Title

Range-wide factors shaping space use and movements by the Neotropic's flagship predator: the jaguar

Range-wide space use by jaguars

Authors

Jeffrey J. Thompson[1,2*], Ronaldo G. Morato[3], Bernardo B. Niebuhr[3,4,5,6], Vanesa Bejarano Alegre[4], Júlia Emi F. Oshima[4], Alan E. de Barros[7], Agustín Paviolo[8,9], J. Antonio de la Torre[10,11], Fernando Lima[4,12], Roy T. McBride Jr.[13], Rogerio C. Paula[3], Laury Cullen Jr.[12], Leandro Silveira[14], Daniel L. Z. Kantek[15], Emiliano E. Ramalho[5,16], Louise Maranhão[15], Mario Haberfeld[17,18,19], Denis A. Sana[5,20], Rodrigo A. Medellin[21], Eduardo Carrillo[22], Victor H. Montalvo[22,23], Octavio Monroy-Vilchis[24], Paula Cruz[6,7], Anah T. A. Jacomo[14], Giselle B. Alves[14,25], Ivonne Cassaigne[26], Ron Thompson[26], Carolina Sáenz-Bolaños[22,23], Juan Carlos Cruz[23,27], Luis D. Alfaro[22], Isabel Hagnauer[28], Marina Xavier da Silva[29], Alexandre Vogliotti[30], Marcela F. D. Moraes[29], Selma S. Miyazaki[15], Gediendson R. Araujo[31,32], Leanes Cruz da Silva[32,33], Lucas Leuzinger[32], Marina M. Carvalho[34], Lilian Rampim[17], Leonardo Sartorello[17], Howard Quigley[18], Fernando R. Tortato[18], Rafael Hoogesteijn[18], Peter G. Crawshaw Jr.[3], Allison L. Devlin[18,35,36], Joares A. May-Junior[5,17,18,37], Estebán Payán[18], Fernando C. C. Azevedo[5,38], Henrique V. B. Concone[5,39], Verónica A. Quiroga[9,40,41], Sebastián A. Costa[8,9], Juan P. Arrabal[9,42], Ezequiel Vanderhoeven[9,42], Yamil E. Di Blanco[8,9], Alexandre M. C. Lopes[43], Milton Cezar Ribeiro[4]

Affiliations

[1] Asociación Guyra Paraguay and CONACYT, Parque Ecológico Asunción Verde, Asunción, Paraguay

[2] Insituto Saite, Asunción, Paraguay

[3] Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros, Instituto Chico Mendes de Conservação da Biodiversidade, Atibaia, SP 12952011, Brazil. 12945010, Brazil

[4] Instituto de Biociências,Universidade Estadual Paulista-UNESP, Departamento de Biodiversidade, Laboratório de Ecologia Espacial e Conservação (LEEC), Rio Claro, SP 13506900, Brazil

[5] Instituto Pró-Carnívoros, Atibaia, SP 12945010, Brazil

[6] Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

[5] Instituto de Biociências, Departamento de Ecologia, Universidade de Sao Paulo, Rua do Matão, Trav. 14, no. 321, Cidade Universitária, São Paulo, SP, 05508-090, Brazil

[8] Instituto de Biología Subtropical, Universidad Nacional de Misiones and CONICET, Puerto Iguazú, Misiones 3370, Argentina

[9]Asociación Civil Centro de Investigaciones del Bosque Atlántico, Puerto Iguazú, Misiones 3370, Argentina

[10]Programa Jaguares de la Selva Maya, Bioconciencia A.C., Ciudad de México, México

[11]School of Environmental and Geographical Sciences, University of Nottingham Malaysia, Jalan Broga, 43500 Semenyih, Selangor, Malaysia

[12]IPÊ-Instituto de Pesquisas Ecológicas, Nazaré Paulista, SP 12960000, Brazil

[13]Faro Moro Eco Research, Departamento de Boquerón, Paraguay

[14]Instituto Onca Pintada, Mineiros, GO 75830000, Brazil

[15]Estacao Ecológica Taiamã, Instituto Chico Mendes de Conservação da Biodiversidade, Cáceres, MT 78210625, Brazil

[16]Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, AM 69553225, Brazil

[17]Associação Onçafari, Rua Ferreira de Araújo,221 - Cj.14 - Sala 4 - Pinheiros _ São Paulo/SP

Cep: 05428-000, Brazil

[18]Panthera, 8 West 40th Street, 18th Floor, New York, NY 10018, USA

[19]Instituto SOS Pantanal , R. Gutemberg, 328 - Centro, Campo Grande - MS, 79002-160, Brazil

[20]Programa de Pós-graduação em Biologia Animal, Instituto de Biociências, Universidade Federal do Rio Grande do Sul - UFRGS, Porto Alegre, RS 91501970, Brazil

[21]Instituto de Ecología, Universidad Nacional Autónoma de México and CONACyT, Ciudad Universitaria, México D.F.04318, México

[22]Instituto Internacional en Conservación y Manejo de Vida Silvestre, Universidad Nacional de Costa Rica, Heredia 1350-3000, Costa Rica

[23]Department of Environmental Conservation, University of Massachusetts, Amherst, 01003, USA

[24]Centro de Investigación en Ciencias Biológicas Aplicadas, Universidad Autónoma del Estado de México, Instituto Literario 100, Col. Centro C.P. 50000, Toluca, Estado de México

[25]Instituto de Biologia, Laboratório de Ecologia de Mamíferos (LEMA), Universidade Federal de Uberlândia, Uberlândia, MG 38408100, Brazil.

[26]Primero Conservation, Box 1588 Pinetop, AZ 85935, USA

[27]Namá Conservation, Ciudad de Heredia, 40101, Costa Rica.

[28]Rescate Animal Zooave, Fundación Restauración de la Naturaleza, Apdo 1327-4050, Alajuela, Costa Rica

[29]Projeto Carnívoros do Iguaçu, Foz do Iguaçu, PR 85851970, Brazil

[30]Universidade Federal da Integração Latino-Americana, Instituto Latino-Americano de Ciências da Vida e da Natureza, Foz do Iguaçu, PR 85851970, Brazil

[31]Universidade Federal de Mato Grosso do Sul, Faculdade de Medicina Veterinária e Zootecnia, Campo Grande, MS 79070-900, Brasil

[32]Instituto Onças do Rio Negro, Fazenda Barranco Alto, Aquidauana, MS 79208000 , Brazil

[33]Departamento de Medicina Veterinária, Universidade Federal de Viçosa, Viçosa, MG 36570, Brazil

[34]Instituto de Defesa e Preservação dos Felídeos Brasileiros, Corumbá de Goiás, GO 72960000, Brazil

[35]SUNY College of Environmental Science & Forestry, Syracuse, NY 13210, USA

[36]Wildlife Biology Program, W.A. Franke College of Forestry & Conservation, University of Montana, Missoula, MT 59812 USA

[37]Universidade do Sul de Santa Catarina, Tubarão, SC 88704-900, Brazil

[38]Universidade Federal de São João del Rei, Departamento de Ciências Naturais, São João del Rei, MG 36301160, Brazil

[39]Laboratório de Ecologia, Manejo e Conservação de Fauna Silvestre, Programa de Pós-Graduação Interunidades em Ecologia Aplicada, Universidade de São Paulo (ESALQ/CENA), Piracicaba, SP 13418-900, Brazil

[40]Universidad Nacional de Córdoba, Facultad de Ciencias Exactas, Físicas y Naturales. Centro de Zoología Aplicada. Córdoba, Argentina.

[41]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Instituto de Diversidad y Ecología Animal (IDEA). Córdoba, Argentina.

[42]Instituto Nacional de Medicina Tropical (ANLIS), Ministerio de Salud de la Nación, Puerto Iguazú, Misiones 3370, Argentina.

[43]Instituto de Pesquisa e Conservação de Tamanduás do Brasil, Parnaíba, PI 64200025, Brazil

ABSTRACT

The range-wide management of the jaguar (*Panthera onca*) depends upon maintaining core populations connected through multi-national, transboundary cooperation, which is dependent upon understanding the movement ecology and space use of jaguars throughout their range. Using 117 telemetry trajectories from 12 ecoregions, we examined the landscape-level environmental and anthropogenic factors related to jaguar home range size and movement parameters. Range-wide and at the ecoregional scale home range size decreased with increasing net productivity and increased with increasing road density. Also, range-wide, home range size decreased with increasing forest cover and decreasing human population density. Movement within home ranges was best explained by a different set of environmental covariates. Range-wide predictions of home range size were consistent with expectations based upon density estimates. Our findings provide a mechanism to evaluate range-wide habitat quality for jaguars and an inferential modeling framework that can be adapted to the conservation of other large terrestrial carnivores.

INTRODUCTION

Globally, anthropogenic disturbance is driving mass extinction across taxa by decreasing species abundance, populations, and distributions which has been especially acute for large terrestrial carnivores, stemming from habitat loss and fragmentation, persecution (fear, retaliation), utilization (black market trade, hunting), infrastructure development, and prey depletion, which are exacerbated by climate change (*1*). The disproportionately high threat to large terrestrial carnivores is of importance since these species play key roles in controlling ecosystem function through top-down trophic effects (*1*) and as their occurrence conserves a greater proportion of biodiversity (i.e., umbrella effect) compared to areas where large carnivores are absent (*2*).

The conservation of large carnivores, however, is challenging given their large spatial needs, dependence on high prey densities, and conflictive relationship with people (*1*). The persistence of large carnivore populations is driven by how individuals use space (*3*, *4*) and consequently, movement ecology is an important and common component of carnivore research (*5*). Due to the large spatial needs of large carnivores their conservation is often multi-national in context and consequently, from both an ecological and a geo-political perspective an understanding of their space use in response to anthropogenic and environmental factors is key for their conservation, the ecosystems they inhabit, the biodiversity for which they are proxy (*6*), and the services that they provide to society (*3*, *7*).

