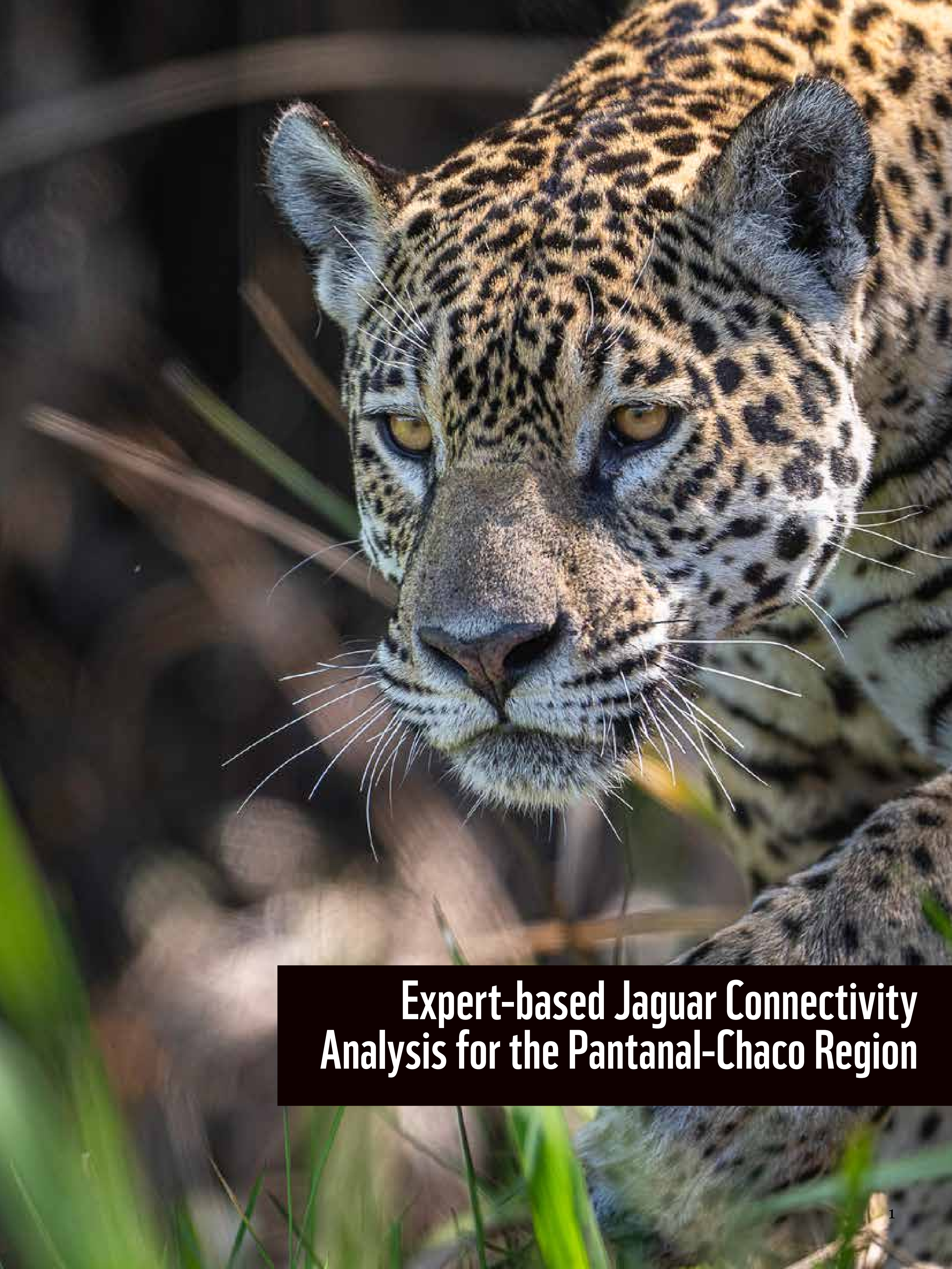

Expert-based Jaguar Connectivity Analysis for the Pantanal-Chaco Region

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INTRODUCTION

WWF is currently engaged in an effort to protect, manage, and restore ecological connectivity in large landscapes on four continents as part of its Wildlife Connect initiative. One of these landscapes is the Pantanal-Chaco (PACHA) landscape in South America, where the jaguar has been selected as a focal species because it is endangered in three of the four PACHA countries, wide-ranging, sensitive to anthropogenic landscape changes, and relatively well studied – all factors that suggest that conserving connectivity for jaguars would also conserve connectivity for many other species. The overall objective of WWF's program in the region is to build a common vision of jaguar connectivity in PACHA.

A key step in achieving this objective is characterizing and mapping ecological network for jaguars, and this report describes a modeling study conducted by the Center for Large Landscape Conservation for this purpose.

The study relies on the knowledge of experts in jaguar biology and local ecology to (1) map core habitat areas among which connectivity should be maintained, (2) identify landscape variables that influence jaguar movement, and (3) quantify the relationship between these landscape variables and resistance to movement. This expert input then informs connectivity models that identify optimal ecological corridors. The results of this study (along with a separate study that models connectivity using empirical data on jaguar movement rather than expert opinion) are intended to support the design of an ecological network of core areas and corridors that preserves connectivity in the PACHA region.


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STUDY AREA

The study area included the whole Pantanal and a big section of the Chaco regions of South America, as defined by PACHA team members, plus a 100-km buffer around these regions to allow the analysis to account for connectivity with jaguar habitat surrounding PACHA (Fig. 1). The study area included portions of Brazil, Bolivia, Paraguay, and Argentina, totaling 1,586,090 km2.

We identified core habitat areas for jaguar within the study area using spatial data on boundaries of protected areas, indigenous territories (i.e., Tierra Comunitaria de Origen, or TCOs), private lands and other conservation units in the World Database on Protected Areas (UNEP-WCMC and IUCN 2022) or provided by PACHA team members. We aggregated all polygons that overlapped or were separated by ≤50 m, then filtered out any aggregated polygons that were less than 100 km2 within the Pantanal region, or less than 1,000 km2 within the Chaco region and the 100-km buffer zone around the PACHA landscape. Exceptions were made for 11 core areas less than 1,000 km2 in the Chaco region (core areas 32, 33, 38, 39, 40, and 46; Table 1) or in the buffer zone (core areas 7, 31, 44, 45, and 47), which experts indicated recent jaguar records and that they were critical jaguar habitat patches or stepping stones despite their small size. Fifty-eight core areas were identified, ranging in size from 78 to 81,734 km2 (Fig. 1; Table 1).

One additional core area, Iberá Provincial Reserve (core area 20), was included in the analysis despite only a 0.1-km2 portion of it lying within the study area boundary because of its exceptional importance for jaguars in the region. Thanks to recent reintroduction efforts, Iberá supports one of the largest populations of jaguars in Argentina, and linking its jaguars with those occupying habitat further north in the Chaco and Pantanal would be highly beneficial. Furthermore, local experts believe that the most likely connection between Iberá and the other core areas in our analysis would run through the southwestern tip of Iberá that abuts our study area.

