field sampling

We obtained a sampling effort of 7220 camera trap nights and 66 independent margay records across the six sampling areas; six of these were in BPWR, 27 in PROMATA, 17 in TEUT, 12 in PFFN, two in SGNP and two in TUSP. These two latter were removed from subsequent statistical analysis due the small sample number.

Also, we obtained 3089 independent records (1 hour-gap)of small birds (Columbidae and Passeriformes), 289 of small mammals (small rodents and small marsupials) and seven of ocelot (*Leopardus pardalis*). In addition we obtained exotic and domestic species independent (1 hour-gap) records:51of domestic cat (*Felis catus*),75 of domestic dog (*Canis familiaris*), 29 of wild boar (*Sus scrofa*), 51 of cows or horses (*Bost aurus, Equus caballus*); some of these were found only in some of the sampled areas (S2 Table).

Population density estimates

We were able to individually identify 23margays,in the four areas considered for analysis: two in BPWR,10 in PROMATA, six in TEUT, and five in PFNF. We identified the sex of 19 individuals and four individuals had the undetermined sex. We discarded from the analyses seven records in which individual identifications were not possible, due the low quality video, totalling 55 available records for the density analysis. The individual encounter frequency ranged from six captures of one individual in the same trap, to only a single capture event (it happened with eight individuals). The four trapping areas and the respective state space are shown in Fig 3.The density estimate from the top-ranked *oSCR* model varied between the areas: 9.6±6.4individuals/100km² in BPWR; 37.4±15.1 individuals/100km² in PROMATA; 29.6±11.4 individuals/100km² in TEUT; 28.4±12.5individuals/100km² in PFNF(Fig 4, Fig 5). The top-ranked model presented variation in the three estimated parameters.

For the first step, the best model was the only one with ΔAIC ≤2 and it also represented 79% of AIC weight (Table 2). In the spatial scale of detection, we found sex influencing the movement σ parameter(β= 0.69, 0.18 – 1.20CI), which was larger for males (1.19 km) than for females (0.59 km), this covariate was maintained in the following models (Fig 6).In the second step we ran 13 alternative models, two of them were the best (ΔAIC<2) with the weight of both representing 54% of the models(Table 3). The top model estimated a positive small birds influence for margay rate of detection (β=0.227 ± 0.09SE [0.04 - 0.42 CI], P=0.02, weight=39%), and the second best model indicated a similar influence of this covariate, and an additional positive effect in the rate of detection(*p*) of small mammals, this one was not significant (β= 0.11±0.43 SE [-0.72 – 0.96 CI],P=0.794)(Fig 6).Because biologically it makes sense that detections of margay respond to the presence of potential prey, we choose the second ranked model as best fitted, and kept it for the variation density models. From the nine candidate models in the third modelling step, the top model included only vegetation cover as density covariate, with 33% of the weight model(Table 4), positively influencing density, and the 95% confidence interval does not include 0 (β=5.81±3.01, SE [-0.09 – 11.72 CI],P=0.05),(Figs 6 and 7). We disregard the second and third models, that represents together 24% of the weight models, due that the covariates (distance of water and population density) are none statically significant in the models. Density estimates varied among studied areas (Fig 5);besides the model including the session covariate (comparison among areas) indicates significant differences between the densities in BPWR and PROMATA (P= 0.04),however, this model was not well ranked(Table 4).

Table 2.Candidate set models evaluating the role of covariates on spatial scale(σ) of margay(AIC: Akaike Information Criteria for small sample sizes; ΔAIC: difference between AIC of each model and the model with the lowest AIC; w:weight).

Density (D)	Detection (p0)	σ	Log-likelihood	Nº of parameters	AIC	ΔAIC	w
1	1	sex	358.24	4	726.47	0.00	0.79
1	1	sex+session	357.69	7	729.37	2.90	0.19
1	1	1	363.20	3	734.40	7.93	0.01
1	1	session	360.89	6	735.78	9.31	0.01

Table 3.Candidate set models evaluating the role of covariates on rate of detection (p0)of margay(σ:spatial scale, AIC: Akaike Information Criteria for small sample sizes;ΔAIC: difference between AIC of each model and the model with the lowest AIC; w: weight).

