

1 **Space use and movement of jaguar (*Panthera onca*) in western Paraguay**

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20 Running title: Jaguar home ranges in Paraguay

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26 **Abstract:** We estimated home range and core area size for jaguar (*Panthera onca*) in western
27 Paraguay in the Dry Chaco, Humid Chaco and Pantanal using an autocorrelated kernel density
28 estimator. Mean home range size was 818 km² (95% CI:425-1981) in the Dry Chaco and 237
29 km² (95% CI:90-427) in the Humid Chaco/Pantanal. Core areas, defined as the home range area
30 where use was equal to expected use, was consistent across sexes and systems represented on
31 average by the 59% utility distribution isopleth (range:56-64%). Males had a higher probability
32 of larger home ranges and more directional and greater daily movements than females
33 collectively and within systems. The large home ranges in the Dry Chaco are attributable to the
34 relatively low productivity of that semi-arid ecosystem and high heterogeneity in resource
35 distribution while larger than expected home ranges in the Humid Chaco/Pantanal compared to
36 home range estimates from the Brazilian Pantanal may be due to differences in geomorphology
37 and hydrological cycle. The large home ranges of jaguars in western Paraguay and a low
38 proportional area of protected areas in the region demonstrate the importance of private
39 ranchland for the long-term conservation of the species.

40

41 **Keywords:** Adaptive kernel density estimation; home range; jaguar; *Panthera onca*; Paraguay

42

43 **Introduction**

44 Globally, apex predators, and the maintenance of their functional roles, are severely threatened
45 due to anthropogenic pressures, particularly associated with large spatial needs to access
46 sufficient prey to meet metabolic requirements and persecution (Ripple et al. 2014). Habitat
47 conversion and degradation and over hunting of prey species increase spatial requirements of

48 apex predators, increasing conflict with humans and affecting social behavior, dispersal and
49 habitat use (McDonald 1983; Crooks 2002; Cardillo et al. 2004; Ripple et al. 2014).
50 Consequently, an understanding of the space use and movement ecology of apex predators is key
51 to effective conservation decision making for these species.

52 The jaguar (*Panthera onca*) is the largest feline in the Americas, distributed from the
53 southwestern United States to northern Argentina, although it presently occupies <50% of its
54 original range, and <80% of the range outside of Amazonia, due to habitat loss and persecution
55 (Sanderson et al. 2002; Zellar 2007; de la Torre et al. 2017). Given the contraction of the
56 species' distribution, range-wide conservation efforts have focused upon maintaining
57 connectivity among key populations throughout the species range (Sanderson et al. 2002;
58 Rabinowitz and Zeller 2010), however, an effective implementation of this management
59 approach is partly dependent upon a thorough understanding of the spatial and movement
60 ecology of jaguars.

61 For a big cat the jaguar is relatively understudied (Brodie 2009), and although multiple
62 studies have estimated jaguar home range size (Schaller and Crawshaw 1980; Rabinowitz and
63 Nottingham 1986; Crawshaw and Quigley 1991; Crawshaw 1995; Scognamillo et al. 2002;
64 Crawshaw et al. 2004; Silveira 2004; Cullen 2006; Azevedo and Murray 2007; Cavalcanti and
65 Gese 2009; Tobler et al. 2013; Morato et al. 2016) and movements (Conde et al. 2010; Colchero
66 et al. 2011; Sollman et al. 2011; Morato et al. 2016), there is still relatively little known about the
67 species' spatial and movement ecology. Since anthropogenic factors drive jaguar occurrence
68 throughout its range by determining habitat availability and quality (Zeller et al. 2012; Petracca
69 et al. 2014a,b; Thompson and Martinez 2015) this conspicuous knowledge gap on how jaguars

70 perceive and use the landscape is of concern as it limits managers' ability to quantifiably design
71 and manage conservation landscapes for the jaguar.

72 Of further concern is that until recently jaguar home range estimates likely
73 underestimated space use as VHF-based estimates were based upon small number of locations,
74 while GPS-based estimates failed to account for autocorrelation inherent in GPS telemetry data
75 (Morato et al. 2016). Furthermore, only recently have movement parameters and quantitative
76 assessment of home range residency been estimated for jaguar (Morato et al. 2016).
77 Consequently, there is an important need for research that incorporates developing
78 methodologies that account for and take advantage of autocorrelation in telemetry data to better
79 quantify jaguar spatial and movement ecology.