Table 1 Core area ID numbers and corresponding conservation unit names

CORE AREA ID	Conservation units included in core area
1	Aguarague / Tierra Comunitaria de Origen Itikaguasa / Tierra Comunitaria de Origen Macharety / Tierra Comunitaria de Origen Weenhayek
2	Amboró
3	Área De Proteção Ambiental Da Chapada Dos Guimarães / Área De Proteção Ambiental Municipal Do Aricá-Açu
4	Área De Proteção Ambiental Estrada Parque De Piraputanga
5	Área De Proteção Ambiental Nascentes Do Rio Paraguai
6	Área De Proteção Ambiental Rio Cênico Rotas Monçoeiras
7	Área Natural de Manejo Integrado Municipal Laguna Marfíl
8	Baia do Guató
9	Bañado la Estrella
10	Buriti
11	Cachoeirinha
12	Cerrados del Tagatiya / Tagatiya-mi / Cerrado del Río Apa / Arrecife / Serrania San Luis / Paso Bravo / Bella Vista
13	Monumento Nacional Cerro Chovoreca / Reserva bajo dominio Privado Lote N° 1 / El Ceibo / Reserva para Parque Nacional Cerro Cabrera-Timane / Parque Nacional Defensores del Chaco / Parque Nacional Medanos del Chaco / Parque Nacional Rio Negro / Otuquis / Kaa-iya del Gran Chaco / TCO Origen Isoso / TCO Santa Teresita / Nembia Guasu / AP Quebracho Colorado / TCO Macharety / Guajukaka / Héroes Del Chaco
14	Copo / Loro Hablador
15	El Impenetrable
16	Estação Ecológica Da Serra Das Araras
17	Estação Ecológica De Taiamã
18	Estação ParecisA
19	Guyrati / Lago Ypoa
20	Iberá Reserva Provincial
21	Iñao / Parabanó / Rio Grande Valles Crucenos / Tierra Comunitaria de Origen Itikaraparirenda / Tierra Comunitaria de Origen Iupaguasu / Tierra Comunitaria de Origen Kaaguazu / Área Guarani Del Manejo De Agua Serranía Irenda
22	Kadiwéu
23	Otuquis
24	Parque Estadual Águas Do Cuiabá / Santana / Área De Proteção Ambiental Das Cabeceiras Do Rio Cuiabá
25	Parque Estadual Das Nascentes Do Rio Taquari
26	Parque Estadual Do Pantanal Do Rio Negro / Reserva Particular Do Patrimônio Natural Fazenda Santa Sofia
27	Parque Estadual Encontro Das Águas / Estrada Parque Transpantaneira
28	Parque Nacional Da Chapada dos Veadeiros / Parque Nacional Das Emas
29	Parque Nacional Da Serra Da Bodoquena

CORE AREA ID	Conservation units included in core area
30	Parque Nacional Da Serra Da Bodoquena / Reserva Particular Do Patrimônio Natural Fazenda São Geraldo
31	Parque Nacional El Rey
32	Parque Nacional Rio Pilcomayo
33	Parque Nacional Teniente Enciso
34	Perigara / Estrada Parque Rodovia Mt 370 / Sesc Pantanal
35	Portal do Encantado / Chiquitano de Baia Grande / Parque Estadual Serra Santa Bárbara
36	Reserva Aborigen / Fuerte Esperanza
37	Reserva Ecológica Municipal Paquió
38	Reserva Nacional Pizarro
39	Reserva Natural 1° Div. Caballeria Cuartel Gral.
40	Reserva Natural Formosa
41	Reserva Particular Do Patrimônio Natural Fazenda Lageado
42	Reserva Particular Do Patrimônio Natural Poleiro Grande
43	Reserva Particular Do Patrimônio Natural Reserva Natural Engenheiro Eliezer Batista / Parque Estadual Do Guirá / Guató / Reserva Particular Do Patrimônio Natural Rumo Ao Oeste / Valle de Tucavaca / Parque Nacional Do Pantanal Matogrossense
44	Reserva Provincial Acambuco / Reserva Provincial Lotes Anexos a Acambuco
45	Reserva Provincial Acambuco / Reserva Provincial Lotes Anexos a Acambuco
46	Reserva Provincial Los Palmares
47	Reserva Provincial Trasfondo del Trementinal
48	Rio Formoso
49	Sangradouro / Volta Grande
50	Yungas Biosphere Reserve: Serranias de Zapla / Parque Nacional Calilegua / Parque Provincial Laguna Pintascayo / Parque Nacional Baritú
51	Tariquía
52	52 Taunay / Ipegue
53	53 Tereza Cristina
54	54 Tierra Comunitaria de Origen Isoso
55	Tierra Comunitaria de Origen Zapoco / Tierra Comunitaria de Origen Lomerio
56	Uirapuru / Paresi / Utiariti / Juininha
57	Umutina
58	Victoria SA
59	Yaguarete Pora

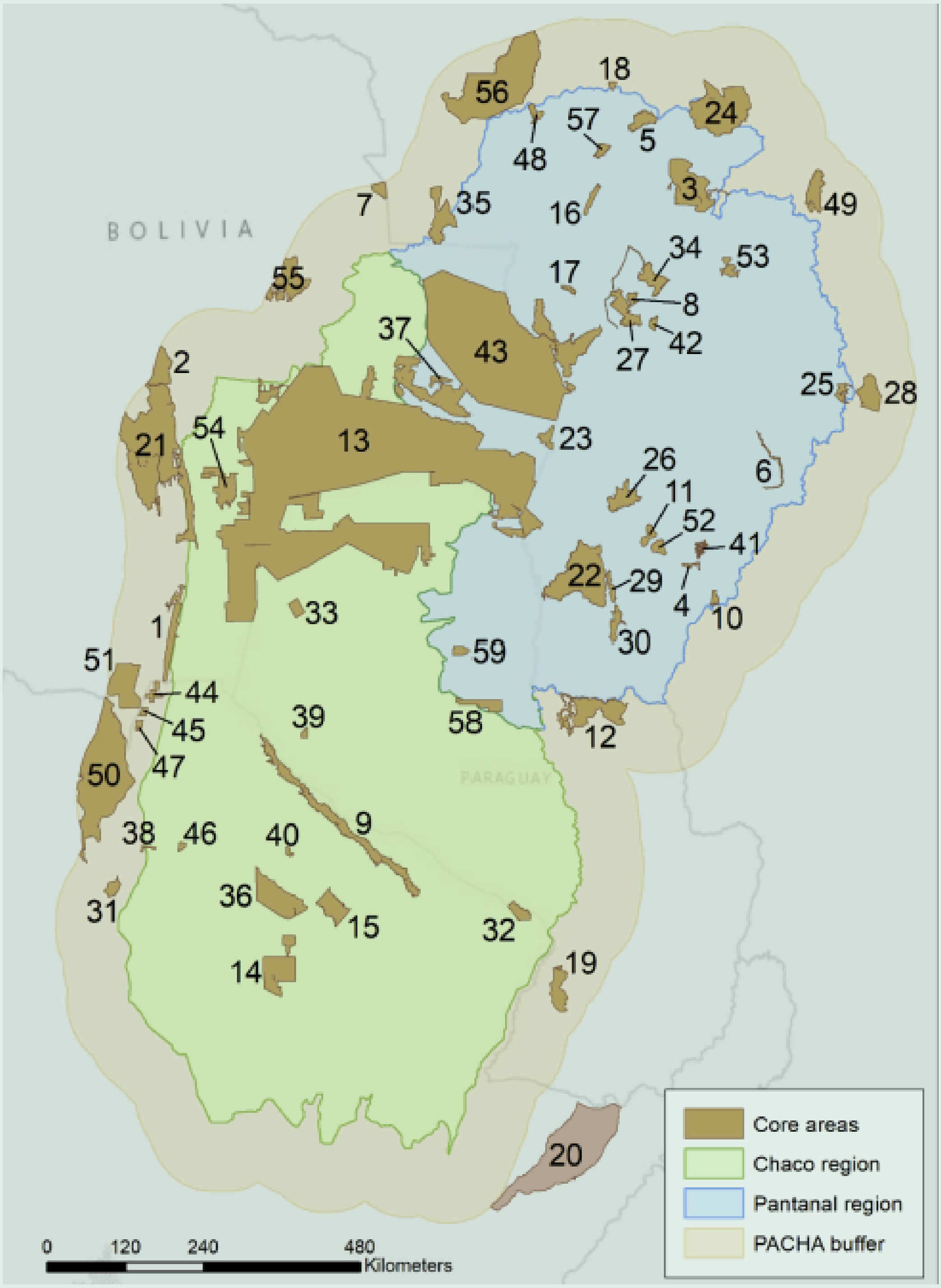

Figure 1. PACHA study area and core areas. Core area numbers correspond with those in the "Core Area ID" column of Table 1, which lists the protected areas and indigenous territories that comprise each core area.

LANDSCAPE VARIABLES

We estimated landscape resistance to jaguar movement as a function of five variables: land cover type, percent tree cover, distance to primary roads, distance to secondary roads, and human population density. Land cover was assessed using the European Space Agency WorldCover data set (Zanaga et al. 2021), which uses 10-m resolution Sentinel satellite imagery from 2020 to assign pixels to eleven cover types. We used the Global Forest Cover Change 30-m resolution data set for 2015 (Sexton et al. 2013) to assess percent tree cover. We filled in small patches of missing data from this data set by interpolating values from neighboring cells. Distance to primary and secondary roads was calculated in ArcGIS using vector data on roads from Open Street Map (OSM; www.openstreetmap.org), a crowd-sourced spatial database of roads and other development features. We considered primary roads to be those classified by OSM as "motorway", "trunk", or "primary" roads, and we considered secondary roads to be those classified as "secondary", "tertiary" "residential", or "unclassified." Human population density was assessed using the WorldPop 100-m resolution, top-down, constrained 2020 population count data set (WorldPop 2018).