Throughout the majority of the Neotropics the jaguar (*Panthera onca*) is the largest felid, an apex predator, and an important flagship and umbrella species for ecosystem and biodiversity conservation (*2*), however its distribution has decreased by >50% from its historic extent (*8*). The loss of the Neoptropic's apex predator over such a large area (~7.3 million km^2) is of concern, not only for the conservation of the jaguar, but the implications for overall biodiversity conservation in the region and subsequently, ecosystem function and the implicit regional and global implications for human well-being via resource provisioning and climate change mitigation. The critical ecological role played by the jaguar in overall biodiversity conservation and in positively affecting human well-being is globally recognized and the focus of multi-national initiatives to conserve the species and its benefits to society (*9*).

The distribution of the jaguar is associated with both environmental and anthropic factors (*10*), and while the drivers of home range size and resource selection have been confined to individual ecoregions (*11–13*), or across ecoregions (*14–17*), demonstrating relationships with environmental and anthropogenic factors (*13–18*) and sex (*15*, *16*, *19*), there have been no range-wide comparative studies of jaguar space use. Since home range size is critical in determining density and ultimately abundance(*20*), the conspicuous lack of range-wide analyses of jaguar space use is of concern as conservation initiatives for the jaguar are range-wide in scope, involving 18 range countries. Consequently, much of the success of those initiatives depends upon gaining inferences on jaguar space use range-wide to facilitate trans-boundary and multi-national cooperation and for maintaining connectivity among core populations (*9*).

Recognizing the need to understand the factors that determine space use by jaguars throughout its range we examined the range-wide drivers of jaguar space use using GPS telemetry data from 113 jaguars from six countries, 12 ecoregions, and two continents (*21*; Fig. 1), covering the breadth of the jaguar's extant range. We estimated jaguar home range size and movement parameters, evaluating their relationships with environmental and anthropogenic variables from the range-wide to ecoregional scales. We identified and quantified the effects of landscape-level anthropogenic and environmental factors on jaguar space use and movement, finding strong commonalities range-wide and within ecoregions. Our study employs the largest movement data set for a large felid to date and is the first to quantify the range-wide drivers of space use and movement by a large felid. In doing so our study has important applications for jaguar conservation, and more broadly provides a framework for gaining inferences for the conservation of large terrestrial carnivores, the services that they provide, and the associated biodiversity that they protect.

RESULTS

Home range and movement parameter estimation

Using published GPS telemetry data from 111 (52 males, 59 females) jaguars in 6 countries and 12 ecoregions (*21*), and additional data from 2 jaguars (1 male, 1 female) from the Colombian Llanos (Fig. 1), we developed 117 telemetry trajectories for 113 individuals. For four individuals we separated their data into two distinct sampling periods each as they were monitored for two periods that were separated by two to three years. We fit continuous-time stochastic movement models to our data (*22*), and using the best fit model, estimated 95% home range areas using autocorrelated kernel density estimation (*22*), as well as home range crossing time, mean daily movement (hereafter speed), and autocorrelation timescale (*23*) .

All individuals demonstrated range residency, with their movements best characterized by the Ornstein–Uhlenbeck or Ornstein–Uhlenbeck with foraging models (*22*), and 95% home range areas ranging from 17 km^2 to 2453 km^2 with home range size for males ranging from 32 – 2453 km^2 and 17 – 1815 km^2 for females (Table S1). For males home range crossing times ranged from 0.8 – 23.8 days and 1.03 – 28.9 days for females, autocorrelation timescale ranged from 0.16 – 5.23 hours and 0.16 – 5.4 hours for males and females, respectively, and speed ranged from 6.1 – 40.2 km/day for males and 1.4 – 49.5 km/day for females (Table S1).

Factors associated with home range size and movement parameters

We modeled the relationship of the estimates of home range, speed, autocorrelation timescale, and home range crossing time with the covariates using generalized linear mixed models (GLMM) (*24*) in maximum likelihood and Bayesian frameworks. We used sex as a random effect to evaluate range-wide factors associated with movement parameters and ecoregion as a random effect to evaluate relationships among covariates and movement parameters at the ecoregion scale.

At both the range-wide and ecoregional scales, for each movement parameter there was a single best-fit model (see Methods, Table S2). For home range size at the range-wide scale the best-fit model contained percent forest cover and net primary productivity which negatively affected home range size and a positive effect from sex (male), human population density, and road density. Based upon the posterior distributions of the effect size of sex from the best-fit model analyzed in a Bayesian framework, males had a 94% probability of having larger home ranges than females (Table 1, Table S3), while percent forest cover and net primary productivity had a 95% and 100% probability, respectively of being related with smaller home range size. Both human population density and road density had 100% probabilities of being related to increasing home range size (Fig. 2, Table S3).

Comparatively, at the ecoregional scale estimated home range size was positively affected by sex (male) and road density and a negatively affected by net primary productivity. Sex and road density had a 100% probability of a positive relationship with home range size and net primary productivity a 92% probability of being associated with decreasing home range size (Fig.3, Table S3). Comparing estimated home size among ecoregions by fixing the transformed covariate values to zero so that estimates are based upon model intercepts, estimated mean home range size was largest for the Cerrado (620.5 km^2) and smallest for the Pantanal (74.4 km^2) which had probabilities of being 92% greater and 81% smaller, respectively than the mean across all ecoregions (Table 1, Table S4, Fig. S1).

The relationship of estimated home range size and movement parameters with covariates demonstrates that at both the range-wide and ecoregional scale most responses are nearly linear, except for human population density at the range-wide scale and net primary productivity at both scales (Fig. 2, Fig. 3). At both scales home range size was estimated to sharply decline and then level off as net primary productivity approached about 5 kg C/m^2/yr, although the effect was stronger at the range-wide scale. Estimated home range size was sensitive to increasing human population density at the range-wide scale as human density increases from 0 to about 3 people/ km^2, with a reduced increase in the effect thereafter (Fig. 2).

Using the parameter estimates from the best-fit range-wide home range model and the corresponding landscape covariates, we spatially modeled the predicted mean home range size across the jaguar's current distribution, showing that ecoregions with lower productivity or higher road and human density such as the Caatinga, Cerrado, Dry Chaco, Central America and Mexican dry forests, and the Caribbean slope of Colombia were predicted to have larger home ranges (Fig. 4). Conversely, systems with high productivity and forest cover or with lower human and road densities such as the eastern slope of the Andes and portions of the Pantanal, Llanos, Amazon Basin, Atlantic forest, and humid Mesoamerican forests had the smallest predicted home range size (Fig. 4). However, within high productivity systems, including Atlantic forest, Amazon basin, Pantanal, and the Llanos, there are areas with high human population and road densities and relatively low forest cover, where predicted home range sizes were considerably larger compared to the expected values for the region.

At both the range-wide and ecoregional scales speed was strongly negatively related to percent forest cover and mean annual precipitation with both covariates having a 100% probability of being related to decreasing speed (Fig. 2,3; Table S2, S3). Although at the ecoregional scale sex was not significantly related to speed, at the range-wide scale males had a 95% probability of faster movement (Table 1, Table S2). Based upon mode intercepts the differences in speed across ecoregions were small with jaguars in the Yucatán dry forest having the highest mean estimated speed (14.2 km/day) and the Alto Paraná Atlantic forest the lowest (12.3 km/day), with only a 55% and 47% probability of being greater than the ecoregional mean and an 56% probability that speed of jaguars in the Yucatán dry forest was greater than those in the Alto Paraná Atlantic forest (Table 1, Fig. S1).

At the range-wide scale males had a 70% probability of having a greater autocorrelation timescale, while there was a 100% probability of the autocorrelation timescale being positively affected by mean annual precipitation (Fig. 2, Table S3). For home range crossing time at the range-wide scale the best fit model had a 98% probability of a positive effect from percent forest cover, with females having an 89% probability of a greater home range crossing time than males (Fig. 2, Table S3). At the ecoregional scale the autocorrelation timescale and home range crossing time were not affected by covariates, but differed among ecoregions. Jaguars had the smallest mean autocorrelation timescale (0.59 h) in the Humid Chaco and the largest (2.76 h) in the Péten-Veracruz moist forest, while the shortest estimated mean home range crossing time was in the Llanos and Cerrado (4.1 days) and the longest in the Purus várzeá of the Amazon (6.0 days; Table S4, Fig. S1).

DISCUSSION

We demonstrated that jaguar home range size increased with increasing anthropogenic factors (human population density, road density), illustrating both the negative effects of human impacts and the plasticity in jaguar space use to cope with anthropogenic habitat degradation (*10, 14*). We also showed that increasing forest cover and ecosystem productivity were related to decreasing home range size. Additionally, jaguar movement within home ranges (speed, autocorrelation timescale, home range crossing time) was independent of home range size and instead related to a different suite of factors which did not include anthropogenic covariates. This indicates that decisions about movement at the relatively short sampling scale of our data (generally 1 – 4 hours) were most dependent upon environmental factors and that jaguars adjust their behavior to account for anthropogenic factors (*14*, *18*, *19*).

Our range-wide predictions of home range size coincide with predicted range-wide densities, which is intuitive as net primary productivity is strongly associated with jaguar densities (*10*). Range-wide, forest cover and net primary productivity were important in determining jaguar home range size and regions with predicted smaller home range sizes coincided with observed high jaguar densities in productive systems such as the Pantanal (*25*), Llanos (*26*), lowland Amazon forest (*27*), Amazon flooded forest (*28*), and western Amazon (*29*). Similarly, regions with the largest predicted home range sizes coincided with semi-arid systems with recorded low jaguar densities such as the Caatinga, Cerrado, Sonoran-Sinaloan subtropical dry forest, and Dry Chaco, where net primary productivity is comparatively low and forest cover is reduced due to biotic factors and land use (*30*–*33*).