Density (D)	Detection (p0)	σ	Log-likelihood	Nº of parameters	AIC	ΔAIC	w
1	sbirds	best	355.89	5	723.78	0	0.39
1	sbirds+small	best	355.86	6	725.72	1.93	0.15
1	1	best	358.23	4	726.47	2.68	0.10
1	dogs	best	357.52	5	727.04	3.26	0.07
1	cows	best	357.75	5	727.50	3.71	0.06
1	trigger	best	358.07	5	728.14	4.35	0.04
1	pir	best	358.11	5	728.22	4.43	0.04
1	ocelot	best	358.17	5	728.35	4.57	0.04
1	small	best	358.18	5	728.37	4.59	0.03
1	trigger+pir	best	357.57	6	729.14	5.35	0.02
1	session	best	357.60	7	731.20	7.42	0.00
1	1	1	363.20	3	734.40	10.61	0.00
1	cats	1*	363.04	4	736.09	12.30	0.00

* The model D(.)*p*(cats)σ(sex) did not worked, we then created a model D(.) *p*(cats)σ(.) in order to not exclude the use of "cats" covariable.

Table 4.Candidate set models evaluating the role of covariates on density (*D*) of margay (σ: spatial scale, AIC: Akaike Information Criteria for small sample sizes;ΔAIC: difference between AIC of each model and the model with the lowest AIC; w: weight).

Density (D)	Detection (p0)	σ	Log-likelihood	Nº of parameters	AIC	ΔAIC	w
ndvi	best	best	353.46	7	712.57	0.00	0.37
ndvi + diswater	best	best	353.36	8	714.56	1.99	0.13
popdens	best	best	354.50	7	714.73	2.16	0.12
diswater	best	best	354.72	7	715.37	2.79	0.09
disroads	best	best	354.72	8	715.67	3.09	0.07
1	best	best	355.86	6	715.69	3.12	0.07
popdens + disroads	best	best	353.96	8	716.14	3.57	0.06
session	best	best	353.14	9	716.84	4.27	0.04
1	1	1	363.20	3	734.40	21.83	0.00

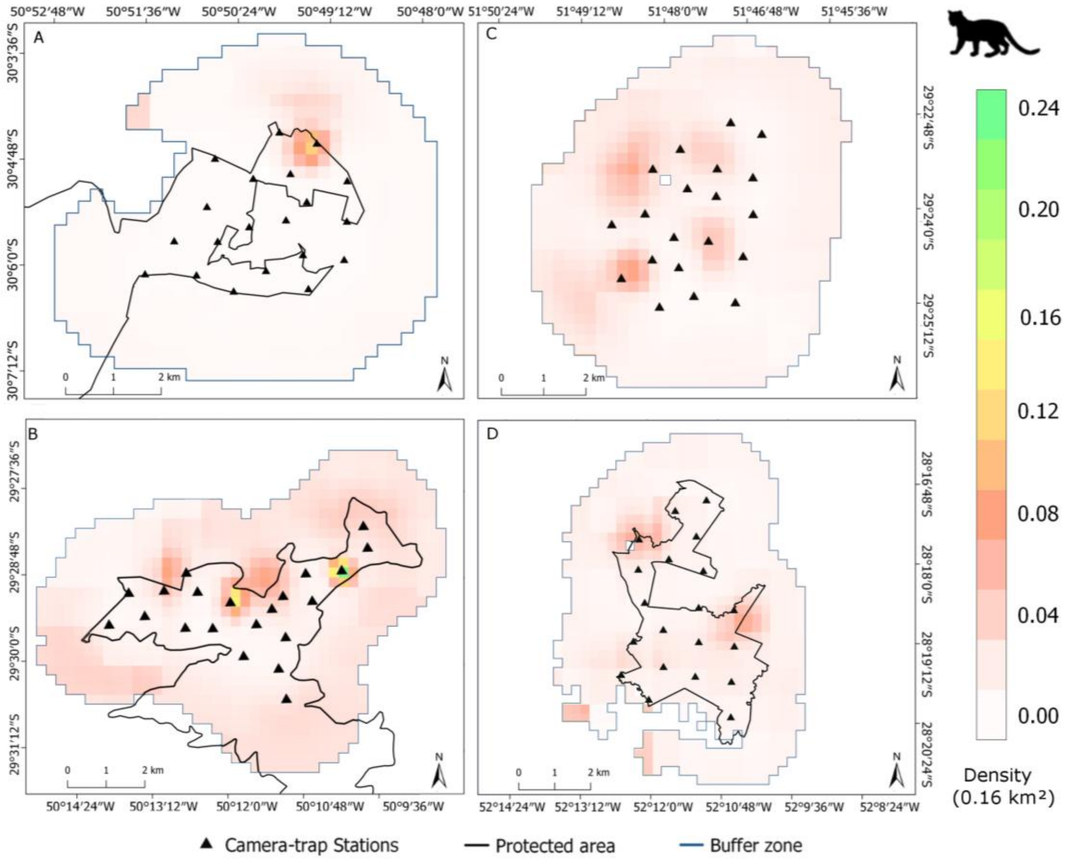

Fig 4. Margay density maps in the sampled areas. Realizeddensitybased on estimates of the best SCR model.Model derived from the camera-trap sampling. A) Banhado dos Pachecos Wildlife Refuge (BPWR), B) Center for Research and Conservation of Nature Pró-Mata (PROMATA), C) Teutônia (TEUT), D) Passo Fundo National Forest (PFNF).Water bodies were removed in A and D. Density scales are specific to each map. Pixel resolution at 250 x 250m; thus, density scales are in margay per 0.16 km².