All spatial layers were clipped to the study area boundary, converted to the South America Albers Equal Area Conic projection, and resampled to a common resolution (30 m) and pixel alignment.

LANDSCAPE RESISTANCE

Resistance values associated with landscape variables were obtained by surveying 21 jaguar experts. Experts were asked to assign resistance values ranging from 1 (least resistant) to 100 (most resistant) for categories associated with each landscape variable (e.g., land cover types and ranges of tree cover, distance to roads, or population density; Table 2).

Table 2. Expert-derived resistance values for five landscape variables assumed to influence jaguar movement.

Variable	Category	Resistance value
Tipo de cobertura terrestre	Árboles	1
	Matorral	29
	Pastizales	62,5
	Tierras de cultivo	80
	Construido	98
	Aguas abiertas	1
	Vegetación estéril/escasa	85
	Humedal	20
Distancia a carreteras primarias	0 - 100 m	90
	101 – 200 m	80
	201 – 400 m	60
	401 – 1000 m	40
	≥ 1001 m	1
Distancia a carreteras secundarias	0 – 100 m	50
	101 – 200 m	20
	≥ 201 m	1

Variable	Category	Resistance value
Densidad de población humana	0-1 persons/km2	1
	2 – 5 persons/km2	40
	6 – 20 persons/km2	70
	21 – 100 persons/km2	90
	≥ 101 persons/km2	100
Porcentaje de cobertura arbórea	0 – 5 %	60
	6 – 20 %	40
	21 – 40 %	20
	41 – 60 %	2,5
	≥ 61 %	1

We conducted multiple rounds of surveying to seek consensus values according to the Delphi method, However, three rounds of surveys did not result in consensus among expert opinions. Therefore, we used the median values obtained from the final round of expert surveys for each resistance category when constructing a resistance surface. We used these median values to construct a univariate resistance surface for each of the five landscape variables.

We also asked jaguar experts to assess the relative influence of landscape variables on jaguar movement by assigning each variable a score from 1 to 10, with higher values indicating greater influence. We used the median of the scores for each variable to determine variable weights (Table 3) and then created a multivariate resistance surface by calculating the pixel-wise weighted mean of the five univariate surfaces (Fig. 2). We aggregated the final resistance surface to 90-m resolution to allow efficient computing during connectivity modeling. Resistance values ranged from 1.0 to 81.7 within the study area.

Table 3. Relative influence of landscape variables on resistance to jaguar movement as determined by experts.

Landscape variable	Median expert score	Model weight
Porcentaje de cobertura arbórea	10	0,24
Tipo de cobertura terrestre	10	0,24
Densidad de población humana	9,5	0,23
Distancia a vías primarias	7	0,17
Distancia a vías secundarias	5	0,12

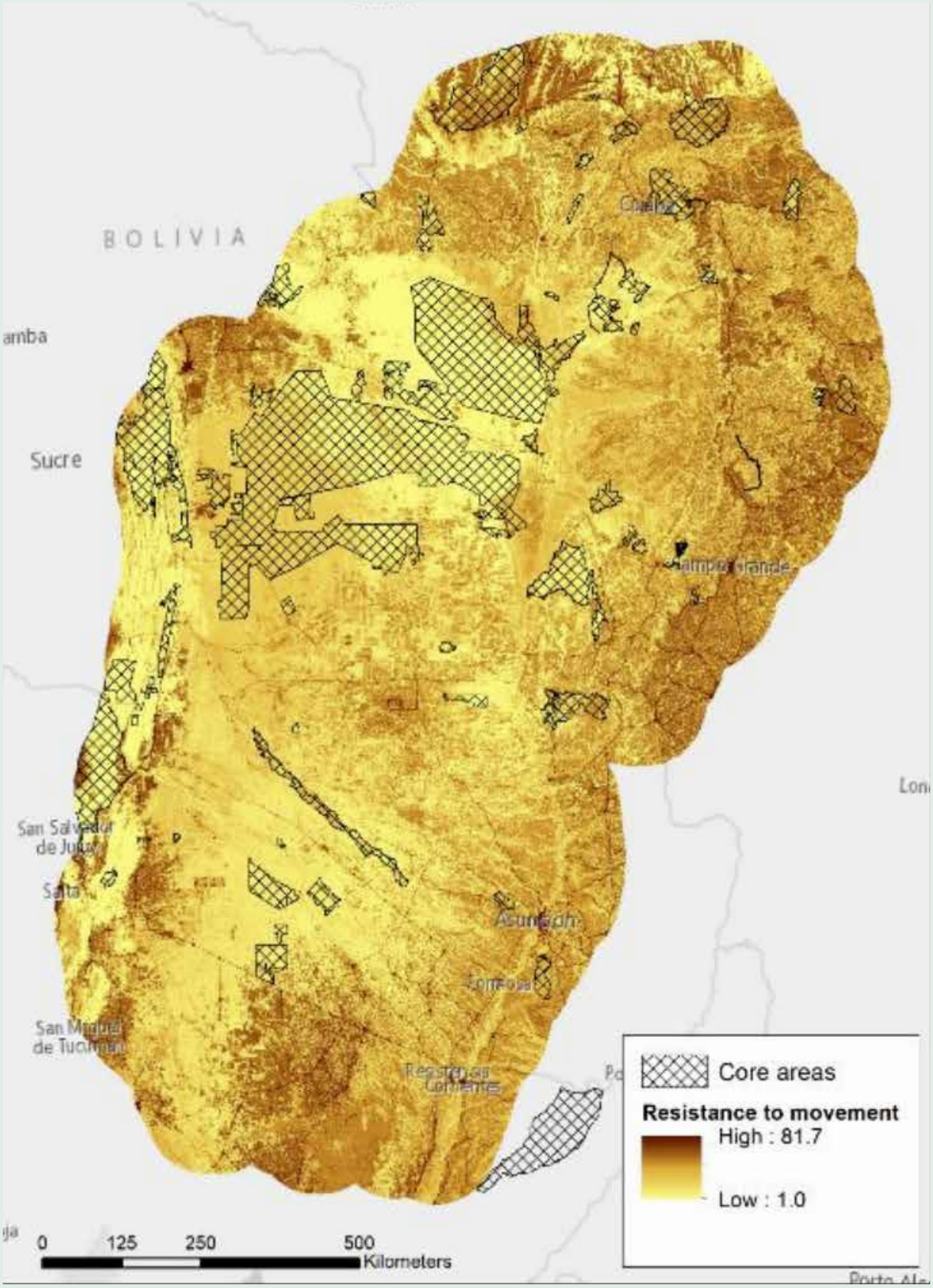

Figure 2. Multivariate landscape resistance to jaguar movement within PACHA study area.

CORRIDOR MODELING

We modeled jaguar connectivity in the study area using the Linkage Pathways tool within the Linkage Mapper software program (McRae and Kavanagh 2011). This program identifies and maps least-cost linkages between neighboring core areas across a resistance surface defined by landscape variables. Individual corridor maps are combined across all corridors within the study area to produce a final map showing the relative value of each pixel in facilitating connectivity among all core areas.

We conducted two analyses: (1) a full network analysis that included corridors between all neighboring core areas, and (2) a limited network analysis that included only corridors between each core areas and its three nearest neighboring core areas (as measured by cost distance) to produce a more limited corridor network that minimized redundancy.

Experts also expressed a desire to model several corridors between parts of a single core area, rather than between core areas. Core area 13 is considerably larger than all others and includes at least 15 adjacent protected areas or indigenous territories. Because core area 13 is roughly C-shaped (Fig. 1), a corridor linking its two arms across unprotected lands could provide for more efficient movement between distant parts of the core area than would be possible by traveling within the core area boundaries. We therefore ran additional Linkage Mapper analyses of the least-cost linkages between the following areas within different arms of core area 13:

(1) Cerro Chovoreca National Monument and Defensores del Chaco,

(2) Cerro Cabrera-Timane and Defensores del Chaco, and

(3) Cerro Cabrera-Timane and Medanos del Chaco.