The relationship between home range size and density can be attributed to a greater amount of preferred habitat and prey in more productive systems which allows for smaller spatial needs, and conversely larger home ranges and lower densities in less productive systems (*34*). Concurrently, habitat degradation, prey reduction, and direct killing stemming from increasing human population density, and facilitated by greater road density, can be attributed to increasing home range size as jaguars require larger areas to meet metabolic needs (*34*, *35*). These observations are consistent with the relatively large home range sizes predicted by our models, and the relatively low estimated densities or occurrence probabilities, in portions of productive systems with strong anthropogenic impacts including the Atlantic Forest (*13*, *15*, *36*), Llanos (*17*), and western Amazon (*29*).

Within ecoregions, as at the range-wide scale, increasing net primary productivity was associated with smaller home range size and increasing road density with larger home range size. A lack of an effect from forest cover and human population density within ecoregions can be attributed to homogeneity and low variability of both factors within ecoregions where the movement data were collected (*13*). Importantly, we illustrated that ecosystem productivity and the presence of roads drive jaguar home range size, both range-wide and among ecoregions, which is consistent with observed behavior of jaguars (*10*, *29*) and other felids (*37*, *38*). We do note, however, that for several ecoregions sample sizes were low and subsequently, despite our efforts to account for this in our modeling, our site-specific results at the ecoregional scale need to be interpreted within the context of the associated uncertainty.

Additionally, apart from determining the covariates at the range-wide and ecoregional scales associated with home range size, we demonstrated a high sensitivity of home range size to increasing net primary productivity at both scales, and to human population density range-wide, at the lower range of the values of those covariates. As expected from previous research (*13*, *15*, *16*), males had larger home ranges than females range-wide and among ecoregions. Male home range size is driven by both food availability and the need to maintain reproductive opportunities by maximizing their contact with females; consequently, their home ranges tend to be larger. In contrast, females have comparatively smaller home ranges to minimize metabolic costs while maximizing food availability and reproductive success (*39*, *40*). Supporting this interpretation, and as indicated by previous research (*15*, *16*, *19*), we found that males moved farther, faster, and more directionally than females which is consistent with male requirements to maintain larger home range areas.

The negative relationship of speed with percent forest cover and mean annual precipitation suggests that forest availability, and potentially forest structure from increased precipitation, as well as a greater availability of water, results in more homogenous, high quality habitat which consequently does not force jaguars to avoid sub-optimal habitats (*14*, *18*). Since daily speed was negatively related with forest cover, a positive relationship in home range crossing time with percent forest cover is logical, as it would be expected that when individuals move slower, they take a longer time to cross their home ranges.

The increase in the autocorrelation timescale with increasing precipitation range-wide suggests that, as with speed, habitat homogeneity and water availability lead to more directional movements (*14*, *18*). Autocorrelation timescale and home range crossing time exhibited a lack of relationship with landscape covariates within ecoregions. This likely indicates that factors different from those that we considered drive jaguar movement behaviors within ecoregions, or may potentially be due to homogeneity in covariates among home ranges within ecoregions. Given individual-level fine scale movement decisions by jaguar (*19*, *21*) the lack of clear relationships among movement parameters and the landscape factors we evaluated is not unexpected and points to a need for analyses of localized, fine-scale movement decisions by jaguars across its range.

Our data set and analysis is the largest to date on the movement ecology of the jaguar, or for any large felid, spanning its complete extant range from its southernmost limits in the province of Misiones, Argentina to its northernmost extent in the state of Sonora, Mexico representing the spectrum of habitat types that jaguars inhabit, including dry and humid forest and wetlands, and varying levels of anthropogenic transformation. We corroborated prior research documenting that the anthropogenic and environmental factors affecting jaguar space use and movement at local and regional scales (*14*, *18*, *19*) act similarly across ecoregions, continents, and range-wide to affect jaguar space use and movements, demonstrating that jaguars perceive their environment similarly, regardless of geographic location or habitat type. In doing so, we provide a set of landscape metrics and a mechanism to evaluate jaguar habitat quality throughout the species' range, facilitating transboundary conservation planning among jaguar range states, which is of significance as the range-wide conservation vision for the jaguar is based upon international collaboration and trans-boundary decision making to maintain connectivity among core jaguar populations (Jaguar Conservation Units) (*9*).

Our analysis is unique in that it is the first to elucidate the range-wide drivers of space use by a terrestrial apex predator, and given the geographic and ecological breadth of our analysis, and its accounting for uncertainty in the data, our inferences not only provide robust generalizations which address key needs for the jaguars' range-wide conservation (*9*), but also for the conservation of other large cats, and large terrestrial carnivores in general. We provide a modeling framework to identify the environmental and anthropogenic factors associated with carnivore space use, which is of significance as understanding the drivers of space use is of critical importance for the range-wide conservation decision-making for not only jaguars (*9*), but other species of large felids (*41–43*), and terrestrial carnivores in general (*1*). Our findings, and the framework presented herein, therefore have immediate and direct applications for the range-wide conservation of jaguars, other large cats, and large terrestrial carnivores around the world and the biodiversity for which they are proxy.

MATERIALS AND METHODS

Home range and movement parameter estimation

To estimate home range size we fit continuous-time stochastic movement models to our data to account for autocorrelation structure in the data over time and for variable sampling intervals (*22*). We fit models in a maximum likelihood framework using starting values derived from semi-variance functions, ranking model fit using Akaike Information Criteria adjusted for small sample size (AICc) and model weights (*23*). We tested three movement models 1) a random search model (Brownian motion) with uncorrelated velocities and no limits to space use, 2) a random search model with constrained space use (Ornstein–Uhlenbeck, OU), and 3) the Ornstein–Uhlenbeck motion with foraging (OUF) which is the OU process with correlated velocities (*22*, *23*). All these models account for autocorrelation in positions, while the OU and

OUF models include range residency (home range), and the OUF model accounts for autocorrelation in velocities. Consequently, the OU and OUF models produce estimates of home range size and home range crossing time, while the OUF model additionally estimates the velocity autocorrelation time scale (time over which movements are correlated) and mean distance traveled per day (speed) (*23*).

If individuals exhibited range residency, 95% home range areas were estimated using autocorrelated kernel density estimation (AKDE) based upon the best fitting model. Semi-variogram analysis, model selection, and AKDE were undertaken using the *ctmm* package (*23*) with the software R. Irregular sampling schedules in the data were accounted for using the *dt* argument within the *variogram* function in the *ctmm* package (*23*).

Modeling factors affecting home range size and movement parameters

Based upon previous research on factors related to jaguar distribution and home range size (*10*, *13*, *15*, *16*) we hypothesized that nine environmental and four anthropogenic covariates could potentially be determinants of home range size of jaguar across its distribution. For each home range area we derived the 1) mean percent forest cover, 2) mean percent area in forest, 3) mean forest patch area, 4) perimeter:area ratio of forest patches, 5) density of forest edge, 6) percent protected area, 7) mean annual precipitation, 8) mean seasonality in precipitation, 9) mean net primary productivity, 10) mean human population density, 11) mean Human Footprint Index, 12) mean cattle density, and 13) primary road density (Table S5). Additionally, we included sex as a covariate based upon exploratory analysis of the data and that sex-based differences in jaguar movements have been illustrated (*15*, *16*, *19*), while we also considered the effect of body mass as it has been shown to be a factor associated with jaguar distribution (*10*).

We tested for correlation among covariates using Pearson's Correlation Coefficient, with coefficient values between -0.6–0.6 considered uncorrelated. Of the original covariate set, seven were uncorrelated with other covariates; mean percent forest cover, percent protected area, mean annual precipitation, mean seasonality in precipitation, mean net primary productivity, mean human population density, and road density. Also, body mass was significantly associated with sex (Kruskal-Wallis χ^2 test, p=0.04) and was not included in the models. We examined covariates for normality with Shapiro-Wilk tests and inspection of Q-Q plots and log transformed covariates if necessary, to ensure normality. If not log transformed, covariates were *z*-transformed so that their means value were equal to zero.

We modeled the relationship of the estimates of home range, speed, autocorrelation timescale, and home range crossing time with the covariates using generalized linear mixed models (GLMM) (*24*) in maximum likelihood and Bayesian frameworks with sex as a random effect to evaluate range-wide factors associated with movement parameters and with ecoregion (as defined by (*44*)) as a random effect to evaluate relationships among covariates and movement parameters at the ecoregion scale. We chose to employ GLMMs since incorporating random effects allowed for borrowing of information and improved accounting of variability and psuedoreplication in our data, which in turn improved the strength of our inferences given low sample sizes for several sites (*24*). We separated our analysis into two components (range-wide and ecoregional) due to a failure of models including sex and ecoregion hierarchies to convergence which we attribute to sample size.

Using a maximum likelihood framework, we chose a most parsimonious model to explain home range size and each movement parameter by starting with the global model and sequentially eliminating the least informative parameter based upon the value of the estimate divided by its standard error until no reduction in AIC was obtained (*45*). Using the best fit maximum likelihood models at each scale for home range size and movement parameters, we modeled the GLMMs in a Bayesian framework which allowed us to incorporate all uncertainty in our data, estimate the effect size of sex and ecoregion, and quantify the strength of covariate effects as probabilities based upon posterior distributions.

The strength of the covariate effects on home range size and movement parameters was measured by the proportion of the parameter posterior distributions above or below 0 (no effect). To test for differences in home range and movement parameters between sexes and among ecoregions we tested the difference between parameter posterior distributions by randomly selecting 1 million values with replacement from posterior distributions, comparing the proportion of times that the selected values from a distribution were greater or smaller than the selected values from the distribution being compared. Where these proportions were 0.5 there was no difference between parameters since they had equal probability of being different (50%:50%), while where the proportional difference was 1 the probability of a difference between distributions was 100%.

For modeling maximum likelihood GLMMs we used the lme4 package (*46*) with the software R (Table S5) and for the development of the Bayesian GLMMs we used WinBUGS (*47*) and the *R2winBUGS* package (*48*), running 3 chains for 1 million iterations, a burn-in period of 100,000 iterations, and a thinning rate of 30. For the prior distributions in the modeling we used diffuse uniform distributions for the random effects and normal distributions for the covariate effects, confirming model convergence with a scale reduction factor ≤1.01 and visual inspection of trace plots for lack of autocorrelation (*24*).