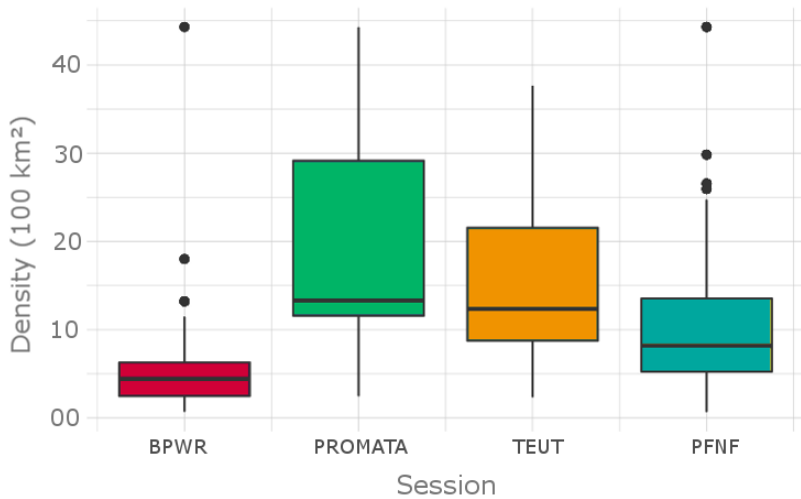

Fig 5. Margay density estimates for the sampled areas. Density estimatesper 100 km².Each session corresponds to a sampling area: 1) Banhado dos Pachecos Wildlife Refuge (BPWR), 2) Pró-MataCenter for Research and Conservation of Nature (PROMATA), 3) Teutônia (TEUT), 4) Passo Fundo National Forest (PFNF).The length of each box shows the range within density estimates values. The median value is represented by a transverse bar inside the box. The black points area outlier values.

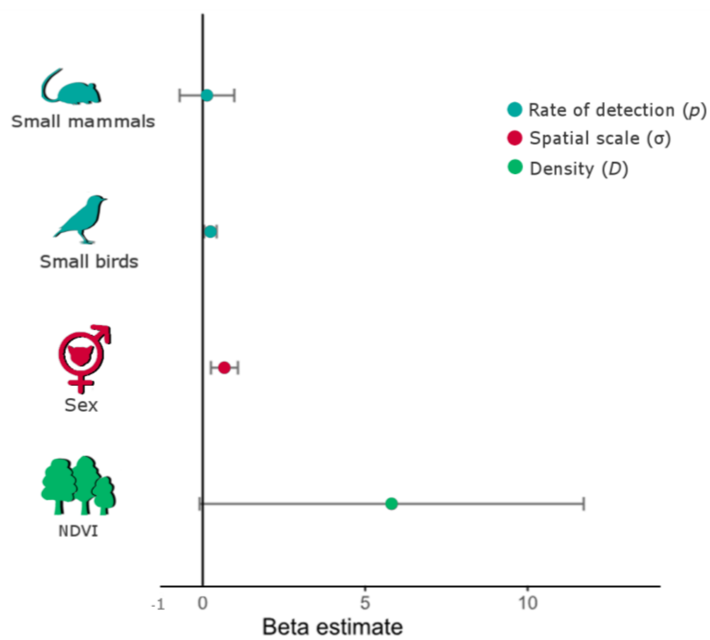

Fig 6.Covariate effect on the density (*D*), spatial scale (σ) and rate of detection (*p*) of margay in the study area. P-values for each of the covariates on the basic parameter based on estimates from the spatial capture–recapture best model**:** vegetation cover/ndvi (0.050), sex (0.008), behavior (0.001), small birds (0.030), and small mammals (0.770).