The output of Linkage Mapper analysis is a continuous surface spanning the entire study area, so to highlight the most important portions of the landscape for connectivity, we used a cost-distance threshold to truncate the output to a set of discrete, high-probability corridors. We retained all pixels within 100,000 cost units of a least-cost path, which is equivalent to an additional 6.8 km of travel through terrain of average resistance. We also truncated corridors to a smaller 50,000-cost-unit threshold (equivalent to an additional 3.4 km of travel through terrain of average resistance) to provide a set of more narrowly defined corridors that may be helpful for siting conservation actions in areas where protection of wide corridors is not feasible.

Figure 3 is a map of corridors truncated to 100,000 cost units for the full network in which core areas are connected to all of their neighboring core areas, while Figure 4 shows corridors for the limited network in which core areas are connected only to their three nearest neighboring core areas. Most of the corridors linking core areas are relatively linear. Many of the longest and narrowest corridors occur along the eastern portion of the study area, while corridors in the western portion tend to be shorter and more diffuse. Many of the corridors are composed of multiple strands (i.e., alternate routes of approximately equal cumulative resistance), which may be helpful when determining possible areas for conservation actions. Figures 5 and 6 show corridors truncated to 50,000 cost units in the full and limited networks, respectively.

Upon review of connectivity modeling results, experts identified one corridor in Argentina that they consider non-functional for jaguar movement due to habitat degradation and the lack of jaguar records for more than 15 years. We have marked this corridor, which links El Rey National Park (core area 31) and Copo/ Loro Hablador (core area 14), in Figures 3-6.

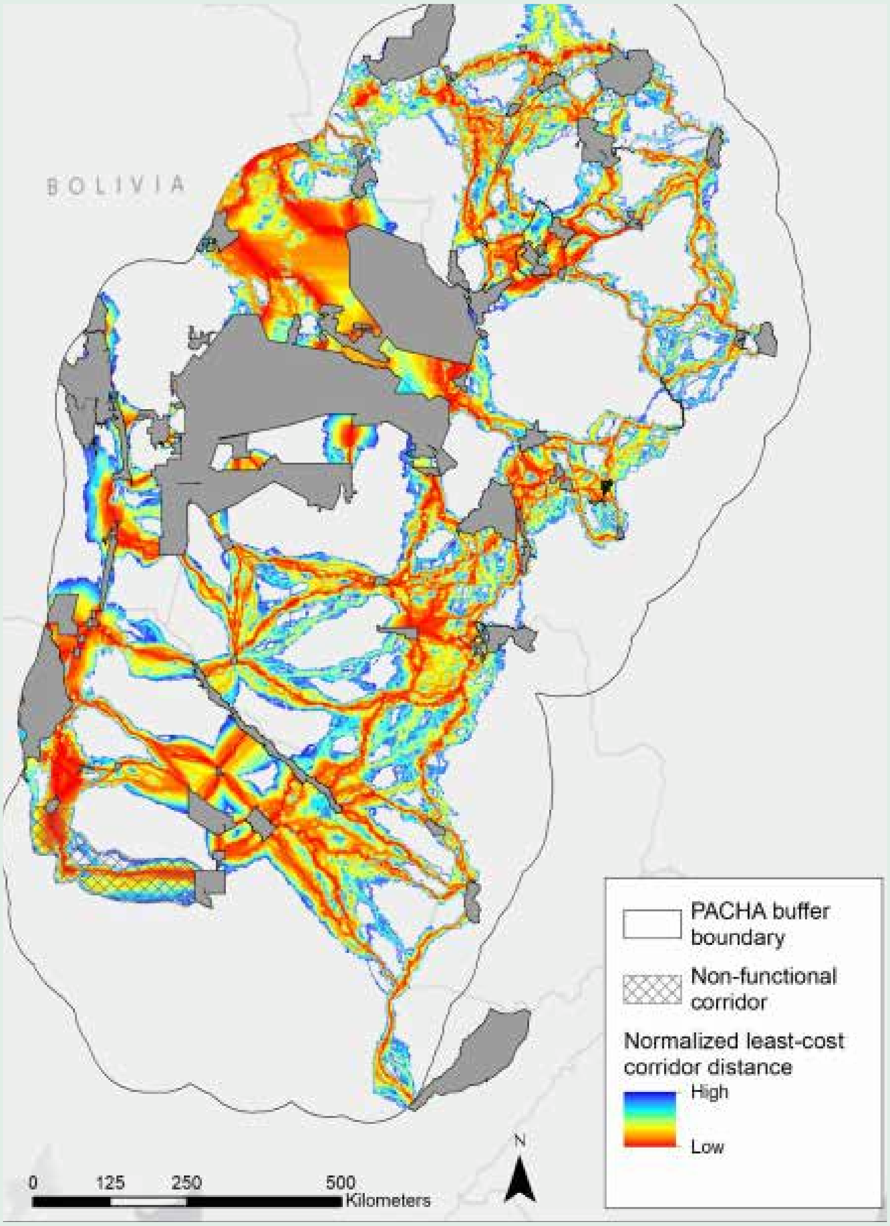

Figure 3. Jaguar corridors in the full network (all neighboring core areas connected), truncated to include only pixels with cost distance less than 100,000 cost units. Lower values (shown with warmer colors) represent lower-cost routes (i.e., more optimal movement paths).