80 Range-wide, the jaguar is considered near threatened (Caso et al. 2008), however, at the
81 austral limit of its distribution the species is considered critically endangered in Argentina and
82 endangered in Brazil and Paraguay. Although multiple studies have investigated space use by
83 jaguar in Brazil and Argentina (Schaller and Crawshaw 1980; Crawshaw and Quigley 1991;
84 Crawshaw 1995; Crawshaw et al. 2004; Silveira 2004; Cullen 2006; Azevedo and Murray 2007;
85 Cavalcanti and Gese 2009; Morato et al. 2016) there has been no such research on the species in
86 Paraguay despite a recognized need in the face of a rapid constriction in the species' distribution
87 in relation to a country-wide expansion of the agricultural sector (Secretaría del Ambiente et al.
88 2016) which has resulted in some of the highest rates of deforestation in the world (Hansen et al.
89 2013).

90 Given the status of the jaguar in Paraguay, the lack of information on the spatial and
91 movement ecology of the species is of concern within the context of continued habitat loss, the
92 maintenance of in-country and trans-boundary connectivity of populations, and their implications

93 for the range-wide conservation of the jaguar. Consequently, we used GPS-based telemetry to
94 study space use and movements of jaguars in western Paraguay in the Dry Chaco, Humid Chaco
95 and Pantanal, the region with the largest jaguar population in the country. Moreover, we
96 employed developing methodologies which allowed us to determine home range residency and
97 account for autocorrelation in the data (Fleming et al. 2014, 2015; Calabrese et al. 2016), which
98 in turn allowed for rigorous comparisons with estimates from other research employing the same
99 methodologies (Morato et al. 2016).

100 Based upon carnivore ecology in general, and jaguar ecology specifically, we expected
101 male home range and movement rates to be higher than females (Mikael 1989; Cavalcanti and
102 Geese 2009; Conde et al. 2010; Sollmann et al. 2011; Morato et al. 2016) and that jaguars in the
103 Dry Chaco would exhibit larger home ranges, higher movement rates, and more directional
104 movement compared to those in the more productive habitats of the Humid Chaco and Pantanal
105 (Mikael 1989; Fahrig 2007; Gutierrez-Gonzalez et al. 2012). Also, when comparing to other sites
106 (Morato et al. 2016) we expected estimated from the Humid Chaco and Pantanal to be similar to
107 those from the Brazilian Pantanal, while estimates from the Dry Chaco would be larger than
108 those from more humid systems but possibly similar to jaguars from the Brazilian Cerrado due to
109 biotic and abiotic similarities between systems. Apart from constituting an important
110 contribution towards the conservation of jaguars within Paraguay, placing our results into a
111 comparative context with research from neighboring countries will facilitate the efficacy of
112 trans-boundary conservation efforts, with important implications for range-wide conservation
113 strategies for jaguar.

114

115 **Materials and methods**

116 **Study area**

117 We conducted our study in three ecosystems in western Paraguay; Dry Chaco, Humid Chaco and
118 Pantanal, (Figure 1). The Dry Chaco is comprised of xeric forest, savannas, and grasslands and
119 the Humid Chaco and Pantanal are a mosaic of seasonally flooded grasslands, palm savanna and
120 xerophilic woodlands on higher ground (Olson et al. 2001; Mereles et al. 2013). We note that
121 delineations between the Humid Chaco and Pantanal differ (Olson et al. 2001; Mereles et al.
122 2013), however, for our purposes the similarities between systems and among our study sites in
123 those systems make this discrepancy moot and consequently we treat the Humid Chaco and
124 Pantanal as a single system in our analysis.

125 The western half of Paraguay is generally semi-arid with a pronounced east–west
126 gradient in precipitation and humidity which divides the Chaco into the Humid Chaco with
127 precipitation approximately > 1000 mm/year and the Dry Chaco with precipitation < 1000
128 mm/year (Olson et al. 2001). The Pantanal is also subjected to this east-west precipitation
129 gradient; however, it and the Humid Chaco are also strongly effect by the hydrological cycles of
130 the Rio Paraguay (Mereles et al. 2013).