Using the parameter estimates for each covariate from the range-wide best-fit model for home range size and the corresponding spatial covariate values we predicted mean home range size throughout the extant home range of the jaguar. The coverage of road density was resampled to a resolution of 0.1 decimal degrees, while all other spatial data and the final map was at a resolution of 0.01 decimal degrees. Additionally, using the mean covariate values range-wide and within ecoregions we estimated mean home range size and movement parameter values by sex and ecoregion. All spatial data manipulation was undertaken using QGIS 3.12.0.

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Acknowledgments

Funding: J.J.T. was partly supported by CONACYT of Paraguay through the program PRONII. Additioanl support was provided by the Fazenda Real filial São Bento, the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001, Fundação de Amparo à Pesquisa do Estado de São Paulo 2018/13037–3, FAPESP 2014/24921-0, FAPESP 2018/24891-5, FAPESP 2014/24921-0, CONICET, CeIBA, WWF Switzerland, Fundación Vida Silvestre Argentina, Panthera Foundation, and Rufford Small Grant Foundation.

Author contributions: J.J.T., R.G.M., B.S., A.P., J.A.T. conceptualized the analysis, J.J.T., B.S., V.B., J.O., A.E.B. undertook the analysis, J.J.T., R.G.M., B.S. led the writing of the manuscript, J.J.T., R.G.M., B.S., A.P., J.A.T., F.L., R.T.M., R.C.P., L.C., L.S., D.L.Z.K., E.E.R., L.M., M.H., D.A.S., R.A.M., E.C., V.M., O.M., P.C., A.T.J., N.M.T., G.B.A., I.C., R.T., C.S., J.C.C., L.D.A., I.H., M.X.S., A.V., M.F.D.M., S.S.M., D.C.P., G.R.A., L.C.S., L.L., M.M.C., L.R., L.S., H.Q., F.T., R.H., P.G.C., A.L.D., J.A.M., E.P., F.C.C.A., H.V.B.C., V.A.Q., S.A.C., J.P.A., E.V., Y.E.D., A.M.C.L., M.C.R provided data.

Competing interests: The authors claim no competing interests.

Data and materials availability: Data used in the analysis are available at https://datadryad.org/stash/dataset/doi:10.5061/dryad.2dh0223

Figures and Tables

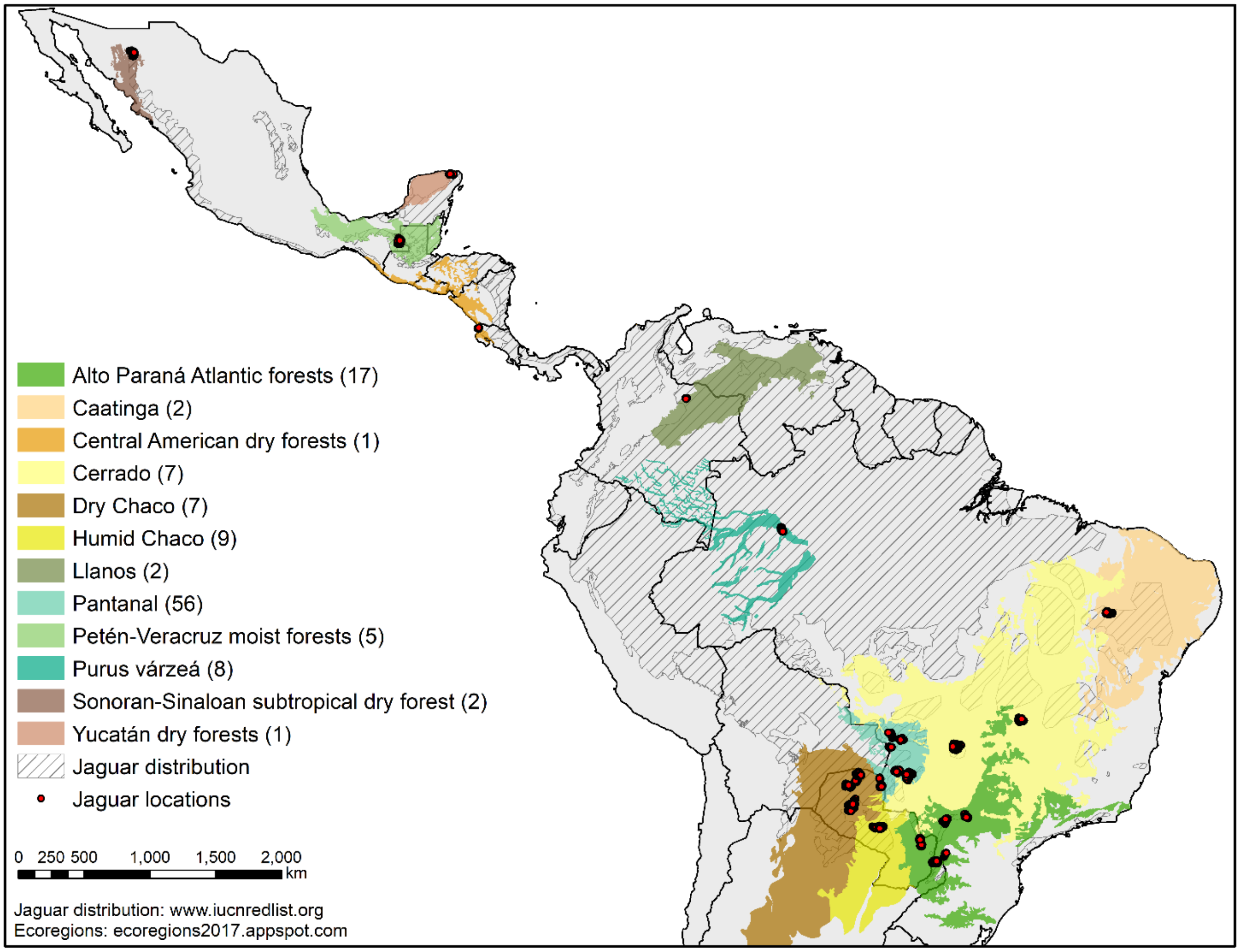

Fig. 1. **Telemetry data locations**. Locations in North and South America by ecoregion of telemetered jaguars included in the analysis. Numbers next to ecoregions represent the number of individuals telemetered.

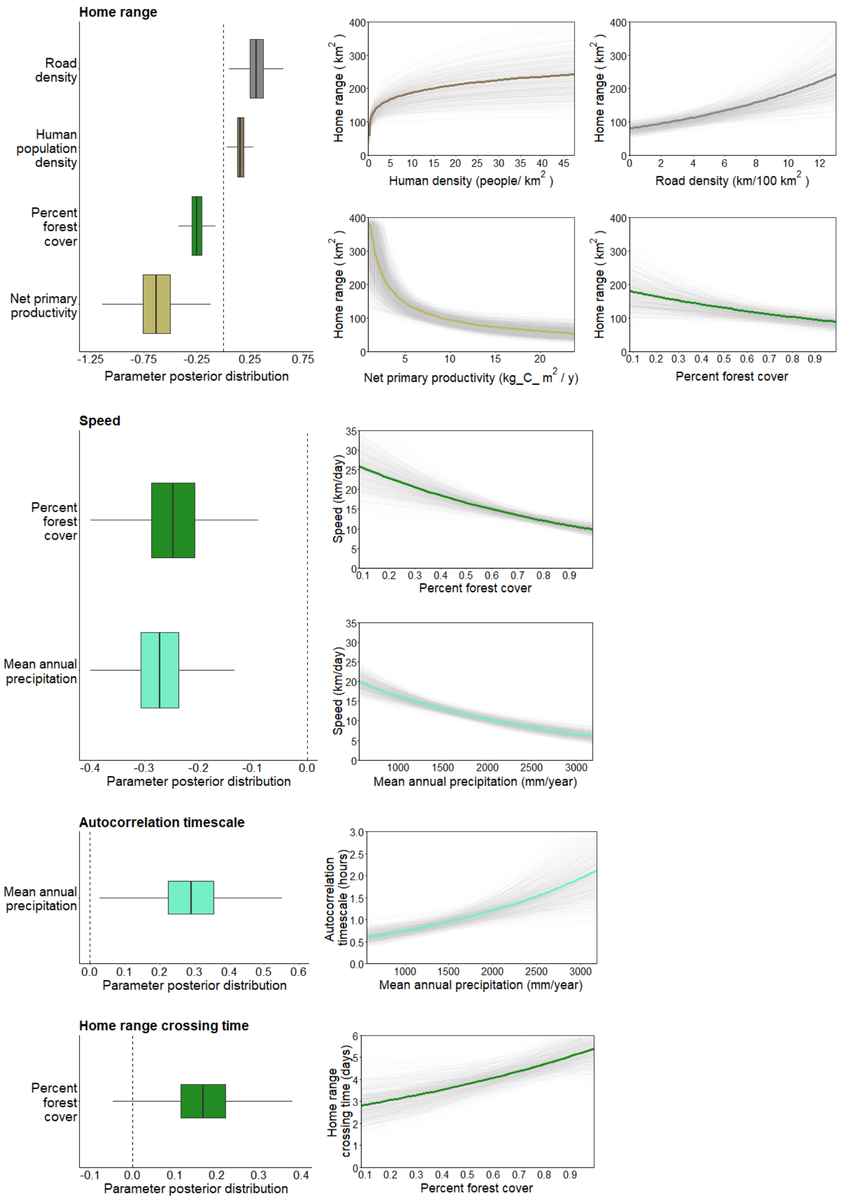

Fig. 2. R**ange-wide scale relationships of home range size with covariates.** (left) Posterior distributions of the parameter estimates from the Bayesian analysis of the best fit range-wide generalized linear mixed model with sex as a random effect for home range size, speed, autocorrelation timescale, and home range crossing time. Boxplots represent the median, 25th and 75th quantiles and whiskers 1.5 times the upper and lower interquartile range, with the dashed line representing the value of no effect upon the movement parameter by the covariate. (right) Estimated responses of home range size and movement parameters to landscape covariates. Colored lines represent mean effect and gray lines are 500 estimated responses based upon random draws from the parameter posterior distributions.

