Jaguar Movement Database: a GPS-based movement dataset of an apex predator in the Neotropics

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Abstract

The field of movement ecology has rapidly grown during the last decade, with important advancements in tracking devices and analytical tools that have provided unprecedented insights into where, when, and why species move across a landscape. Although there has been an increasing emphasis on making animal movement data publicly available, there has also been a conspicuous dearth in the availability of such data on large carnivores. Globally, large predators are of conservation concern. However, due to their secretive behavior and low densities, obtaining movement data on apex predators is expensive and logistically challenging. Consequently, the relatively small sample sizes typical of large carnivore movement studies may limit insights into the ecology and behavior of these elusive predators. The aim of this initiative is to make available to the conservation-scientific community a dataset of 134,690 locations of

jaguars (*Panthera onca*) collected from 117 individuals (54 males and 63 females) tracked by GPS technology. Individual jaguars were monitored in five different range countries representing a large portion of the species' distribution. This dataset may be used to answer a variety of ecological questions including but not limited to: improved models of connectivity from local to continental scales; the use of natural or human-modified landscapes by jaguars; movement behavior of jaguars in regions not represented in this dataset; intraspecific interactions; and predator-prey interactions. In making our dataset publicly available, we hope to motivate other research groups to do the same in the near future. Specifically, we aim to help inform a better understanding of jaguar movement ecology with applications towards effective decision making and maximizing long-term conservation efforts for this ecologically important species. There are no costs, copyright, or proprietary restrictions associated with this data set. When using this data set, please cite this article to recognize the effort involved in gathering and collating the data and the willingness of the authors to make it publicly available.

Keywords

Behavior, conservation, GPS radio-collars, habitat use, landscape, *Panthera onca*, movement ecology.

Introduction

Apex predators have undergone recent and dramatic population declines and range contraction (Estes et al. 2011, Ripple et al. 2014). The jaguar (*Panthera onca*) has been extirpated from 55% of its historical range and most of its subpopulations throughout Latin America are now considered Endangered or Critically Endangered (de la Torre et al. 2017b, Quigley et al. 2017). Anthropogenic factors such as habitat loss, fragmentation, and poaching are the major threats to the long-term survival of this species, and these threats directly impact individual movement and space use (Colchero et al. 2011, Conde et al. 2010, de la Torre et al. 2017b, Morato et al. 2016).

Movement is a key behavior for the survival of non-sessile species because it assures access to food and water, evasion from predators and competitors, and reproductive success (Morales et al. 2010). Consequently, disrupting patterns in animal movement can have important implications for ecosystem dynamics and function, including disturbances to food webs and nutrient cycling (Allen and Singh 2016). Thus, a comprehensive analysis of animal space use and movement is crucial to understanding the mechanisms driving species ecology and ecosystem function.

The field of movement ecology has rapidly grown in the last decade, with improvements in tracking devices and analytical tools providing unprecedented insights into where, when, and why species move across the landscape (Jeltsch et al. 2013). Recent efforts to incorporate movement ecology into conservation planning have shown great potential for a flexible spatio-temporal approach when addressing conservation problems and opportunities. Innovative initiatives that have adopted this integration have helped reduce conflict among stakeholders, prioritize conservation activities, and guide more efficient use of financial resources (Allen and Singh, 2016, Iwamura et al. 2014, Martin et al. 2007, Seidler et al. 2015).

Despite the growing number of studies using GPS telemetry, and the development of online platforms that make movement data available (e.g., movebank.org), to our knowledge, there are currently no large predator movement datasets that are fully and publicly available. Although researchers interested in movement ecology actively use repositories such as Movebank, the data are usually restricted and only available upon request from owners after collaborative agreement. Nevertheless, open databases are needed to allow researchers to test the effects of

broad-scale drivers of local populations or to investigate habitat use, movement patterns, and potential corridors that could facilitate wildlife movement. Because of their natural history, monitoring apex predators such as jaguars is expensive and logistically challenging. Only large and well-funded research groups working in areas with high jaguar densities are able to capture and monitor more than 10 individuals at any given study site, so the conclusions of the resulting scientific publications are still limited.

Here, we present the first large-scale compilation of jaguar GPS telemetry data. The main objective of this initiative is to make available to the conservation-scientific community a dataset of 134,690 locations collected from 117 individuals (54 males and 63 females) tracked by GPS radio-collars. Jaguars were monitored in five different countries, encompassing a large portion of the species' range (Figure 1). This dataset presents information on individual jaguar movements from 20 independent study sites. The fine scale data provided here go well beyond presence-only data that traditionally formed the basis for most species conservation planning (Sanderson et al. 2002, Rabinowitz and Zeller 2010, Rodríguez-Soto et al. 2011, De Angelo et al. 2013, Morato et al. 2014).

Open access datasets provide a new and unique opportunity for researchers and conservationists to explore the ecology, behavior, and conservation of solitary large felids from fine to broad spatial scales. This dataset represents the first joint effort of over 55 jaguar experts to make this information freely available. We assume that either retaliation or poaching will not be favored by this dataset as the movement data are historical. Contrarily, we anticipate that this dataset will be invaluable for future research to answer specific questions about jaguar ecology that will ultimately have a significant impact upon the species' long-term survival.