131 In the Humid Chaco our study area was Estancia Aurora, a 30,000 ha cattle ranch in the
132 north of the department of Villa Hayes and in the Pantanal on the 65,000 ha ranch Estancia
133 Fortín Patria and on the 80,000 ha ranch Estancia Leda. In the central Dry Chaco, we worked on
134 the 40,000 ha Faro Moro ranch and more northerly in the 7,200 km² Defensores del Chaco
135 National Park and the neighboring 269,000 ha of ranchland of the consortium *Grupo Chovoreca*.

136 **Jaguar captures**

137 Jaguars were captured using trained hounds to tree or bay jaguars which were then anesthetized
138 using a weight-dependent dose of a mix of ketamine hydrochloride and xylazine hydrochloride

139 injected by a dart shot from a tranquilizer gun (McBride and McBride 2007). Capture methods
140 followed ASM protocols (Sikes 2016) and in > 60 captures and recaptures of jaguar and puma
141 over the study period there were no deaths or noticeable injury to animals.

142 From 2002–2009 jaguars were fitted with Telonics Generation II, data stored-on-board,
143 GPS collars (Telonics, Mesa, Arizona, USA) which were set to record locations at 4 hour
144 intervals. Starting in 2009 we used Northstar GPS collars (D-cell, Northstar, King George,
145 Virginia, USA) programmed to record locations at three or four hour intervals and in 2012 we
146 switched to Telonics Generation III GPS collars (Telonics, Mesa, Arizona, USA) which were set
147 to record locations daily every two hours from 1800 to 0600 hours.

148 **Home range estimation**

149 Semi-variogram analysis, model selection and AKDE estimates were undertaken using the *ctmm*
150 package (Calabrese et al. 2016) in R 3.3.2 (R Development Core Team 2010). Starting values
151 derived from semi-variograms were used for maximum likelihood model fitting with model
152 selection based upon Akaike Information Criteria, adjusted for small sample size (AICc), and
153 model weights (Fleming et al. 2014, 2015; Calabrese et al. 2016). We accounted for data
154 collected with an irregular sampling schedule from collars used starting in 2012 with the *dt*
155 argument within the *variogram* function in the *ctmm* package (Calabrese et al. 2016).

156 Movement models tested were an independent identically distributed (IID) model which
157 ignores autocorrelation in the data and is equivalent to kernel density estimation (KDE) (Worton
158 et al. 1989), a random search model (Brownian motion) with no home range, Brownian motion
159 within a home range (Ornstein–Uhlenbeck, OU), and Ornstein–Uhlenbeck motion with foraging
160 (OUF) (Fleming et al. 2014; Calabrese et al. 2016). Both the OU and OUF models produce

161 estimates of home range size and home range crossing time, while the OUF model additionally
162 estimates the velocity autocorrelation time scale (a measure of path sinuosity) and mean distance
163 traveled (Fleming et al. 2014; Calabrese et al. 2016).

164 Home ranges were estimated using the best fit model for each individual using AKDE
165 (Fleming et al. 2015; Calabrese et al. 2016). For comparison with home range estimates from
166 previous research we estimated 95% KDE home ranges using the IID model and 95% Minimum
167 Convex Polygons (MCP) home ranges using the `adehabitatHR` package in R (Calenge 2006)
168 (Supplementary material Appendix 1).

169 **Core area estimation**

170 We estimated core areas of AKDE home ranges as the area encompassed within the isopleth
171 where the proportional use of the estimated home range is equal to the predicted probability of
172 use (Seaman and Powell 1990; Bingham and Noon 1997; Vander Wal and Rodgers 2012). We
173 determined this by fitting an exponential curve to the isopleths of the utility distribution of each
174 individual at 10% increments from 10% to 90%, and at the 95% and 99% isopleths of the AKDE
175 home range and the proportional area of the home range that each of those isopleths
176 encompassed based upon the area of the 99% home range estimate. We then determined the
177 threshold where proportional home range size begins to increase at a rate greater than the
178 probability of use (slope=1; Seaman and Powell 1990; Bingham and Noon 1997; Vander Wal
179 and Rodgers 2012) to define the isopleth that represented the core area boundary.