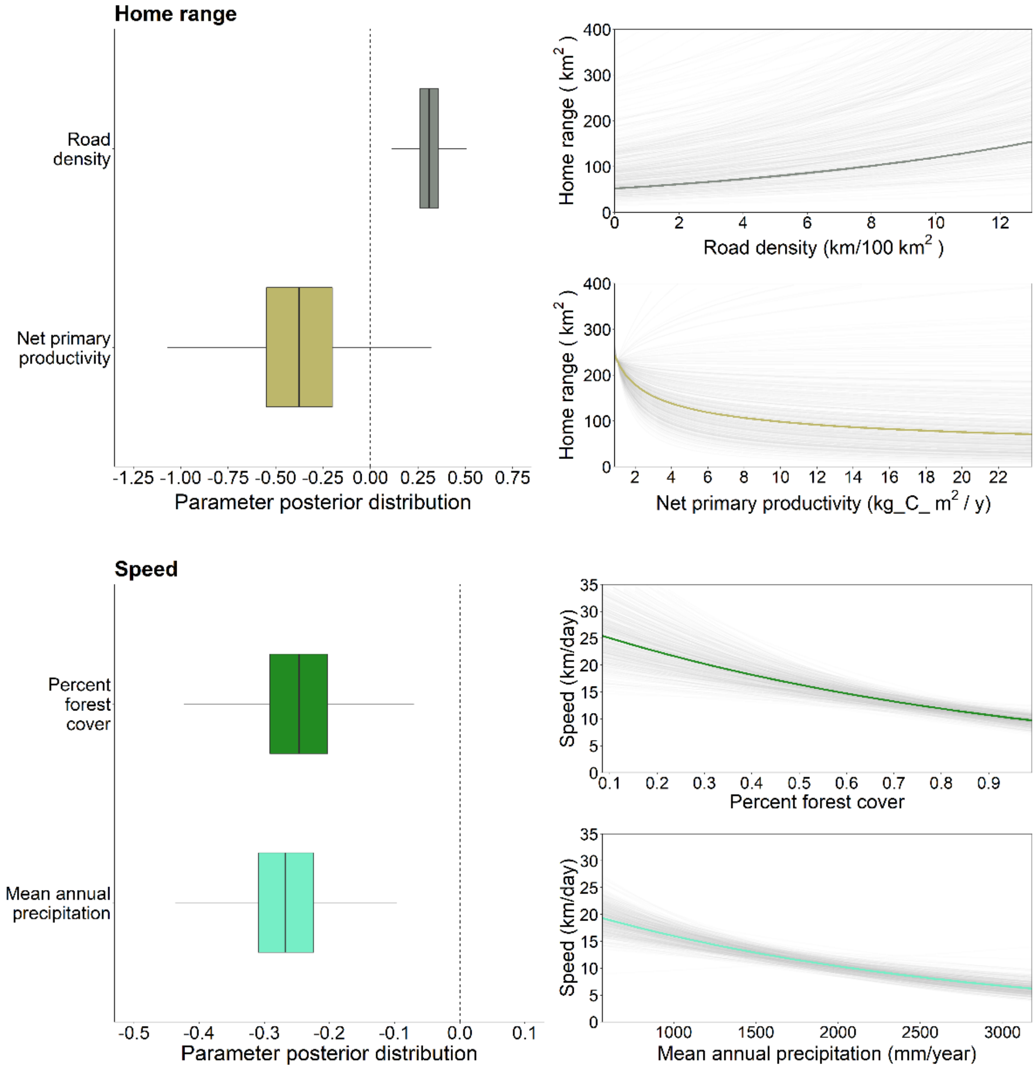

Fig. 3. Ecoregional scale relationships of home range size with covariates. (left) Posterior distributions of the parameter estimates from the Bayesian analysis of the best fit ecoregional scale generalized linear mixed model with ecoregion as a random effect for home range size and speed. Boxplots represent the median, 25th and 75th quantiles and whiskers 1.5 times the upper and lower interquartile range, with the dashed line representing the value of no effect upon the movement parameter by the covariate (left). Estimated responses of home range size and movement parameters to landscape covariates (right). Colored lines represent mean effect and gray lines are 500 estimated responses based upon random draws from the parameter posterior distributions.

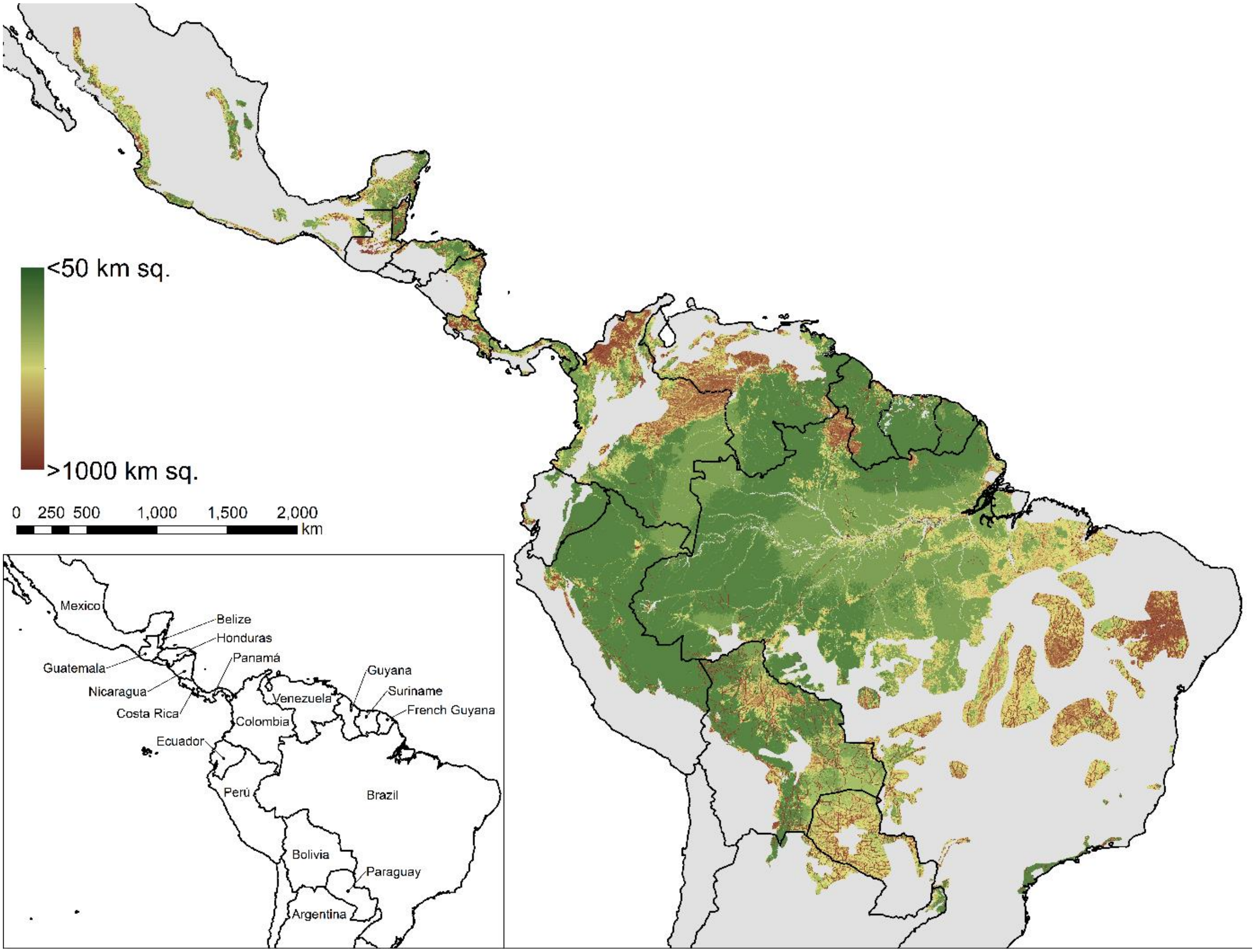

Fig. 4. Range-wide predicted mean jaguar home range size. Predicted mean home range size for jaguar across its distribution based upon the best fit range-wide home range model and corresponding covariates.

Table 1. Model estimates of jaguar home range size and movement parameters. Estimated mean movement parameters and 95% credibility intervals (CRI) range-wide and by ecoregion from the Bayesian form of the best fit range-wide and ecoregion-scale generalized linear mixed model with transformed covariates equal to 0.