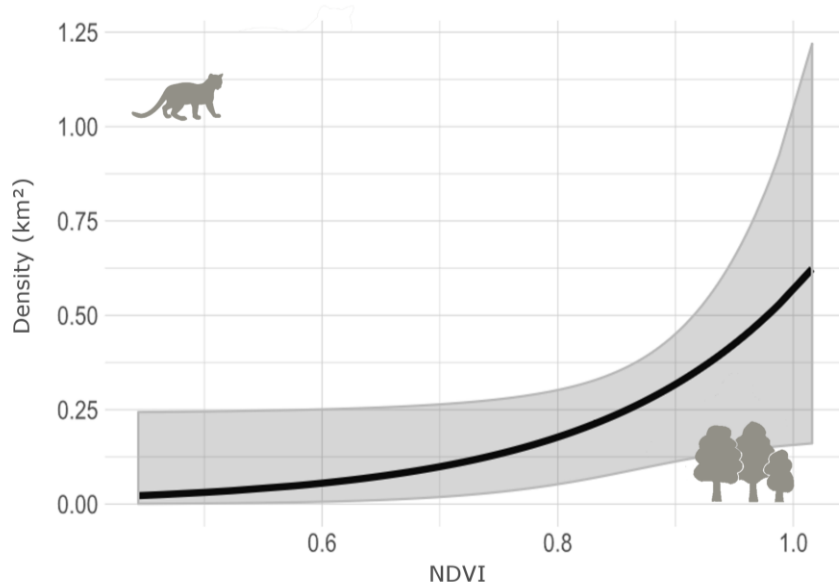

Fig 7.Effect of vegetation cover (NDVI) on the estimative of density of margay (km²) in the study area.

Activity patterns

For evaluating the activity pattern of margay we considered 62 independent records, excluding the records of SGNP and TUSP areas (n=2 for both). Because the margay and small mammals sampled areas were homogeneous among each other (Table 5), uniformity of the daily and overlapping patterns was tested clumping all areas. The margay showed a statistically significant non-uniform activity pattern (Rao's Spacing Test, $r = 261.29$; $P < 0.001$), with a mean direction between 01:00 and 02:00am (Fig 8A). Regarding the activity patterns of the margay potential prey, small mammals also presented a non-uniform activity pattern throughout the daily cycle (Rao's Spacing Test $r = 341.31$, $P < 0.001$) with a mean direction of 00:00(Fig 8B).Temporal coefficient overlap between margay and small mammals was 0.73 (0.62 – 0.87 CI) (Fig 8C).

Table 5.Estimates of Watson's Two-Sample Test of Homogeneity of margay cat and its potential prey; Estimates (P-values).

		Watson's Two-Sample Test			
		BPWF	**PROMATA**	**TEUT**	**PFNF**
Margay	**BPWF**		0.07 (>0.10)	0.06 (>0.10)	0.05 (>0.10)
Small birds		.	0.69 (<0.00)	0.91 (<0.00)	0.47(<0.00)
Small mammals			0.15 (>0.10)	0.08 (>0.10)	0.08 (>0.10)
Margay	**PROMATA**			0.10 (>0.10)	0.11 (>0.10)
Small birds		.	.	1.11 (<0.00)	0.55 (<0.00)
Small mammals				0.10 (>0.10)	0.17 (>0.10)
Margay	**TEUT**				0.04 (>0.10)
Small birds		.	.	.	0.32 (<0.01)
Small mammals					0.13 (>0.10)
Margay	**PFNF**				
Small birds		.	.	.	.
Small mammals					

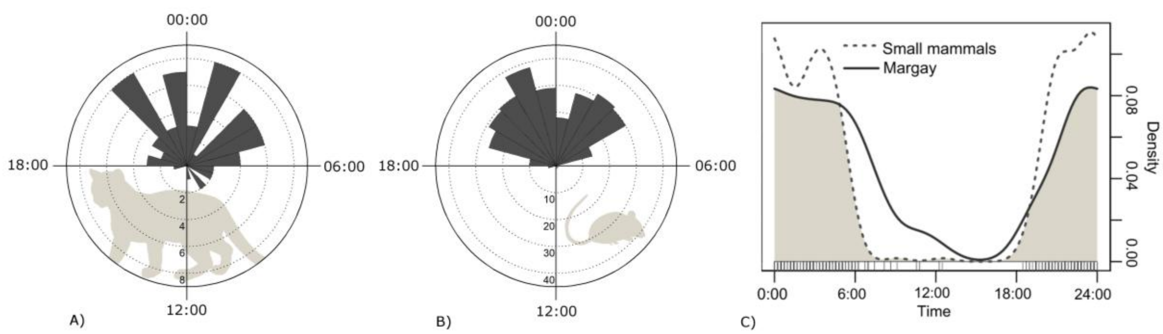

Fig 8.Daily activity patterns and temporal overlap of margay and small mammals for the study area.A) margay, B) small mammals, C) temporal overlap of margay and small mammals.

Overlap coefficients between margay and dogs ranged from 0.24 to 0.56 (Fig 9). The temporal overlap between margay and domestic cats was only possible for BPWR and TEUT, with 0.48 and 0.73 coefficient overlap, respectively (Fig 9). The lowest temporal overlap estimated was with humans, cattle and small birds (Fig 9).Temporal overlap between margay and ocelot, and margay and wild boar were estimated only for PROMATA: 0.45 and 0.44, respectively (Fig 9).