180 **Statistical analyses**

181 For our statistical analysis we combined jaguars from the Humid Chaco and the Pantanal into a
182 single group as the characteristics of the system are highly similar, the delineation between the

183 two systems is debatable (Olson et al. 2001; Mereles et al. 2013), and consequently jaguars from
184 those systems are subjected to similar ecological and anthropogenic drivers. Additionally, only
185 individuals that exhibited residency in their movement behavior through semi-variogram analysis
186 and space use best explained by the OUF model were included in our comparative analysis of
187 differences between sexes and ecosystems.

188 We used a fixed-effect one-way analysis of variance (ANOVA) in a Bayesian modeling
189 framework to test for differences in estimates of home range size, home range crossing time,
190 directionality in movement (velocity autocorrelation time scale) and mean daily distance traveled
191 between sexes across systems, between systems (sexes combined), between sexes within a
192 system, and between same sexes between systems. We tested normality using the Shapiro-Wilk
193 test and log-transforming the data when its distribution did not meet assumptions of normality.

194 All analyses were undertaken in R 3.2.2. (R Development Core Team 2010) using
195 WinBUGS (Lunn et al. 2000) and the *R2bugs* package (Sturtz et al. 2005) for the Bayesian
196 analysis. We ran 3 chains in WinBUGS with 100,000 iterations and a 20,000 iteration burn-in
197 period; confirming convergence by a scale reduction factor ≤ 1.01 and visual inspection of trace
198 plots for lack of autocorrelation. We tested differences between groups by taking 10,000 random
199 samples from posterior distributions for each group of interest, comparing the proportional
200 frequency that posterior estimates parameters were greater for males than females overall and
201 within systems, greater for all individuals, and between same sexes, in the Dry Chaco compared
202 to the Humid Chaco/Pantanal.

203

204 **Results**

205 **Jaguar captures and data collection**

206 We captured and collared 35 jaguars from June 2002 to June 2014 of which 19 individuals
207 provided sufficient data for analysis; 7 in the Dry Chaco (5 males, 2 females), 9 in the Humid
208 Chaco (3 males, 6 females) and 3 in the Pantanal (1 male, 2 females) with estimated ages
209 between 2 and 10 years (Table 1). Collars collected data between 52 and 439 days, obtaining
210 from 148 to 3462 locations (Table 1). The length of the study period and the annual frequency of
211 captures were dependent upon resource availability and logistical restraints that dictated captures
212 and collar recovery.

213 **Home range, core area and movement parameter estimates.**

214 Best fitting models for the movement of jaguars were either the OU or OUF models with 16
215 individuals demonstrating residency (Table 1). Estimated home range sizes varied between 86
216 and 2,909 km² and core areas between 21-509 km². Core areas were represented by a consistent
217 proportion of the utility distribution; ranging between 56%-64% isopleths (Table 2).

218 Male and female mean home range size were 727 km² (95% CI:355-1954) and 255 km²
219 (95% CI:90-578), respectively and 818 km² (95% CI:425-1981) and 237 km² (95% CI:90-427)
220 for jaguars in the Dry Chaco and Humid Chaco/Pantanal, respectively (Fig. 2, Fig.3). In the Dry
221 Chaco mean home range size for males was 925 km² (95% CI:424-2035) and 551 km² (95%
222 CI:513-590) for females, while in the Humid Chaco/Pantanal the mean home range was 398 km²
223 (95% CI:345-427) and 156 km² (95% CI:90-267) for males and females, respectively (Fig. 4).

224 Males demonstrated larger home ranges ($P=0.99$), higher daily movement ($P=0.84$),
225 greater directionality in movement (velocity autocorrelation time scale) ($P=0.84$) and lower
226 home range crossing times ($P=0.9$) (Table 2, Figure 2). Between systems, home ranges were

227 larger ($P=1$), movements more directional ($P=0.99$) and home range crossing times greater
228 ($P=0.77$) in the Dry Chaco, while daily travel distance was similar between systems but with a
229 slightly higher probability of being larger in the Dry Chaco ($P= 0.61$, Figure 3).

230 Between systems males in the Dry Chaco had higher probabilities to have larger home
231 ranges ($P=0.91$), higher home range crossing time ($P=0.75$), greater directionality in movement
232 ($P=0.86$), and greater daily travel distances ($P=0.72$) (Table 2), although values for all
233 parameters were more variable in males from the Dry Chaco (Figure 4). A similar pattern was
234 evident between females in both systems for home range size ($P=0.99$), home range crossing
235 time ($P=0.89$) and directionality in movement ($P=0.96$) which were greater for females in the
236 Dry Chaco, however, females in the Dry Chaco had lower daily movements ($P=0.23$) than those
237 in the Humid Chaco/Pantanal (Table 4).