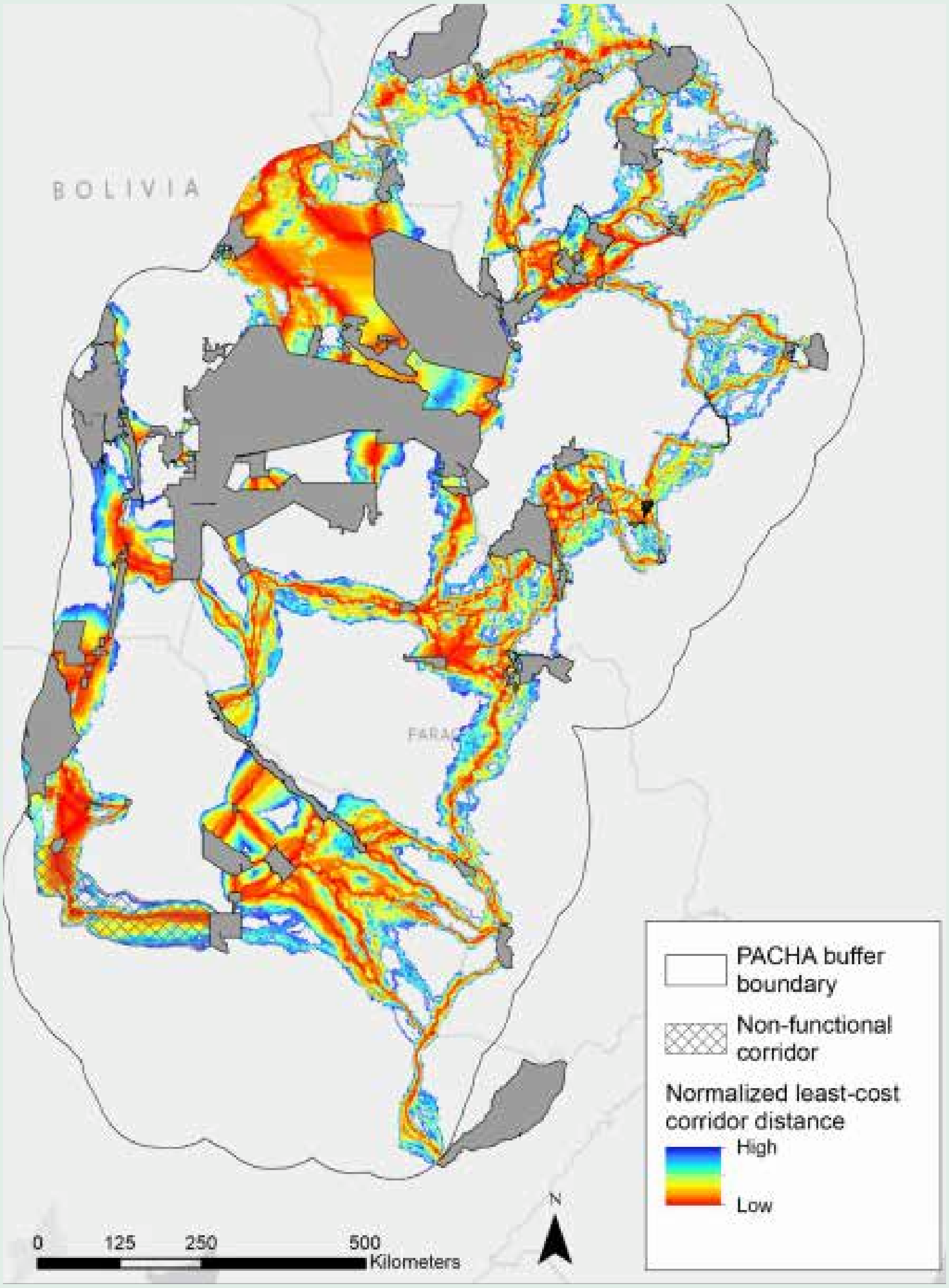

Figure 4. Jaguar corridors in the limited network (connections only with three nearest neighboring core areas), truncated to include only pixels with cost distance less than 100,000 cost units. Lower values (shown with warmer colors) represent lower-cost routes (i.e., more optimal movement paths).

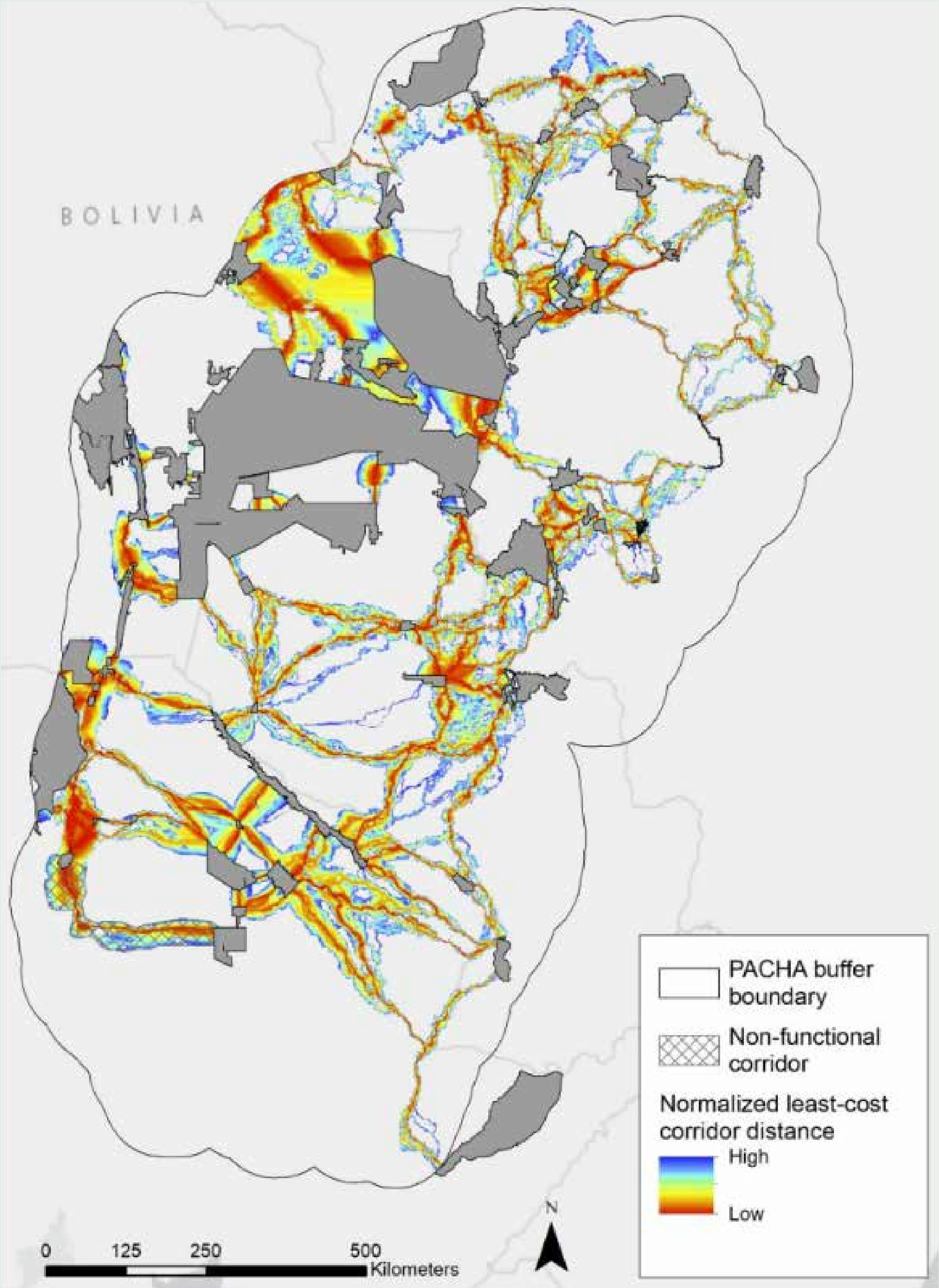

Figure 5. Jaguar corridors in the full network (all neighboring core areas connected), truncated to include only pixels with cost distance less than 50,000 cost units. Lower values (shown with warmer colors) represent lower-cost routes (i.e., more optimal movement paths).

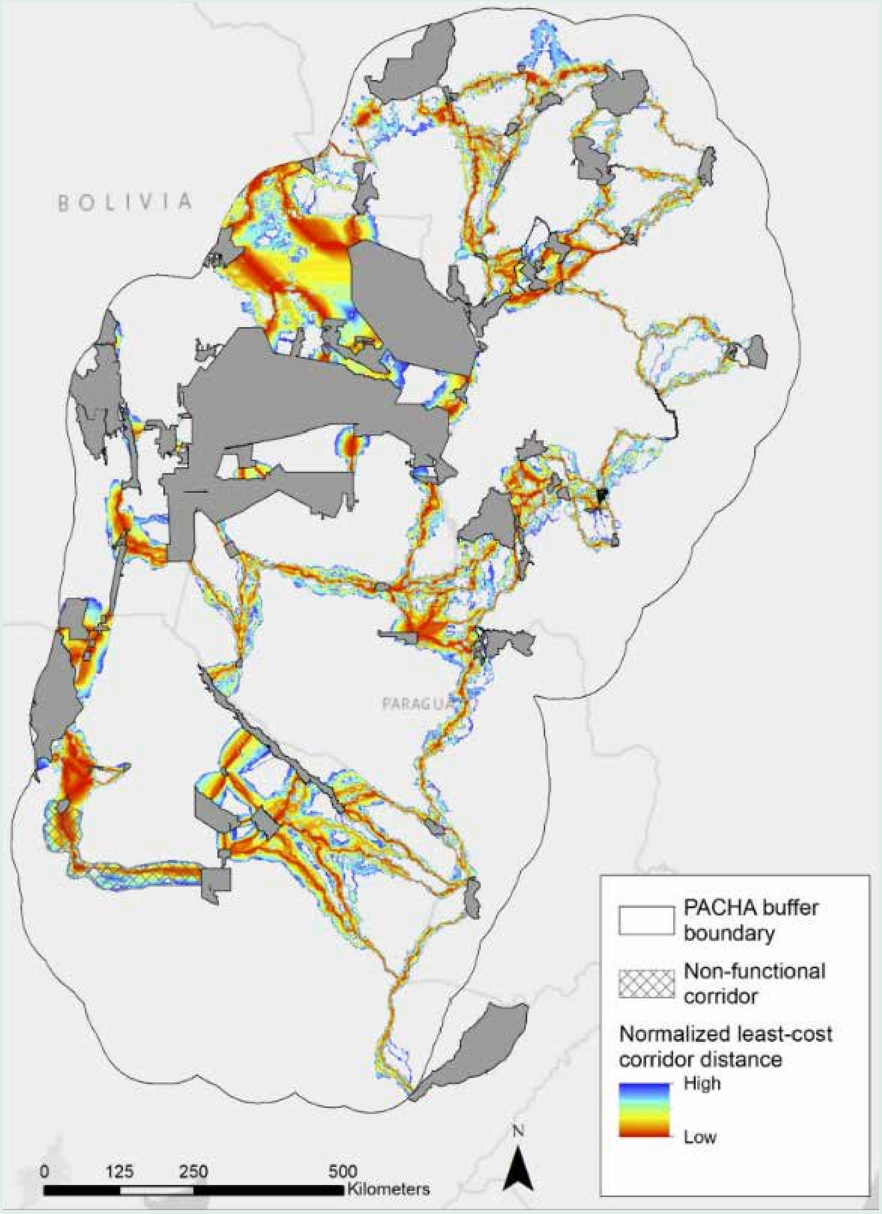

Figure 6. Jaguar corridors in the limited network (connections only with three nearest neighboring core areas), truncated to include only pixels with cost distance less than 50,000 cost units. Lower values (shown with warmer colors) represent lower-cost routes (i.e., more optimal movement paths).