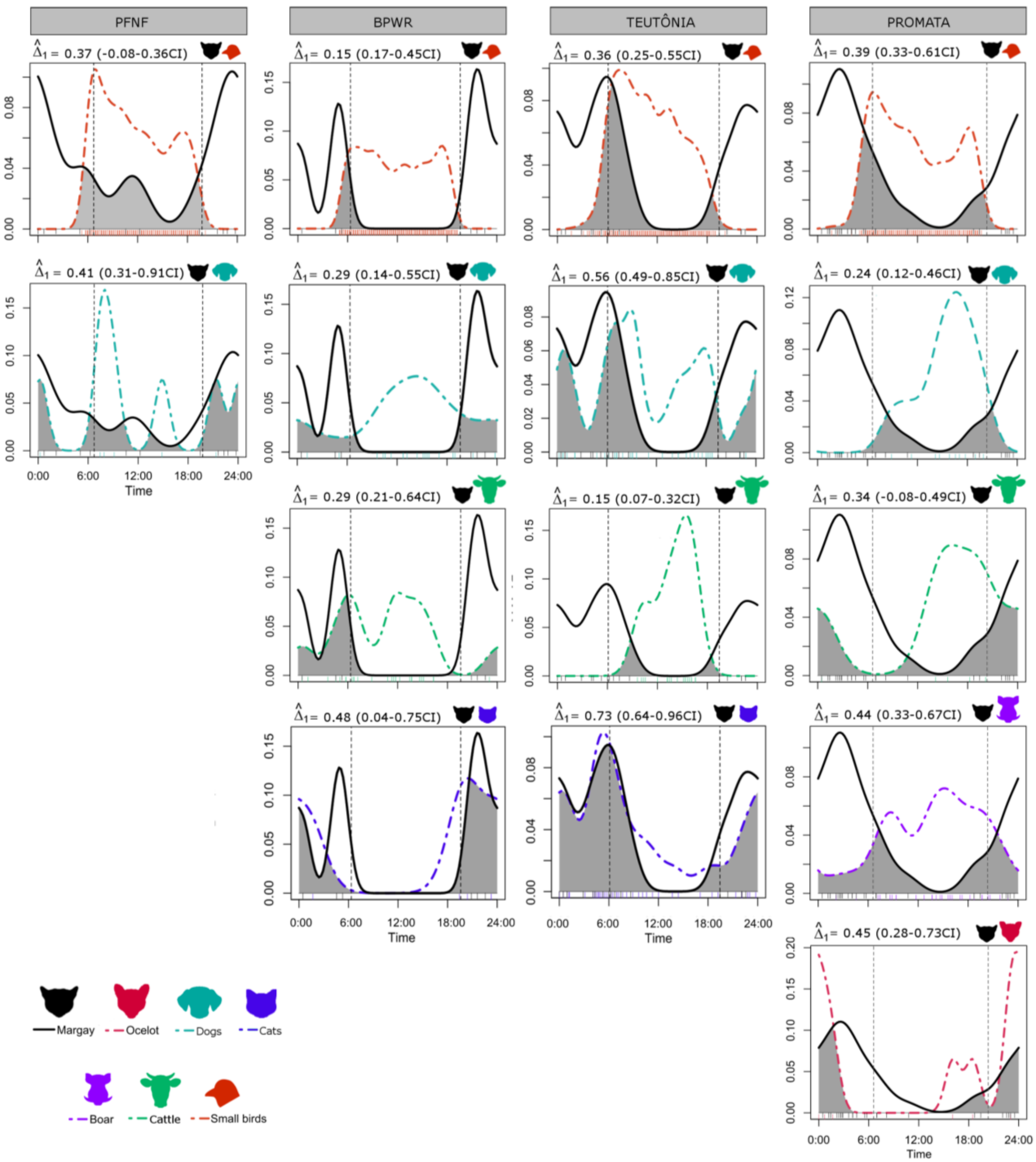

Fig 9.Activity and temporal overlap (Δ_1,CI) of margay and the evaluated species in the study area. Overlap coefficient (Δ_1) between pairs corresponds to the shaded area. The dotted grey lines represent sunset and sunrise time during the sampled period in each area (S3 Table).

Discussion

Few studies estimated density of margay [28,34,74] and compare temporal activities of Neotropical small cats with human related species or human impacts [17,75]. Our study represents the first large-scale evaluation of density and activity patterns of margay for the southernmost limit of the Atlantic Forest, and can be used as a model for other studies seeking small felids conservation.