238

239 **Discussion**

240 We present the first estimates of movement parameters and home range and core area for jaguar
241 in the Dry Chaco, Humid Chaco, and Paraguayan Pantanal, which furthermore take advantage of
242 developing methods to empirically test for home range residency and account for autocorrelation
243 in telemetry data when estimating space use (Fleming et al. 2014. 2015; Calabrese et al. 2016).
244 Our results include the largest home range estimates recorded for jaguar (Dry Chaco) and, as
245 expected, jaguars in the more productive Humid Chaco/Pantanal had smaller home ranges, lower
246 movement rates and had less directionality in movements compared to jaguars in the Dry Chaco.
247 Also, consistent with previous research males had larger home ranges, higher movement rates
248 and more directional movements than females overall and within systems.

249 Overall and between systems male home ranges were larger than females which was
250 expected (Calvalcanti and Gese 2009; Sollmann et al. 2011; Morato et al. 2016) as smaller home
251 ranges of females are driven by food availability in relation to reproductive and offspring rearing
252 needs which in-turn drives larger male home ranges towards optimizing reproductive
253 opportunities (Mikael 1989; Sunquist and Sunquist 1989). This relationship is further supported
254 by our estimated movement parameters which showed that males traveled farther, faster, and
255 more directionally than females in utilizing home ranges.

256 Consistent with our expectations home range sizes of jaguars in the Dry Chaco were
257 larger than in the Humid Chaco and Pantanal, overall and between sexes within systems where
258 male home ranges were greater than females. The larger home ranges in the Dry Chaco are
259 attributable to the lower productivity of that semi-arid ecosystem, more heterogeneously
260 distributed prey and water, and negative effects of anthropogenic factors (i.e., deforestation;
261 Fahrig 2007; Gutierrez-Gonzalez et al. 2012). The difference between sexes within systems is
262 attributable to differences in territorial organization stemming from aforementioned reproductive
263 and social needs (Mikael 1989; Sunquist and Sunquist 1989).

264 Home range estimates from the Dry Chaco for both males and females are considerably
265 larger than other estimates from this study and Morato et al. (2016), although our estimates of
266 male home range size from the Dry Chaco (mean:925 km², 95% CI:424-2035) are consistent
267 with the estimate for a single male from the Brazilian Cerrado (1269 km²), a semi-arid ecosystem
268 with environmental and land use similarities to the Gran Chaco. Morato et al. (2016)
269 demonstrated that increasing home range size of jaguars was associated with lower habitat
270 quality, which is consistent with the very large home ranges from the Dry Chaco which were

271 closest in size to Morato et al's (2016) home ranges in the Atlantic forest which they considered
272 to be of the lowest habitat quality of their study areas.

273 We expected home range sizes from the Humid Chaco/Pantanal to be similar to estimates
274 from the Brazilian Pantanal, however, our estimates were 59% and 112% larger for males and
275 females, respectively than home ranges reported for the Brazilian Pantanal; falling between
276 estimates from the Amazon and Atlantic forest, although most similar to jaguars from the
277 Amazon (Morato et al. 2016; Fig. 5). These differences may be related to differences in the
278 geomorphology of the two regions and its interaction with the local hydrological cycles.

279 The Paraguayan Pantanal and our study area in the Humid Chaco have less forest area
280 and a relatively greater area of inundated land during a large portion of the year compared to the
281 Pantanal study areas of Morato et al. (2016) in Brazil. Consequently, the reduced forest area,
282 with smaller and more isolated forest patches during annual flooding, could drive the
283 comparatively larger home ranges observed in the Paraguayan Pantanal and Humid Chaco,
284 although reduced jaguar densities resulting from persecution may also play a role in liberating
285 available space and permitting greater space use.

286 Differences in the mean movement parameters were evident between jaguars in the
287 Humid Chaco/Pantanal and in the Brazilian Pantanal whereby movements were more directional
288 in the Humid Chaco/Pantanal, although still relatively sinuous but most similar to jaguars in the
289 Atlantic forest, while daily movements were very similar to those in the Amazon (Fig. 6).
290 Jaguars in the Dry Chaco had high movement rates and directionality in movement, similar to
291 individuals in the Amazon from seasonally flooded forests (Morato et al. 2016).