	Home range (km^2)		**Speed (km/day)**		**Autocorrelation timescale (hours)**		**Home range crossing time (days)**	
Sex	**Mean**	**CRI**	**Mean**	**CRI**	**Mean**	**CRI**	**Mean**	**CRI**
Female	491.4	192.5–1041.9	12.3	10.4–14.4	0.91	0.68–1.19	4.9	3.9–6.0
Male	1255.4	505.3–2617.6	14.3	12.6–17.0	0.97	0.74–1.26	4.0	3.2–5.0
Ecoregion								
Alto Paraná Atlantic forest	212.9	37.2–683.4	12.3	8.9–15.0	1.35	0.75–2.25	4.4	3.1–5.9
Caatinga	278.7	63.4–810.8	13.0	9.0–16.8	0.86	0.30–1.84	5.2	3.0–9.4
Central American dry forest	167.2	21.2–593.5	13.4	9.3–18.2	1.05	0.30–2.50	4.7	2.4–8.0
Cerrado	618.7	148.3–1752.9	13.0	9.8–16.3	1.03	0.55–1.74	4.1	2.4–5.9
Dry Chaco	230.2	85.6–503.7	13.3	10.2–16.9	1.46	0.79–2.52	5.4	3.6–8.6
Humid Chaco	158.8	47.5–393.1	13.8	11.0–17.9	0.59	0.30–1.05	5.1	3.5–7.7
Llanos	83.4	12.8–275.3	13.6	9.9–18.5	0.91	0.33–1.94	4.1	1.9–6.5
Pantanal	74.2	20.7–189.8	14.0	12.2–16.4	0.80	0.60–1.05	4.2	3.3–5.1
Petén–Veracruz moist forest	210.2	44.2–623.9	13.0	8.9–16.8	2.76	1.08–5.98	5.7	3.6–10.0
Purus várzeá	167.8	33.0–506.2	13.1	9.0–17.0	1.70	0.90–2.99	6.0	3.9–10.1
Sonoran–Sinaloan subtropical dry forest	209.9	57.6–546.2	13.4	8.9–19.0	1.41	0.24–4.43	4.7	2.6–7.9
Yucatán dry forest	263.5	35.0–959.1	14.2	10.4–21.4	0.99	0.28–2.33	4.6	2.3–7.9

Supplementary Materials

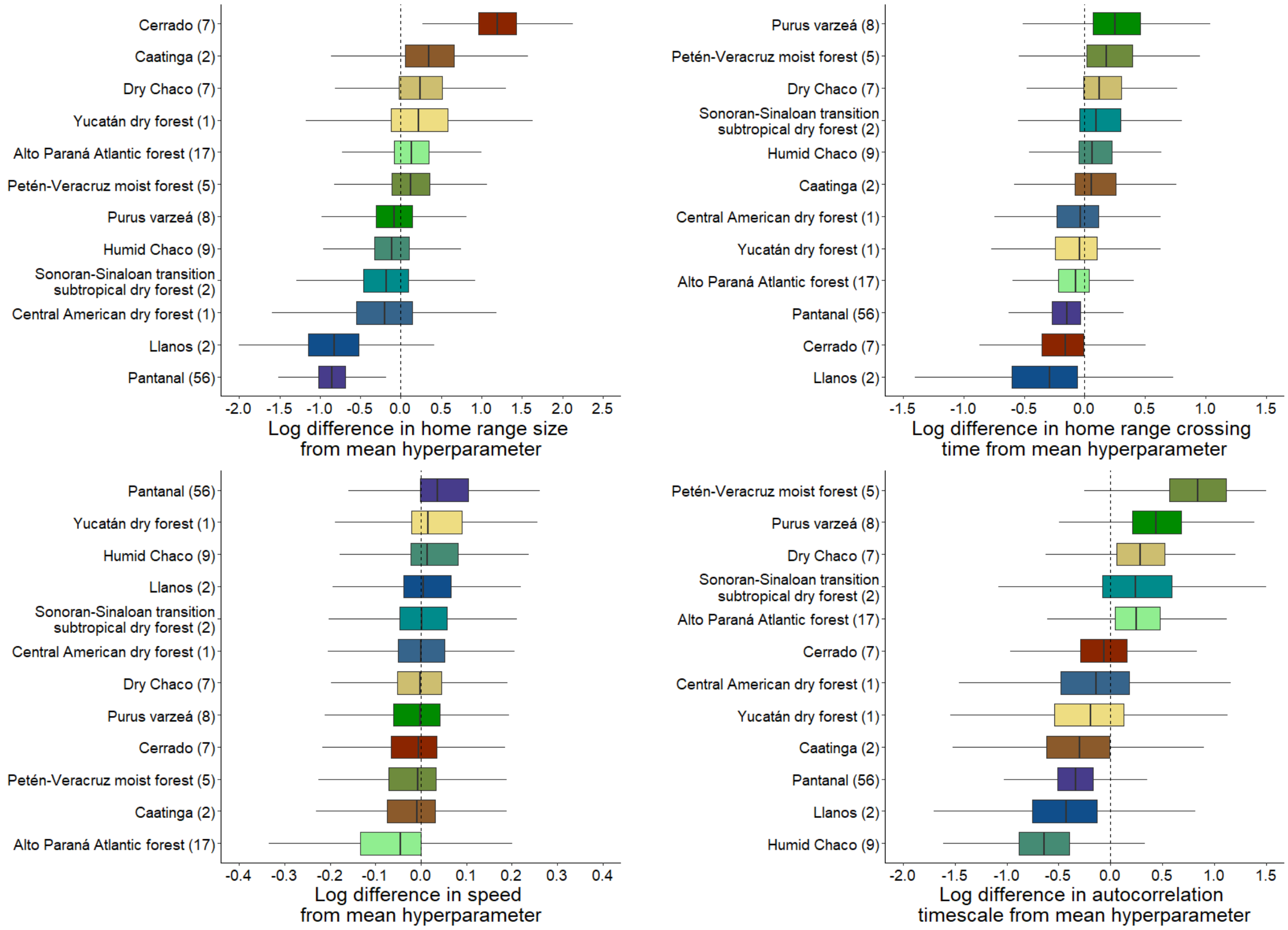

Fig. S1. Estimated ecoregion effect on home range size and movement parameters. Posterior distributions of the effect size of ecoregion compared to the mean effect from the ecoregional generalized linear mixed model with ecoregion as a random effect for home range size, speed, autocorrelation timescale, and home range crossing time. Dashed line represents the mean value of the ecoregion hyper–parameter. Boxplots are ordered by median value and represent the median, 25th and 75th quantiles and whiskers 1.5 times the upper and lower interquartile range. Sample size for each ecoregion is in parentheses.

Table S1. Estimated movement parameters for individual jaguars in the analysis.

Autocorrelated kernel density estimated home ranges and movement parameters for jaguars used in the analysis.

Ecoregion	Sex	95% AKDE home range (km^2)	Home crossing time (day)	Autocorrelation timescale (hours)	Speed (km/day)
Alto Paraná Atlantic forest	Female	105.6 (83.5–130.2)	2.4 (1.5–3.9)	3.68 (1.43–9.49)	6.0 (4.6–7.3)
Alto Paraná Atlantic forest	Female	146.0 (107.1–191.0)	6.0 (4.0–8.9))	0.82 (0.07–10.34)	9.3 (5.7–13.0)
Alto Paraná Atlantic forest	Female	51.3 (31.1–76.4)	5.3 (2.5–11.1)	—	—
Alto Paraná Atlantic forest	Female	133.3 (75.8–206.7)	1.0 (0.0–3.0)	1.03 (0.0–2.96)	4.5 (0.86–8.46)
Alto Paraná Atlantic forest	Female	115.8 (77.3–161.9)	4.4 (2.6–7.3)	—	—
Alto Paraná Atlantic forest	Female	260.0 (141.4–414.1)	16.5 (0.0–34.0)	—	—
Alto Paraná Atlantic forest	Female	256.8 (191.1–332.0)	7.3 (5.1–10.6)	—	—
Alto Paraná Atlantic forest	Female	722.8 (296.8–1335.1)	18.5 (4.7–72.6)	—	—
Alto Paraná Atlantic forest	Female	144.4 (97.9–199.8)	2.4 (1.2–4.9)	—	—
Alto Paraná Atlantic forest	Female	235.0 (170.0–310.4)	7.9 (5.4–11.6)	1.56 (1.22–1.98)	7.5 (7.0–8.1)
Alto Paraná Atlantic forest	Female	137.6 (112.2–165.5)	1.6 (1.2–2,1)	2.19 (1.49–3.22)	10.0 (9.0–11.0)
Alto Paraná Atlantic forest	Male	151 (117.8–188.1)	4.5 (3.3–6.1)	0.04 (0.03–0.05)	7.1 (6.6–7.6)
Alto Paraná Atlantic forest	Male	112.6 (88.9–139.1)	1.6 (1.1–2.2)	—	—
Alto Paraná Atlantic forest	Male	702.3 (528.4–900.6)	2.1 (1.4–3.2)	—	—
Alto Paraná Atlantic forest	Male	504.8 (400.4–621.2)	4.6 (3.5–6.1)	0.89 (0.25–3.21)	21.8 (14.9–28.8)
Alto Paraná Atlantic forest	Male	174.8 (69.1–328.7)	10.6 (2.5–43.8)	0.6 (0.45–0.80)	8.5 (7.8–9.2)
Alto Paraná Atlantic forest	Male	685.1 (264.8–1301.7)	6.3 (1.2–31.5)	—	—
Caatinga	Male	2188.7 (795.5–4274.5)	1.9 (0.38–10.1)	0.81 (0.78–0.84)	10.7 (10.6–10.9)
Caatinga	Male	476.0 (86.3–1191.8)	23.8 (20.0–26.6)	0.38 (0.33–0.44)	11.7 (11.2–12.1)
Central America dry forest	Female	84.9 (73.0–97.8)	3.1 (2.6–3.7)	0.73 (0.68–0.78)	11.3 (11.1–11.6)
Cerrado	Female	1141.7 (683.7–1715.2)	14.3 (7.8–26.5)	0.37 (0.28–0.48)	23.4 (21.1–25.7)
Cerrado	Female	1815.7 (368.5–4394.6)	1.2 (0.0–2.7)	1.89 (0.50–7.08)	8.0 (5.7–10.3)
Cerrado	Male	2131.9 (754.4–4212.3)	1.2 (0.2–7.0)	1.07 (0.88–1.30)	10.9 (10.1–11.6)
Cerrado	Male	1003.4 (837.3–1184.2)	3.4 (2.8–4.1)	0.76 (0.66–0.88)	34.6 (32.8–36.4)
Cerrado	Male	2453.5 (1118.4–4304.2)	1.2 (0.4–3.5)	0.71 (0.59–0.86)	15.9 (14.7–17.0)
Cerrado	Male	1278.2 (780.3–1896.8)	6.9 (3.8–12.5)	0.83 (0.76–0.91)	25.9 (25.3–26.6)
Cerrado	Male	1171.3 (835.4–1563.1)	4.5 (3.0–6.7)	1.91 (1.61–2.27)	20.2 (19.3–21.1)
Dry Chaco	Female	504.4 (359.0–673.2)	9.5 (6.4–14.0)	1.72 (1.49–1.99)	9.7 (9.3–10.1)
Dry Chaco	Female	612.8 (425.3–833.8)	11.5 (7.6–17.5)	1.09 (0.89–1.34)	11.9 (11.1–12.6)
Dry Chaco	Male	410.8 (351.5–474.5)	2.7 (2.3–3.2)	1.37 (1.27–1.49)	17.1 (16.7–17.4)
Dry Chaco	Male	2326.7 (1691.6–3061.4)	8.0 (5.6–11.5)	1.15 (0.96–1.37)	28.8 (27.1–30.5)
Dry Chaco	Male	352.2 (240.1–485.4)	11.5 (7.3–18.0)	1.78 (1.51–2.10)	7.9 (7.5–8.3)
Dry Chaco	Male	563.5 (356.8–816.5)	3.5 (2.0–6.2)	1.93 (1.65–2.25)	15.1 (14.8–15.7)
Dry Chaco	Male	1052 (812.9–1321.5)	4.8 (3.6–6.4))	2.15 (1.90–2.43)	19.3 (18.6–20.0)
Humid Chaco	Female	309.7 (214.4– 422.3)	6.2 (3.9–9.9)	1.52 (0.93–2.48)	9.3 (7.9–10.6)
Humid Chaco	Female	96.9 (79.6–115.9)	1.2 (0.91–1.62)	0.47 (0.01–24.29)	21.0 (12.3–29.8)
Humid Chaco	Female	86.3 (41.3–147.8)	5.7 (2.1–15.5)	—	—
Humid Chaco	Female	124.0 (74.4–186.0)	9.9 (5.4–17)	0.16 (0.09–0.28)	14.1 (11.3–16.9)
Humid Chaco	Female	245.1 (172.2–330.8)	9.2 (6.2–13.7)	0.15 (0.09–0.23)	22.6 (18.7–26.4)
Humid Chaco	Female	111.6 (78.4–150.6)	9.4 (6.3–14.1)	0.16 (0.63–0.42)	14.2 (10.1–18.3)
Humid Chaco	Male	1066.7 (594.0–1675.6)	5.9 (2.7–12.7)	—	—