Margay: an undoubtedly forest cat, sensitive to human modifications of the landscape

In the southern limit of the Brazilian Atlantic Forest, the margay seems to occur in higher densities in areas with higher vegetation cover, as hypothesized mostly due to the known arboreal habit of the species[20,22]. This arboreal behavior also seems to contribute to the potential relevance of small birds in its diet [38,76]; indeed, the rate of detection of small birds positively impacted rate of detection of margay and though we did not evaluate diet composition, this pattern suggests that these two groups, small mammals and small birds, constitute important food resources for the species[38,76]. Males also seem to use larger areas (1.19 km) when compared with females (0.59 km). A similar pattern was already reported by Carvajal-Villarreal et al. (2012) for Mexican margay populations, who estimated average home ranges of 4.1 km^2 for males and of 0.72 km^2 for females.

Densities of margay respond to environmental changes, particularly those of human-origin and, apparently, result also from biotic interactions. In the southernmost limit of the Atlantic Forest, highest densities of margay occurred in PROMATA, it is the largest federal privately protected area of Rio Grande do Sul and of low ocelot occurrence. This area presents low human land-use intensity and is in large part occupied by primary forests, and forest and natural fields under natural regeneration from agricultural use for the last two decades[77]. The existence of high densities of margay indicates that, unless a landscape is profoundly modified, active management practices towards forest regeneration should allow the persistence of a significant number of individuals of this species in a more reduced area, most likely because arboreal shelters and prey exist in sufficient numbers to reduce intraspecific competition[78,79]. Consistently, the lower density estimate within our study area was obtained for BPWR. In this area are minimal forest areas and, besides, it is located close to the largest urban areas of the Rio Grande do Sul state (ca.28 km from the capital of state Porto Alegre, 1,409 million of habitants), suffering the expected associated impacts: illegal hunting, water drainage, and intensive agricultural schemes, particularly with rice production [80]. Still, originally the area should not have harbored higher densities of margay, because most of the natural habitats are flooded [81,82], and suitability models suggest the species to be negatively correlated to flooded grasslands and savannas[23]. Additionally, this area is included in a ecotone zone between the Atlantic Forest and the Brazilian Pampa, including significant areas occupied by typical open-area physiognomies: marshlands, restingas and dry fields[81]. Marginal occurrence of the margay in Pampa landscapes should be tied with the natural forest fragments of the biome, which occur mostly bordering water courses [23].

TEUT and PFNF presented intermediate densities suggesting similar responses of margay populations in these two areas. PFNF is a relevant representative of the Araucaria Forest physiognomy in the southern Atlantic Forest, showing a gradient of regeneration after somewhat intensive human use in the last decades[54,55]. Although a conservation area of sustainable use, it is located in a matrix of monocultures and livestock production, representing an isolated fragment with low connectivity with other forest fragments; agriculture and illegal hunting represent the major negative impacts on native fauna. These characteristics may explain why, being a protected area, with somewhat similar features to PROMATA it presents densities of margay closest to TEUT an altogether non-protected area. TEUT is basically an area of small properties with different agricultural uses, harboring forested fragments in those areas considered unsuitable for crop production. The estimated margay density is higher in this region than that estimated for other neotropical cats, as the southern tiger cat (*Leopardus guttulus*) and the jaguarondi (*Herpailurus yagouaroundi)* (8 individuals/100km^2 and 4 individuals/100km^2, respectively[83]), that used others methods to obtain the population density.

We were unable to estimate densities for TUSP and SGNP, due the small number of records obtained for these areas. In TUSP low margay occurrences contrast with high ocelot densities (14–66 (13 – 41 CI) individuals/100km^2 [84] and 15.5±6 individuals/100km^2 [85]). The suspected ‘ocelot effect’ may be affecting the density of margay; still, because this is quite a pristine area, with high native tree cover we expected to collect enough data to at least estimate the density in the area, which was not the case. We suspect that the somewhat intensive presence of exotic/domestic fauna within the park (cattle, boars and buffalos), as several areas are still ongoing private expropriation, could explain the low number of margay records in SGNP[23]. Additionally, the area is a mosaic of forest and open field, compared with other areas, SGNP is the sampled area with more grassland habitat we sampled, this may also affected the low records of margay, since the species in positively influenced by vegetation cover.

Generally, our density estimates were higher than those estimated for other regions of Atlantic Forest 22individuals/100 km^2 (T. Oliveira, pers.comm.,[31]), but still smaller than those estimated for southwest and southeastern Mexico, which varied from 12 individuals/100 km^2[28]to 81individuals/100 km^2[29], respectively. Overall, margay densities seem to respond to forest habitat conversion levels, with higher estimated values for more preserved regions and lower values for more human-altered landscapes and higher intensities of use (with human settlements, agricultural activities, presence of exotic species); estimated intermediate density values in areas of moderate human use suggest that conservation strategies focusing on these less pristine and even fragmented areas may have positive effects on the density of margays across its distribution range.