292 We believe that these similarities are responses to movements among sporadically
293 distributed critical resources despite the large differences in ecosystem characteristics.
294 Conversely, although daily movement rate of jaguars in the Humid Chaco/Pantanal were similar
295 to those in the Dry Chaco and Amazon, the relatively low directionality demonstrated by jaguars
296 in the Humid Chaco/Pantanal suggests that, although jaguars are covering relatively large areas,
297 movements are in response to more homogenously distributed resources within home ranges.

298 Core areas, as measured by the utility distribution isopleth were highly similar across
299 systems and sexes, encompassed on average by the 59% isopleth (95% CI:56-64%), which
300 represented on average 29% (95% CI:21-34%) of total home range area. This indicates that
301 despite home range size, sex, or system jaguars are most intensively using about a third of their
302 home range area. Additionally, our results suggests a cautious interpretation of arbitrarily
303 defined core area delimitations, typically assigned to the 50% utility distribution isopleths which
304 falls outside of the 95% confidence limits of our estimates (Powell 2012).

305 In light of the extensive deforestation that is occurring in the Dry Chaco of western
306 Paraguay, the large home ranges that we observed in this system, which are consistent with the
307 estimated low density of jaguar in the Bolivian Dry Chaco (Noss et al. 2012), are of concern as
308 they demonstrate the large forested area that jaguars in the Dry Chaco require. In the Humid
309 Chaco/Pantanal spatial requirement of jaguars were greater than expected based on estimates
310 from the Brazilian Pantanal, which suggests lower than expected densities in these systems in
311 Paraguay and cautions against extrapolating population parameter estimates from other regions
312 within the Pantanal to the Rio Paraguay flood plain in Paraguay.

313 In both the Dry Chaco and the Humid Chaco/Pantanal we recognize that there may be an
314 important effect on space use caused by reduced jaguar densities from persecution which is
315 pervasive throughout western Paraguay, illustrated by our confirmation, or high probability, of
316 ~75% of our study animals being killed due to persecution. Persecution is common throughout
317 the range of the jaguar, however, its practice and magnitude is not equivocal geographically and
318 consequently how the removal of individuals may impact space use, and subsequently
319 comparisons among ecosystems and regions, needs to be considered and is of interest for future
320 research.

321 The large spatial requirements of jaguars in western Paraguay, particularly in the Dry
322 Chaco, indicate that the protected areas of the region which, represent <5% of the total regional
323 area are likely insufficient to maintain a viable regional population, especially in light of the
324 level of persecution on private lands. This highlights an urgent need to mitigate jaguar-human
325 conflict in the region by actively including the livestock production sector in the conservation
326 decision making process. Furthermore, given continuing deforestation, conservation initiatives
327 need to take into account the large spatial needs of jaguar in western Paraguay by recognizing
328 and incorporating the role of private lands in the long-term conservation of the species in
329 Paraguay and in maintaining trans-boundary connectivity among populations.

330

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489 Table 1. Sex, age, sample characteristics and estimated movement parameters, AKDE home
 490 range, core area and core area utility distribution isopleths for study jaguars in the Paraguayan
 491 Dry Chaco, Humid Chaco and Pantanal.

ID	Sex/age (yr)	Number of fixes/days	Velocity autocorre- lation timescale (h)	Home range crossing time (days)	Average distance traveled (km/day)	Home range (km ²) (95% CI)	Core (km ²)	Core area isopleths (%)
<i>Dry Chaco</i>								
DC1	M/5	1094/376	1.1	8.0	28.8	2143 (1558-2820)	504	59
DC3	M/2	722/363	1.8	11.5	7.9	421 (288-580)	107	63
DC4	M/5	620/82	1.9	3.5	15.0	550 (349-797)	182	58
DC6	M/7	1387/393	2.2	4.8	19.3	1063 (822-1335)	329	57
DC7	M/5	3462/439	1.4	2.7	17.1	445 (381-515)	85	64
DC5	F/6	1610/386	1.1	11.5	11.8	591 (411-805)	178	59
DC2	F/8	921/379	1.7	9.5	9.7	511 (363-683)	176	56
<i>Humid Chaco/Pantanal</i>								
Pan2	F/2	1694/375	1.1	4.3	7.9	71 (58-85)	24	60
HC5	F/4	593/242	0.5	1.2	20.9	92 (75-110)	23	61
HC4	F/3	288/266	1.5	6.2	9.3	270 (187-369)	86	57
HC8	F/1	980/170	0.2	10.2	13.7	121 (71-183)	32	58
HC7	F/6	1668/324	0.1	9.2	22.3	246 (172-332)	73	57