Humid Chaco	Male	430.1 (293.5–592.3)	4.4 (2.9–7.0)	1.42 (1.2–1.67)	15.0 (14.4–15.6)
Humid Chaco	Male	352.2 (227.1–504.4)	5.3 (3.2–9.1)	0.85 (0.60–1.22)	13.5 (12.0–14.9)
Llanos	Female	35.0 (19.9–54.2)	1.7 (0.8–3.7)	0.3 (0.13–0.70)	20.2 (15.4–24.9)
Llanos	Male	100.3 (77.4–134.0)	2.0 (1.3–3.2)	1.31 (0.58–2.97)	11.1 (8.9–13.4)
Pantanal	Female	475.5 (182.9–905.4)	25.6 (5.84–112.1)	0.36 (0.33–0.40)	11.7 (11.3–12.0)
Pantanal	Female	27.5 (20.6–36.2)	20.5 (14.9–28.3)	0.31 (0.26–0.36)	19.7 (18.7–20.6)
Pantanal	Female	37.2 (28.6–46.9)	2.0 (1.5–2.7)	4.3 (3.4–5.4)	26.9 (24.4–29.5)
Pantanal	Female	39.9 (28.3–53.5)	1.3 (0.9–1.9)	5.02 (3.21–7.85)	34.3 (28.7–53.5)
Pantanal	Female	36.2 (27.4–46.3)	3.3 (2.4–4.6)	—	—
Pantanal	Female	30.7 (22.4–40.3)	2.0 (1.3–2.9)	—	—
Pantanal	Female	36.3 (24.5–50.4)	1.6 (0.7–3.5)	2.88 (0.64–12.8)	4.9 (3.7–6.2)
Pantanal	Female	49.0 (40.9–57.9)	2.9 (2.3–3.5)	—	—
Pantanal	Female	30.9 (21.8–41.5)	2.1 (1.2–3.4)	—	—
Pantanal	Female	98.2 (79.7–118.7)	1.2 (0.9–1.7)	—	—
Pantanal	Female	68.3 (46.4–94.5)	2.7 (1.6–4.5)	—	—
Pantanal	Female	19.3 (14.9–24.2)	3.7 (2.8–4.9)	0.33 (0.31–0.36)	7.2 (7.1–7.4)
Pantanal	Female	16.7 (7.9–28.7)	3.0 (1.1–8.4)	0.27 (0.20–0.36)	7.7 (7.0–8.4)
Pantanal	Female	116.6 (89.9–146.7)	3.1 (2.3–4.1)	0.23 (0.21–0.26)	23.9 (22.9–24.9)
Pantanal	Female	64.6 (52.8–77.6)	2.6 (2.0–3.2)	—	—
Pantanal	Female	89.8 (71.2–110.5)	4.3 (3.3–5.6)	1.12 (0.94–1.35)	7.9 (7.4–8.3)
Pantanal	Female	60.1 (43.4–79.6)	3.1 (2.1–4.4)	0.24 (0.21–0.28)	15.2 (14.4–16.0)
Pantanal	Female	61.5 (50.5–73.5)	2.5 (2.0–3.1)	0.19 (0.17–0.22)	19.1 (18.2–19.9)
Pantanal	Female	143.0 (92.4–204.4)	3.7 (2.2–6.1)	0.07 (0.05–0.09)	40.8 (35.7–45.8)
Pantanal	Female	26.1 (17.7–36.0)	19.6 (12.4–31.0)	0.05 (0.3–0.09)	49.5 (40.4–58.6)
Pantanal	Female	52.2 (33.3–75.1)	7.9 (4.7–13.3)	0.01 (0.04–0.20)	25.2 (15.4–35.03)
Pantanal	Female	477.2 (193.1–887.7)	9.8 (2.4–40.2)	1.07 (0.62–1.85)	10.8 (9.0–12.6)
Pantanal	Female	68.8 (59.3–79.1)	2.4 (2.03–2.82)	—	—
Pantanal	Female	55.2 (43.3–68.6)	15.0 (10.7–21.0)	—	—
Pantanal	Female	48.1 (39.5–57.5)	4.5 (3.6–5.5)	—	—
Pantanal	Female	95.6 (50.8–154.6)	6.6 (2.9–14.9)	—	—
Pantanal	Female	36.6 (31.1–42.6)	1.2 (1.0–1.5)	—	—
Pantanal	Female	142.3 (131.4–153.8)	8.8 (7.9–9.9)	—	—
Pantanal	Female	119.9 (92.2–151.1)	3.8 (2.8–5.1)	0.87 (0.66–1.15)	9.9 (9.0–10.8)
Pantanal	Female	37.5 (25.6–51.6)	4.2 (2.7–6.4)	0.39 (0.36–0.43)	8.3 (8.1–8.5)
Pantanal	Male	37.3 (29.3–46.3)	3.3 (2.5–4.3)	0.30 (0.28–0.33)	12.3 (11.9–12.6)
Pantanal	Male	726.9 (57.5–2223.4)	14.7 (0.0–38.0)	0.40 (0.27–0.60)	17.5 (15.4–19.6)
Pantanal	Male	280.8 (173.3–413.8)	3.9 (2.2–6.8)	0.39 (0.35–0.45)	23.5 (22.6–24.4)
Pantanal	Male	107.8 (71.6–151.2)	4.9 (3.06–7.8)	0.33 (0.29–0.37)	13.7 (13.2–14.2)
Pantanal	Male	92.4 (60.3–131.2)	9.4 (5.8–15.4)	0.32 (0.30–0.35)	9.5 (9.2–9.7)
Pantanal	Male	36.0 (12.2–72.3)	6.5 (0.9–44.7)	0.16 (0.08–0.32)	9.1 (7.3–10.8)
Pantanal	Male	561.0 (394.8–756.1)	6.2 (4.2–9.2)	0.54 (0.52–0.56)	21.7 (21.4–21.9)
Pantanal	Male	423.1 (316.4–545.1)	3.4 (2.4–4.8)	1.39 (1.13–1.70)	16.7 (15.7–17.7)
Pantanal	Male	63.5 (45.0–85.2)	1.0 (0.6–1.8)	0.61 (0.0–1.42)	16.4 (7.6–25.2)
Pantanal	Male	200.7 (136.0–278.0)	3.8 (2.3–6.2)	—	—
Pantanal	Male	32.9 (14.3–59.0)	6.2 (1.8–20.9)	—	—
Pantanal	Male	69.8 (50.4–92.2)	1.8 (1.1–2.9)	—	—
Pantanal	Male	58.0 (39.7–79.7)	2.1 (1.1–4.0)	1.42 (0.01–2.3)	8.0 (5.0–11.0)
Pantanal	Male	172.6 (134.4–215.5)	2.2 (1.5–3.0)	2.09 (1.33–3.29)	11.9 (10.2–13.5)