EFFECTIVE RESISTANCE

We used the Pinchpoint Mapper tool in Linkage Mapper to run Circuitscape within each 100,000-cost-unit truncated corridor in the full network and estimate the effective resistance associated with each corridor.

Effective resistance measures how connected two core areas are as a function of their proximity, the number of alternative pathways between them, and the resistance of the landscape along those pathways. Effective resistance values for each corridor in the full network are shown in Table 4.

Table 4. Effective resistance and centrality of corridors in the full network (all neighboring core areas connected) as calculated using Circuitscape.

From Core Area ID	To Core Area ID	Effective Resistance	Centrality
1	13	216.3	223.8
1	21	164.8	361.1
1	44	25.6	538.1
2	21	1.7	58.0
3	5	1,325.0	59.2
3	16	1,096.3	32.9
3	24	597.5	60.7
3	34	860.8	97.2
3	49	2,970.7	34.4
3	53	1,114.4	81.4
4	10	932.0	30.2
4	41	156.3	95.0
4	52	615.1	72.6
5	16	1,162.9	51.7
5	18	530.6	39.3
5	24	1,059.5	59.6
5	57	608.5	73.9
6	25	1,625.1	78.3
6	26	6,911.7	47.8
6	41	2,214.7	76.0
6	42	7,497.8	58.8
7	35	510.4	46.7
7	43	465.1	35.3

From Core Area ID	To Core Area ID	Effective Resistance	Centrality
7	55	550.6	46.1
8	27	18.7	120.4
8	34	69.0	71.5
9	12	911.6	70.9
	15	185.3	159.4
9	19	3,336.6	42.9
9	32	1,828.5	70.7
9	39	376.8	123.1
9	40	283.9	71.3
9	44	1,107.3	88.2
9	58	1,423.4	71.4
10	41	1,724.8	29.6
10	52	1,403.1	34.8
11	22	400.4	109.2
11	26	272.2	117.3
11	52	87.5	129.2
12	22	1,079.5	92.0
12	30	2,018.9	113.8
12	32	2,413.8	87.1
12	58	232.3	86.8
13	21	309.7	194.7
13	22	809.6	173.6
13	23	60.3	173.6
13	26	1,203.8	122.6
13	33	648.7	92.8
13	39	3,184.0	45.9
13	43	9.6	567.5
13	54	120.2	214.4
13	55	199.9	64.0
13	59	1,747.4	91.3
14	15	231.8	60.5
14	31	1,761.4	42.9
14	36	164.2	46.9
15	19	3,154.5	50.5
15	20	7,964.2	37.9

From Core Area ID	To Core Area ID	Effective Resistance	Centrality
15	36	163.6	148.3
15	40	434.0	34.4
16	17	1,219.3	68.5
16	27	1,018.9	81.4
16	48	802.6	37.0
16	57	502.7	72.1
17	27	386.4	86.5
17	43	275.6	108.7
17	48	1,813.7	46.1
17	56	2,252.6	27.7
18	24	857.8	52.2
18	48	1,549.1	70.0
18	57	1,338.7	27.8
19	20	11,565.6	35.7
19	32	2,051.9	65.9
21	54	240.0	196.2
22	26	303.5	112.4
22	29	10.3	169.0
22	52	366.1	72.0
22	58	666.8	70.0
22	59	965.4	63.9
23	43	18.9	204.9
24	49	7,653.1	51.5
25	28	627.0	58.0
25	42	7,134.3	55.9
25	49	4,975.6	43.2
25	53	8,202.0	47.8
26	41	1,513.3	63.6
26	43	1,117.3	113.5
27	34	46.3	166.4
27	42	77.8	107.2
27	43	77.7	435.2
29	30	144.3	157.4
29	52	397.3	72.3
31	36	2,036.2	50.9

From Core Area ID	To Core Area ID	Effective Resistance	Centrality
31	38	71.9	77.2
31	46	1,306.6	30.5
31	50	151.2	113.6
33	39	1,998.7	44.4
33	59	2,585.5	33.0
34	42	116.4	74.4
34	53	743.0	105.5
35	43	156.2	127.2
35	56	1,339.7	96.9
36	40	236.0	53.5
36	46	793.7	75.8
36	50	3,069.5	62.0
37	43	4.0	58.0
38	46	1,244.5	48.6
38	50	140.9	116.8
39	58	2,254.5	34.4
39	59	2,315.8	35.3
40	50	2,994.5	57.2
41	52	494.3	70.7
42	43	333.1	119.4
42	53	965.2	70.8
43	55	105.3	46.8
44	45	22.7	237.3
44	51	24.9	255.0
45	47	18.8	132.0
45	51	30.6	108.4
46	50	1,028.0	42.0
47	50	40.7	97.3
48	56	454.6	107.9
48	57	1,410.2	50.9
49	53	2,418.8	38.0
50	51	18.9	314.0
58	59	400.5	103.8

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CENTRALITY ANALYSIS

Finally, we used the Centrality Mapper tool within Linkage Mapper to determine which corridors and core areas within the study area are most important for keeping the PACHA network connected.

Each core area and corridor was assigned a current flow centrality score, with larger values indicating greater importance for network connectivity.

Figures 7 and 8 below show centrality scores for core areas and corridors in the full network and the limited network, respectively. Core areas near the center of the study area have the highest centrality, which is a consequence of their location near the center of the network and therefore as intermediary steps along many connections among distant core areas.

The highest-centrality corridors within the study area also tend to be associated with these central core areas, although there are several corridors along the margins of the study area that have relatively high centrality and may therefore be key sites for connectivity conservation. Centrality scores for corridors are also listed in Table 4.