Margays prefer the night: avoiding antagonists or simply following prey?

The temporal activity of margay was nocturnal in all our studied areas of the southernmost Atlantic Forest, consistently to what has been found in other studies [17,28,29,37,86].In fact, our results did not support our prediction of changes in the activity pattern in response to human disturbance: margay was strictly nocturnal across a range of human-altered landscapes. This pattern probably co-evolved as a response to the activity pattern of their preferential prey – small mammals[76] – but may have also been intensified in the last centuries, by human disturbance[15], including hunting pressure and occupancy by antagonist species – potential predators such as domestic dogs, competitors such as domestic cats, or simply antagonists in the sense of profound habitat modifiers such as wild boars [75,87,88].

Small mammals are recognized as most important dietary item of margay[38,89,90]; similar nocturnal activity patterns probably co-evolved over millions of years increasing on the one hand the chances of prey capture by the margay, but on the other, for the potential prey, higher possibilities of escaping than if they were diurnal. However, small birds, also an important item in diet of margay [38,76], are mostly diurnal, suggesting that if eaten in our study areas, they are probably preyed upon while resting and are more exposed to predation[91].

Ocelot activity did not overlap significantly with that of the margay, and that is a pattern already described for southeast remnants of the Brazilian Atlantic Forest [38]. Temporal segregation facilitates species coexistence, by reducing competition for space and prey[6,38,92].However, it is important to notice that the number of ocelot records in our study was small, and it will be necessary more data in future to support this result. Apartfrom temporal segregation, segregation by vertical stratification between the ocelot and the margay still needs to be tested, as it has been suggested as the factor behind the higher activity overlap between the two species in the Argentine Atlantic Forest [17].

Temporal overlap between the margay and domestic pets (dogs and cats) were, in general, low. BPWR, PROMATA and PFNF indicated lowest overlap. However, most domestic pets were dogs, which presented diurnal activity pattern, consistently with the pattern found in other Atlantic Forest areas [93,94]. Theoretically, such low overlap suggests that domestic dogs probably do not prey upon margays. Still, they may have indirect effects, representing an important cause of decreased prey populations[95]. Domestic cats, on the other hand, revealed to be mostly nocturnal, and this was particularly evident in TEUT where a considerable higher number of domestic cat records was obtained, probably related to the higher number of human habitations [96]. Domestic cats, therefore, may represent a potential important competitor for food regarding the margay and other felids (e.g. southern tiger cat, jaguarondi), as they show similar opportunistic predatory behavior[88,97]. Disease transmission is a potential indirect negative impact resulting from the occurrence of both species in the wild, representing an additional threat to native felids [18,96–100].

We also found cattle and wild boar in some of the studied areas, although both were mainly diurnal. Potential impacts of both species on margay populations are thus probably related to changes in the landscape[101–105], especially by the wild boar, known for intense nest predation and destruction of native wildlife habitats [87,106–108].

Conclusion

To our knowledge, this is the first study specifically attempting to estimate multi-area density and activity patterns of margay, and also to compare daily activity pattern of margay with those of with human related species. We agreed with the first hypothesis, that the density will differs across study areas, once we found differences between BPWR and PROMATA densities. The other two areas seem to be in a gradient of density of margay and vegetation cover among the first ones. . We refute the second hypothesis, since the margay presents a nocturnal activity pattern in the all study areas.

We observed the margay is mostly a forest nocturnal cat, whose densities are positively influenced by forest cover and negatively influenced by intense human habitat modifications, while not changing its activity pattern across landscapes with distinct intensities of human use. Undoubtedly, large pristine forest areas, with high prey – small birds and mammals – availability, are fundamental for the persistence of dense populations of the species. However, under moderate levels of habitat modification, the margay is still able to persist – at least in intermediate densities – suggesting that the conservation of even small native forest remnants, especially those showing some degree of connectivity among them, is key for margay populations' management and conservation in the southern limit of the Brazilian Atlantic Forest.

Support Information

S1 Table. Variance inflation factor test results of the density covariates models.

S2 Table. Independent species records obtain in the study areas and the total of species records.

S3 Table. Mean and standard deviation for time of sunrise and time of sunset of the study period in each area; data obtained for the Viamão, São Franscisco de Paula, Teutônia and Passo Fundo municipalities (which include our study areas), RS, Brazil**.**

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Supporting information

S1 Table. Variance inflation factor test results of the density covariates models.