Pantanal	Male	89.4 (72.2–108.4)	21.4 (12.6–36.3)	1.7 (0.08–34.3)	13.4 (8.7–18.2)
Pantanal	Male	76.8 (67.4–86.8)	1.2 (1.0–1.4)	—	—
Pantanal	Male	302.7 (156.5–496.4)	6.0 (2.3–15.9)	2.36 (1.19–4.65)	7.8 (6.4–9.2)
Pantanal	Male	181.7 (99.3–288.6)()	3.9 (1.8–8.3)	0.09 (0.06–0.12)	40.2 (35.7–44.7)
Pantanal	Male	457.7 (214.5–791.6)	2.1 (0.8–5.7)	0.2 (0.18–0.22)	10.7 (10.4–11.0)
Pantanal	Male	248.4 (198.2–304.1)	2.1 (1.5–2.8)	1.2 (0.89–1.61)	17.7 (15.9–19.4)
Pantanal	Male	401.1 (237.8–606.5)	3.1 (1.5–6.2)	0.65 (0.33–1.28)	24.4 (19.3–77.1)
Pantanal	Male	187.5 (140.3–241.3)	22.7 (14.7–35.0)	1.39 (0.84–2.31)	21.1 (18.6–23.6)
Pantanal	Male	98.7 (63.1–142.3)	3.5 (1.9–6.3)	0.79 (0.41–1.52)	10.4 (8.6–12.3)
Pantanal	Male	122.8 (97.0–151.5)	1.3 (0.9–1.7)	0.32 (0.0–0.70)	30.9 (15.4–46.5)
Pantanal	Male	219.5 (166.7–279.5)	1.0 (0.7–1.5)	—	—
Pantanal	Male	209.3 (109.7–340.7)	16.0 (7.1–36.2)	0.4 (0.36–0.43)	10.2 (9.9–10.4)
Petén–Veracruz moist forest	Female	643.1 (360.6–1005.9)	28.9 (13.4–62.2)	—	—
Petén–Veracruz moist forest	Female	45.7 (6.06–124.5)	9.4 (0.0–23.5)	5.40 (2.40–12.14)	1.4 (1.2–1.7)
Petén–Veracruz moist forest	Female	258.7 (190.9–336.7)	5.9 (4.1–8.7)	2.91 (2.24–3.77)	7.0 (6.4–7.5)
Petén–Veracruz moist forest	Male	370.2 (294.0–454.9)	4.5 (3.4–6.0)	4.27 (3.55–5.13)	8.0 (7.6–8.4)
Petén–Veracruz moist forest	Male	718.4 (415.1–1103.5)	4.8 (1.9–12.3)	5.24 (2.93–9.33)	9.6 (8.3–11.0)
Purus várzeá	Female	86.9 (45.8–140.8)	9.8 (4.1–23.2)	2.53 (1.97–3.26)	3.3 (3.05–3.49)
Purus várzeá	Female	49.4 (38.0–62.4)	4.8 (3.5–6.7)	0.88 (0.39–2.0)	6.0 (4.8–7.4)
Purus várzeá	Female	70.2 (52.2–90.7)	7.7 (5.6–10.7)	1.03 (0.96–1.11)	5.5 (5.4–5.6)
Purus várzeá	Female	232.2 (85.4–451.1)	28.7 (0.0–59.1)	2.58 (0.4–16.7)	3.3 (2.4–4.2)
Purus várzeá	Male	207.7 (157.5–264.8)	6.8 (5.0–9.4)	2.61 (2,21–3.09)	6.3 (6.0–6.6)
Purus várzeá	Male	254.9 (171.2–355.0)	5.9 (3.6–9.7)	3.36 (2.72–4.14)	6.5 (6.1–6.9)
Purus várzeá	Male	75.8 (42.0–118.6)	3.4 (1.1–11.1)	1.87 (1.02–3.41)	6.1 (5.1–7.0)
Purus várzeá	Male	312.2 (177.9–483.6)	20.4 (10.1–41.0)	—	—
Sonoran–Sinaloan subtropical dry forest	Female	462.9 (245.5–748.1)	9.8 (4.4–21.9)	—	—
Sonoran–Sinaloan subtropical dry forest	Male	805.3 (698.0–920.2)	1.8 (1.5–2.1)	—	—
Yucatán dry forest	Male	305.2 (239.8–378.3)	2.8 (2.1–3.7)	0.57 (0.45–0.71)	25.5 (23.7–27.3)

Table S2. Best fit models. Range–wide and ecoregion scale best fit generalized linear mixed models for home range size, speed, home range crossing time and autocorrelation timescale with sex and ecoregion, respectively as a random effect.

Range–wide	
Random effect	$\alpha \sim Normal(mean_{sex}, var_{sex})$
Home range	$log(home\ range_i) = \alpha_{sex_i} + \beta_1(forest_i) + \beta_2(net\ primary\ productivity_i) + \beta_3(human\ population\ density_i) + \beta_4(road\ density_i)$
Speed	$log(speed_i) = \alpha_{sex_i} + \beta_1(forest_i) + \beta_2(mean\ annual\ precipitation_i)$
Home range crossing time	$\log(home\ range\ crossing\ time_i) = \alpha_{sex_i} + \beta_1(forest_i)$
Autocorrelation timescale	$\log(autocorrelation\ timescale_i) = \alpha_{sex_i} + \beta_1(mean\ annual\ precipitation_i)$
Ecoregion	
Random effect	$\alpha \sim Normal\left(mean_{ecoregion}, var_{ecoregion}\right)$
Home range	$log(home\ range_i) = \alpha_{ecoregion_i} + \beta_1(net\ primary\ productivity_i) + \beta_2(road\ density_i) + \beta_3(sex_i)$
Speed	$log(speed_i) = \alpha_{ecoregion_i} + \beta_1(forest_i) + \beta_2(mean\ annual\ precipitation_i)$
Home range crossing time	$\log(home\ range\ crossing\ time_i) = \alpha_{ecoregion_i}$
Autocorrelation timescale	$\log(autocorrelation\ timescale_i) = \alpha_{ecoregion_i}$

Table S3. Range–wide scale parameter estimates. Covariate parameter estimates and 95% credibility intervals (CRI) for the Bayesian form of the best fit generalized linear mixed model at the range–wide scale with sex as a random effect.

	Log home range (km^2)		**Log speed (km/day)**		**Log autocorrelation timescale (h)**		**Log home range crossing time (d)**	
Parameter	**mean**	**95% CRI**	**mean**	**95% CRI**	**mean**	**95% CRI**	**mean**	**95% CRI**
Percent forest cover	-0.18	-0.36–0.00	-0.25	-0.37–-0.13	–	–	0.17	0.01–0.32
Net primary productivity	-0.63	-1.01–-0.25	–	–	–	–	–	–
Human population density	0.16	0.07–0.26	–	–	–	–	–	–
Road density	0.31	0.13–0.50	–	–	–	–	–	–
Mean annual precipitation	–	–	-0.27	-0.38–-0.17	0.30	0.11–0.49	–	–
Male (intercept)	7.05	6.22–7.88	2.68	2.53–2.83	-0.03	-0.30–0.23	1.38	1.15–1.60
Female (intercept)	6.11	5.26–6.96	2.50	2.34–2.66	-0.09	-0.37–0.20	1.57	1.36–1.79
Sex hyperparameter	6.56	2.77–10.34	2.59	-0.35–5.47	-0.05	-2.80–2.75	1.47	-1.46–4.39

Table S4. Ecoregional scale parameter estimates. Covariate parameter estimates and 95% credibility intervals (CRI) for the Bayesian form of the best fit generalized linear mixed model with ecoregion as a random effect.

	Log home range (km^2)		**Log speed (km/day)**		**Log autocorrelation timescale (h)**		**Log home range crossing time (d)**	
Parameter	**mean**	**95% CRI**	**mean**	**95% CRI**	**mean**	**95% CRI**	**mean**	**95% CRI**
Percent forest cover	–	–	-0.25	-0.38–-0.12	–	–	–	–
Net primary productivity	-0.37	-0.87–0.15	–	–	–	–	–	–
Road density	0.31	0.16–0.45	–	–	–	–	–	–
Mean annual precipitation	–	–	-0.26	-0.39–-0.12	–	–	–	–
Sex	0.81	0.55–1.08	–	–	–	–	–	–
Ecoregion intercepts								
Alto Paraná Atlantic forest	5.09	3.62–6.50	2.50	2.18–2.71	0.26	-0.28–0.81	1.46	1.13–1.77
Caatinga	5.41	4.14–6.68	2.55	2.20–2.82	-0.25	-1.20–0.61	1.60	1.10–2.23
Central American dry forest	4.77	3.06–6.39	2.58	2.23–2.90	-0.09	-1.20–0.92	1.49	0.84–2.09
Cerrado	6.23	5.00–7.46	2.56	2.28–2.79	-0.02	-0.59–0.55	1.39	0.88–1.77
Dry Chaco	5.34	4.46–6.21	2.58	2.32–2.83	0.33	-0.24–0.92	1.65	1.27–2.15
Humid Chaco	4.92	3.86–5.96	2.62	2.39–2.88	-0.57	-1.21–0.05	1.61	1.24–2.04
Llanos	4.12	2.53–5.60	2.60	2.29–2.92	-0.19	-1.12–0.66	1.38	0.65–1.87
Pantanal	4.15	3.03–5.22	2.64	2.50–2.80	-0.23	-0.51–0.05	1.42	1.20–1.62
Petén–Veracruz moist forest	5.12	3.78–6.43	2.55	2.18–2.82	0.92	0.08–1.79	1.70	1.30–2.30
Purus várzeá	4.88	3.50–6.22	2.56	2.20–2.84	0.48	-0.11–1.10	1.76	1.36–2.31
Sonoran–Sinaloan subtropical dry forest	5.18	4.06–6.30	2.58	2.19–2.94	0.04	-1.42–1.49	1.52	0.96–2.07
Yucatán dry forest	5.22	3.56–6.84	2.64	2.34–3.06	-0.15	-1.27–0.85	1.48	0.82–2.06
Ecoregion hyperparameter	5.04	3.82–6.22	2.58	2.40–2.74	0.04	-0.45–0.52	1.54	1.27–1.82

Table S5. Data sources. Data sources used in the analysis.

Landscape variable	**Internet address**
Ecoregions (*44*)	https://ecoregions2017.appspot.com/
Forest cover (*49*)	www.globalforestwatch.org
Protected area (*50*)	www.protectedplanet.net
Annual precipitation (*51*)	http://worldclim.org/
Seasonality in precipitation (*51*)	http://worldclim.org/
Net primary productivity (*52*)	http://files.ntsg.umt.edu/data/NTSG_Products/MOD17/
Human pop density (*53*)	http://sedac.ciesin.columbia.edu/data/set/gpw–v4–population–density–rev10
Human footprint index (*54*)	https://wcshumanfootprint.org/
Cattle density (*55*)	https://livestock.geo–wiki.org/home–2/
Primary Roads (*56*)	http://sedac.ciesin.columbia.edu/data/set/groads–global–roads–open–access–v1