HC9	F/6	928/362	0.2	9.7	13.9	118 (83-159)	33	59
Pan3	M/6	727/192	1.4	3.4	16.6	428 (320-550)	134	57
HC3	M/4	983/143	1.4	4.4	15.0	424 (290-584)	138	56
HC6	M/10	660/133	0.9	5.5	13.4	341 (216-494)	91	60
Pan1	F/4	1695/366	NA	3.5	NA	550 (349-797)	21	60
HC1	M/6	148/88	NA	5.9	NA	958 (534-1505)	283	58
HC2	F/6	280/54	NA	5.7	NA	73 (35-125)	22	57

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503 Table 2. Probabilites, based upon posterior distributions, that home range and movement
 504 parameters are different between sex and ecosystem, between sexes within systems, and between
 505 same sexes between systems.

	Home range (km ²)	Home range crossing time (days)	Velocity autocorrelation timescale (h)	Average distance traveled (km/day)
Dry Chaco male > Dry Chaco female	0.71	0.08	0.71	0.89
Humid Chaco/Pantanal male > Humid Chaco/Pantanal female	0.99	0.17	0.95	0.52
Dry Chaco male > Humid Chaco/Pantanal male	0.91	0.75	0.86	0.72
Dry Chaco female > Humid Chaco/Pantanal female	0.99	0.89	0.96	0.23
All Dry Chaco > All Humid Chaco/Pantanal	1	0.77	0.99	0.61
Male > Female	0.99	0.10	0.99	0.84

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507 **Supplementary material**

508 Table A.1. Comparative home range sizes for study jaguars based upon autocorrelated kernel
 509 density estimator (AKDE), 95% kernel density estimator (KDE), and 95% minimum convex
 510 polygon (MCP).

ID	Sex/age (yr)	AKDE Home range (km ²) (95% CI)	95% KDE (km ²)	95% MCP (km ²)
<i>Dry Chaco</i>				
DC1	M/5	2143 (1558-2820)	1674	1813
DC3	M/2	421 (288-580)	193	152
DC4	M/5	550 (349-797)	453	389
DC6	M/7	1063 (822-1335)	877	950
DC7	M/5	445 (381-515)	418	587
DC5	F/6	591 (411-805)	479	475
DC2	F/8	511 (363-683)	402	298
<i>Humid Chaco/Pantanal</i>				
Pan2	F/2	71 (58-85)	71	87
HC5	F/4	92 (75-110)	102	89
HC4	F/3	270 (187-369)	176	151
HC7	F/1	121 (71-183)	87	88
HC8	F/6	246 (172-332)	205	184
HC9	F/6	118 (83-159)	87	96
Pan3	M/6	428 (320-550)	350	288

HC2	M/4	424 (290-584)	302	255
HC6	M/10	341 (216-494)	280	256
Pan1	F/4	550 (349-797)	59	67
HC1	M/6	958 (534-1505)	644	491
HC3	F/6	73 (35-125)	52	36

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524 Figure 1. Map showing the distribution of the Dry and Humid Chaco and Pantanal in western
525 Paraguay (Olson et al. 2001) and study areas where jaguar movements were monitored.

526 Figure 2. Home range and movement parameters of male and female jaguars across all study
527 sites.

528 Figure 3. Home range and movement parameters for study jaguars in the Dry Chaco and Humid
529 Chaco/Pantanal.

530 Figure 4. Home range and movement parameters of male and female jaguars in the Dry Chaco
531 and Humid Chaco/Pantanal.

532 Figure 5. Mean male and female home ranges (error bars represent 95% confidence interval)
533 from this study and AKDE estimates from Morato et al. (2016) by ecosystem. The numbers next
534 to points represent sample size.

535 Figure 6. Mean of the mean distance traveled and the velocity autocorrelation timescale (error
536 bars represent SE) of jaguars from this study and mean estimates from Morato et al. (2016) by
537 ecosystem.