Variables	VIF score
Small mammals (smam)	2.08827
Small birds (sbirds)	1.550713
Distance water (diswater)	1.226475
Ocelot (ocelot)	1.645949
Vegetation cover (ndvi)	1.296269
Population density (popdens)	1.267173
Distance of roads (disroads)	1.802655

S2 Table. Independent species records obtain in the study areas and the total of species records.

Species	BPWR	PRO-MATA	TEUT	FNPF	Total
Small mammals (Small rodents and small marsupials)	10	16	120	143	289
Small birds (Columbiformes and Passeriformes)	1375	425	732	557	3089
Ocelot *(Leoparduspardalis)*	0	7	0	0	7
Domestic cat *(Feliscatus)*	4	0	47	0	51
Domestic dog *(Canis lupus familiaris)*	20	10	39	6	75
Wild boar *(Susscrofa)*	0	29	0	0	29
Cows and Horses *(Bostaurus, Equuscaballus)*	27	5	19	0	51
Humans *(Homo sapiens sapien)*	13	50	8	1	72

S3 Table. Mean and standard deviation for time of sunrise and time ofsunset of the study period in each area; data obtained for the Viamão, São Franscisco de Paula, TeutôniaandPasso Fundo municipalities (which include our study areas), RS, Brazil.

	Sunrise		Sunset	
	Mean	SD	Mean	SD
BPWR	06:20	0.01	19:35	0.024
PROMATA	06:36	0.009	20:20	0.002
TEUT	06:06	0.014	19:26	0.002
PFNF	06:43	0.014	19:45	0.029

*Data base collected from © 2011-2019 sunrise-and-sunset.com

CAPÍTULO III

Conclusão

Este estudo foi realizado a partir de dados obtidos com armadilhamento fotográfico em diferentes áreas da Mata Atlântica no sul do Brasil. Foi encontrada uma resposta positiva da densidade populacional de gato-maracajá ao aumento da cobertura florestal, visto que é tida como uma espécie dependente de floresta [1]. A área do PROMATA apresentou a maior densidade populacional de gato-maracajá neste estudo, sendo também a área com maior cobertura florestal utilizada nas análises de estimativas de densidade. Adicionalmente, nessa área, a elevada densidade do gato-maracajá pode estar associada ao poucos registros coletados de jaguatirica *L. pardalis*. Diferentemente de áreas como o Parque Estadual do Turvo, onde a cobertura vegetal é igualmente elevada, mas a jaguatirica parece ocorrer em maiores densidades [2,3]. Nessa área, foram encontrados poucos registros para o gato-maracajá, evidenciando um possível "efeito pardalis" como descrito por Oliveira et al. (2010) e encontrado em outros estudos [4].

Além disso, a atividade humana também parece influenciaras densidades do gato-maracajá, uma vez que locais com níveis mais elevados de atividade antrópica indicaram densidades baixas; porém, áreas com perturbação ou alteração humana moderada revelaram densidades intermédias evidenciando que, até certo nível, o gato-maracajá tolera modificações antrópicas. Os resultados obtidos para a densidade populacional da espécie, no presente estudo, foram menores do que os encontrados em outros estudos ao norte de sua distribuição, como México [5–7], porém apresentaram valores mais elevados quando comparados à outras estimativas no Brasil[8].

O padrão de atividade, como esperado para a espécie, foi significativamente noturno. Esse padrão já encontrado por estudos anteriores [5,6,9,10]. A sobreposição temporal do gato-maracajá com os animais domésticos, mas especificamente com o gatodoméstico, para a área de TEUT, foi a mais alta encontrada no estudo, o que pode indicar algum nível de competição. Encontramos uma baixa sobreposição temporal entre o gato-maracajá e a jaguatirica pra a área do PROMATA, semelhante ao já encontrado em áreas de Mata Atlântica [10], indicando uma coexistência das espécies possivelmente facilitada por essa segregação temporal [10,11]. No entanto, essa relação precisa ser melhor avaliada, devido ao baixo número de registros encontrados para jaguatirica.

Em suma, este estudo forneceu as primeiras informações de densidade populacional de gato-maracajá para o extremo sul da Mata Atlântica obtidas em larga-escala, além da caracterização do padrão de atividade da espécie ao longo de um gradiente de modificação humana. Visto que, os valores intermédios de densidade populacional foram encontrados em áreas com alterações antrópicas moderadas, sugere-se que os pequenos fragmentos florestais sejam considerados como importantes para a espécie. Essas áreas juntamente com áreas maiores e mais preservadas, em particular em unidades de conservação, são cruciais para planejamento de estratégias de conservação para *L. wiedii*.

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