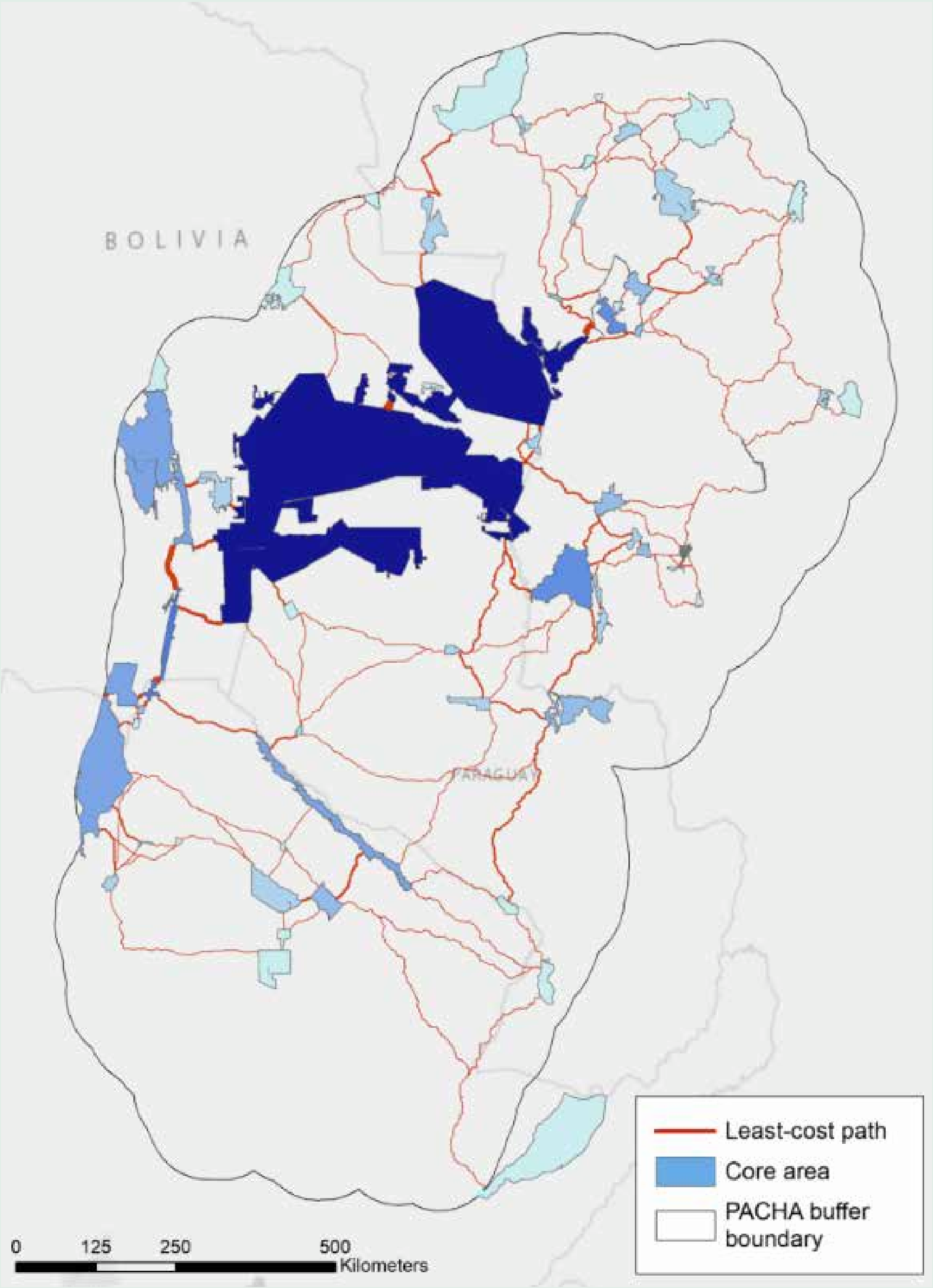


Figure 7. Centrality of jaguar core areas and corridors in the full network (all neighboring core areas connected). Core areas shown with darker shades of blue have higher centrality. Least-cost paths shown with thicker lines represent corridors with higher centrality.

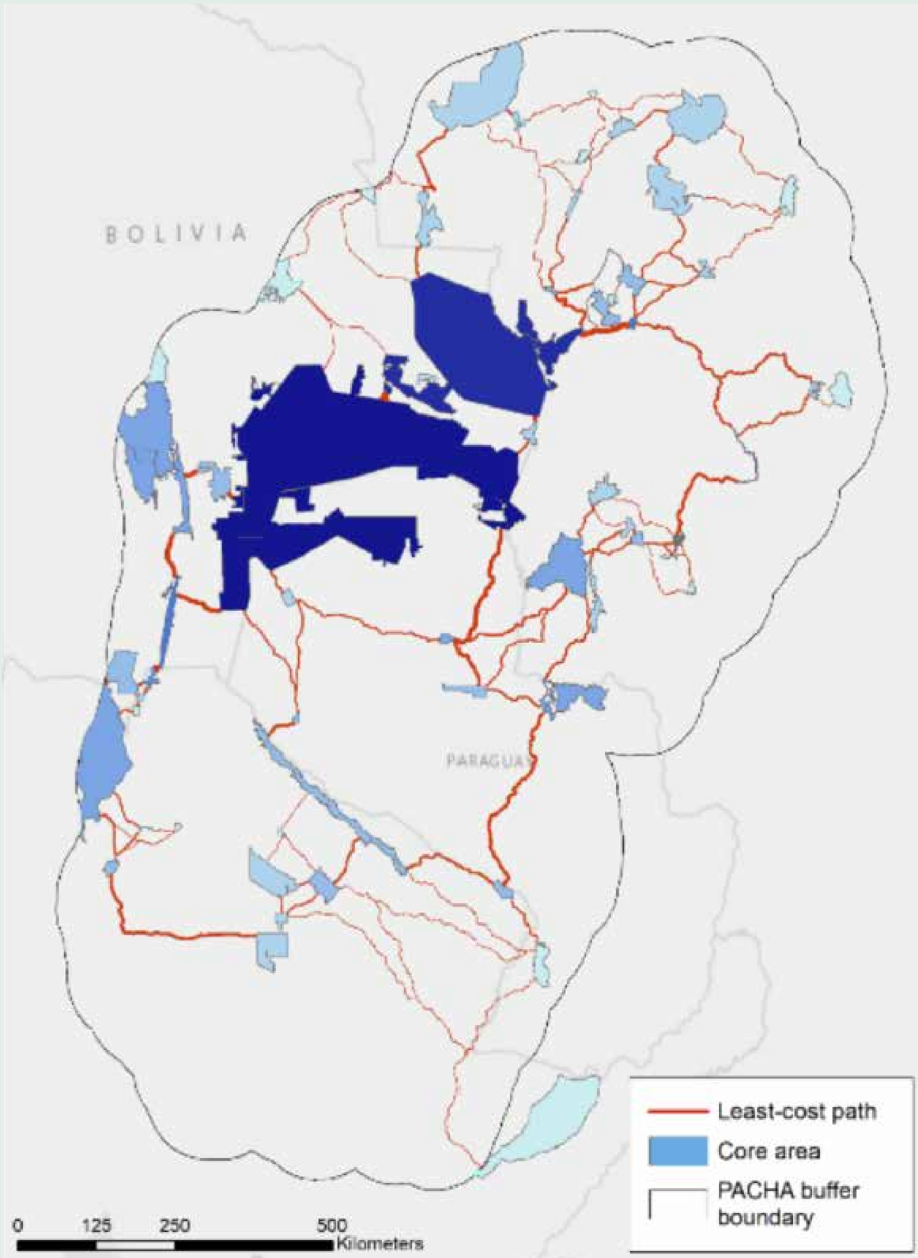


Figure 8. Centrality of jaguar core areas and corridors in the limited network (connections only with three nearest neighboring core areas). Core areas shown with darker shades of blue have higher centrality. Least-cost paths shown with thicker lines represent corridors with higher centrality.

DISCUSSION

The jaguar movement corridors identified in this analysis provide a useful starting point for connectivity conservation planning in the PACHA region. Incorporating existing data on jaguar movement and presence could help validate the corridors suggested by the model. For instance, overlaying expert-based corridors with locations where jaguars have been recorded, either as point locations (e.g., sightings) or movement paths from collared individuals, would provide independent supporting evidence for corridors. Conversely, it could suggest that other areas not identified by the expert-based models are important movement corridors.

The connectivity modeling approach we used resulted in a least-cost corridor mapped between all neighboring core areas, regardless of the distance or intervening habitat quality between them. But the best corridors linking some core area pairs may have poor potential for facilitating jaguar movements, and therefore may not be practical targets for conservation actions. Our aim with this analysis was to provide a comprehensive map of the best possible corridors between protected areas, but we recommend that experts carefully review corridors to determine whether they seem feasible given the best available knowledge about jaguar occurrence and movement behavior.

We caution, however, that a lack of recent jaguar observations within a modeled corridor should not necessarily be interpreted as evidence that the corridor is unimportant. Some corridors may have no recorded evidence of jaguar use simply because there has been minimal effort to detect their presence in the area. Furthermore, even corridors that serve as important dispersal pathways may be used very infrequently, and therefore are unlikely to have recorded jaguar presences, but rare dispersal events are still critical for gene flow and metapopulation persistence.

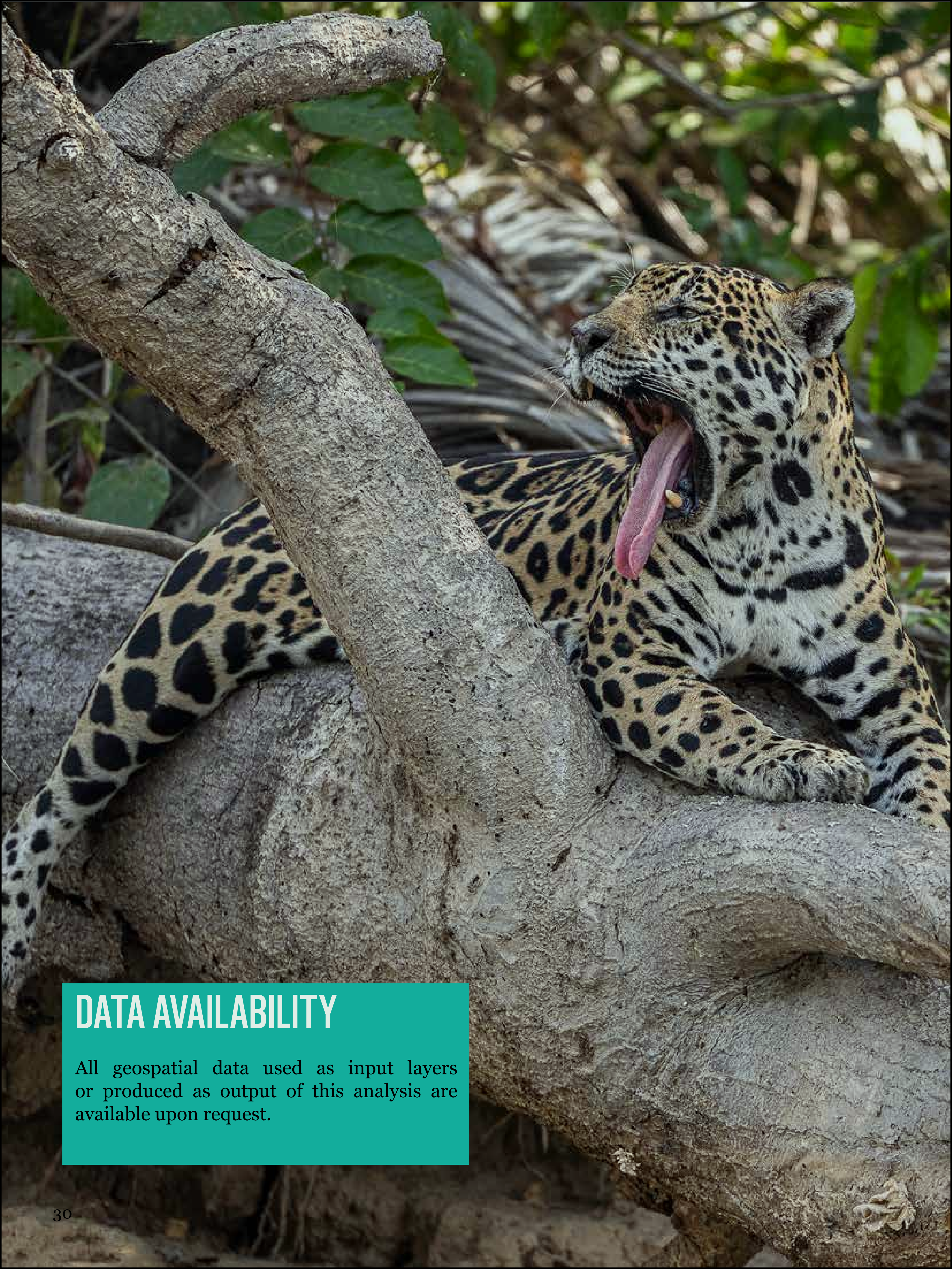
The approach used in this analysis seeks to identify corridors between core areas defined by administrative boundaries rather than by ecological boundaries based on habitat suitability for jaguars. The vast majority of the core areas are protected areas or indigenous territories, although a few exceptions were made for conservation units that currently lack formal protection but experts are confident will remain conserved for a number of years. This protected area-based approach was chosen because (1) maintaining corridors between protected areas ensures that landscape connectivity will persist even if the unprotected matrix between protected areas is degraded, and (2) protected areas serve as habitat for many species other than jaguar. However, we recognize that not all protected areas in our analysis are currently high quality, occupied jaguar habitat, and therefore some of the modeled corridors may not serve as useful links between jaguar populations at present. A separate analysis that explores connectivity between jaguar habitat patches could complement the analysis presented here and provide additional information on contemporary landscape connectivity for jaguars.

Further analyses could also consider using landcover data with higher thematic resolution to better distinguish between cover classes that are structurally similar but may be perceived differently by jaguars. For instance, the ESA WorldCover dataset we used included a single class for grasslands, which did not allow us to distinguish between natural grasslands (generally favorable habitat for jaguars) and pastures (grazed by domestic livestock and generally less favorable habitat for jaguars). The MapBiomas landcover dataset (https://mapbiomas.org/en) has higher thematic resolution than ESA WorldCover and would be a good choice for future studies. We did not use MapBiomas in the current analysis because when we were soliciting information from experts on resistance of land cover classes, a MapBiomas product fully covering the PACHA study area had not been finalized. Differences in land cover classes between MapBiomas and ESA WorldCover are large enough that our original resistance values cannot easily be crosswalked from one classification scheme to another, so additional rounds of expert solicitation would be needed to incorporate MapBiomas in an analysis.

One landscape variable that may influence jaguar movement within PACHA but is not included in the resistance surface for this analysis is slope. Experts suggested that slopes greater than 60 degrees are unsuitable for jaguars, but we did not include this variable because the number of pixels with slopes exceeding this threshold was negligible at the 90-m resolution of our analysis. However, steep slopes do exist within the PACHA landscape, and a finer-resolution slope layer may be useful to consult when considering conservation actions to ensure suitable topography for jaguars within corridors. The expert-based resistance model is a good first step towards identifying connectivity conservation priorities within PACHA, but the lack of agreement among experts regarding resistance values associated with landscape variables suggests that a data-driven model could provide additional, and perhaps more accurate, insights. Using high-resolution movement data from GPS-collared jaguars in the region (Morato et al. 2018), we have also collaborated with the authors of a recent jaguar habitat modeling study (Costa-Alvarenga et al. 2021) to develop an alternative, empirically-based resistance surface. A preliminary version of that empirical model was submitted to WWF in late 2022, but CLLC is currently working to refine that model by considering additional landscape variables and developing subregional models that account for variation in jaguar movement behavior and landscape influences within the PACHA study area. The PACHA connectivity conservation plan developed by WWF should consider the corridors identified by both the expert-based model presented here and the empirical model currently being finalized – particularly locations that the two models agree are critical for jaguar movement.

El modelo de resistencia de expertos es un primer paso para identificar las prioridades de conservación de la conexión en PACHA, pero la falta de acuerdo con los valores de resistencia asociados a variables del paisaje sugiere que un modelo basado en datos podría proporcionar conocimientos adicionales, y quizás más precisos utilizando datos de movimiento de alta resolución de jaguares con collares GPS en la región (Morato et al. 2018).También hemos colaborado con los autores de un estudio reciente de modelado del hábitat del jaguar (Costa-Alvarenga et al. 2021) para desarrollar una superficie de resistencia alternativa basada en datos empíricos. Se envió una versión preliminar de ese modelo empírico a WWF a fines de 2022, pero CLLC trabaja para perfeccionarlo considerando variables de paisaje adicionales y desarrollando modelos subregionales que consideren la variación en el comportamiento del movimiento del jaguar y las influencias del paisaje en el área de estudio de PACHA. El plan de conservación de la conectividad de PACHA desarrollado por WWF debe considerar corredores identificados tanto por el modelo basado en expertos presentado aquí como por el empírico que se está finalizando, en especial los lugares que ambos modelos coinciden en sitios críticos para los desplazamientos del jaguar.

The connectivity information contained in this report (plus the empirical connectivity modeling report) can serve as the basis for a PACHA linkage design that ensures long-term conservation of connectivity for jaguar and other wildlife species. However, a linkage design is only one step in the broader connectivity conservation planning effort for PACHA. That effort will require WWF and its collaborators to establish priorities for conservation action, and the connectivity value of corridors is only one factor that must be considered. Factors that were not included in our connectivity models but influence conservation planning include other ecological, economic, and social benefits provided by corridors; the costs of land acquisition/protection; the magnitude and immediacy of threats to corridors from development; the degree of local support for conservation; and various other considerations. Thus, this connectivity report is one piece of a more comprehensive planning effort.



DATA AVAILABILITY

All geospatial data used as input layers or produced as output of this analysis are available upon request.

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