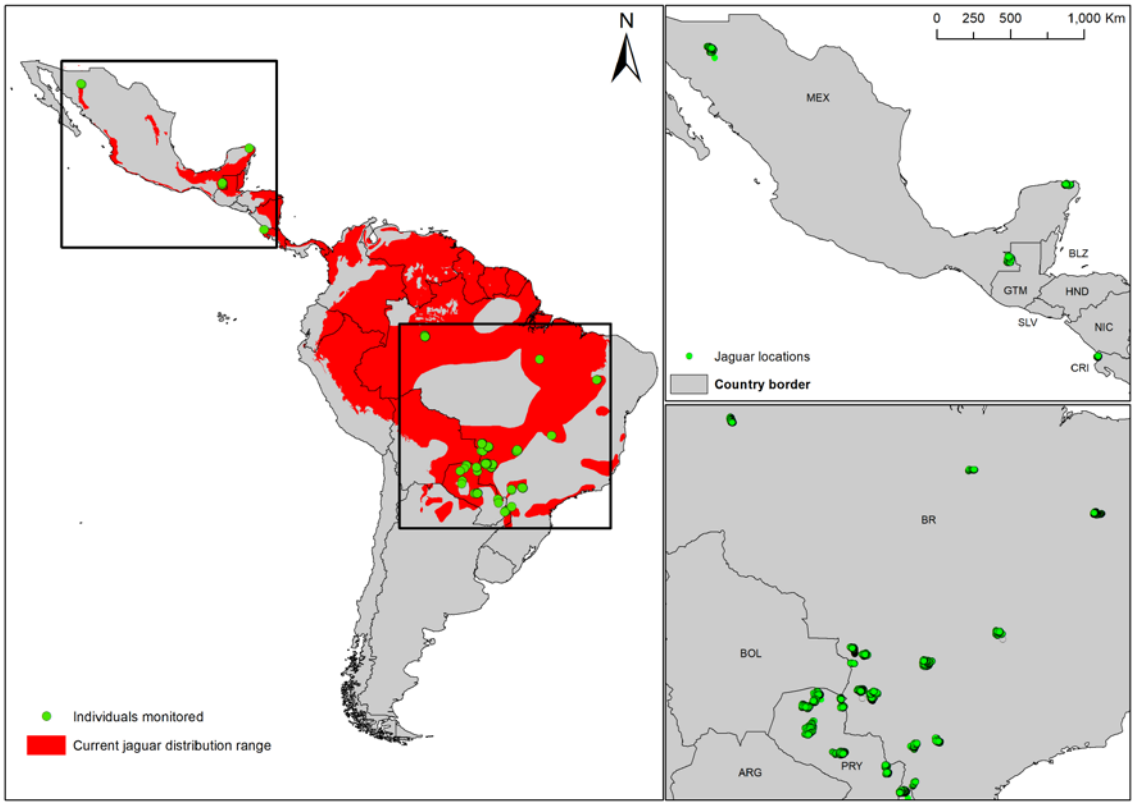

Fig. 1. Location of jaguar individuals monitored (green dot) across the species' current distribution range (red area). Box highlights the study sites at different countries. Top right: Mexico and Central America. Bottom right: South America

Metadata

Class I. Dataset descriptors

A. Dataset identity

Title: Jaguar Movement Database.

B. Dataset and metadata identification codes

Suggested dataset identity codes: jaguar_additional_information.csv

jaguar_movement_data.csv

C. Dataset description

Principal Investigators:

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Class II. Research origin descriptors

A. Overall project description

Identity: A dataset integrating GPS telemetry locations from 117 jaguars in 20 independent studies from 5 countries.

Period of Study: Raw monitoring data range from 1999 to 2016.

Objective: Our goal in compiling this dataset is to make available to the conservation-scientific community an integrated dataset of individual jaguar locations collected from GPS radio-collars deployed throughout this species' distribution range.

Abstract: Same as above.

Sources of funding: RGM studies were funded by FAPESP (2013-10029-6 and 2014-24921-0), CNPq (Brazilian Government Research Council) provided a research grant for RGM (process 301652/2015-5), Cat Heaven Endangered Species-Project Survival and Dallas World Aquarium. MSX, AV and MFDM study was funded by Orient Express Hotels do Brasil. AP, PC, VAQ, SAC, JPA, EV and YEB study was funded by WWF Switzerland-Fundacion Vida Silvestre Argentina. EER study was by Panthera Foundation and Rufford Small Grant. CNPq (Brazilian Government Research Council) provided a research grant for MCR (312045/2013-1), who also thanks FAPESP (process 2013/50421-2) for their financial support. FL and LC studies were funded by Fundação Grupo Boticário de Proteção à Natureza, The Scott Neotropical Fund of the Lincoln Park Zoological Society, The Species Survival Fund from Wildlife Trust, IdeaWild Grant Program, WWF/US, WWF-EFN Scholarship Program, DICE Small Grant Program, The Liz Claiborne Art Ortenberg Foundation, The Ashoka Foundation, Conservation, Food and Health Foundation, 100% Fund from Fauna and Flora International, The Woodland Park Zoo, The Whitley Awards, The Rolex Awards, Durrell Wildlife Conservation Trust, The Rufford Small Grants Program, Ridgeway Trust and CTG-Brasil. From 2012 – 2015 financial support for data management, curation and analysis were granted by Fundo Brasileiro para a Biodiversidade – Tropical Forest Conservation Act agreement (FUNBio/TFCA). Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) provided support FL PhD. JAT study was funded by Conservation Food & Health Foundation, Conservation Leadership Programme, Cleveland Metropark Zoo and Cleveland Zoological Society, Commission of Natural Protected Areas of the Mexican Federal Government (CONANP), the Mesoamerican Biological Corridor- Mexico, and the National Council

of Science and Technology of Mexico (CONACyT). JJT studies were funded by Programa PRONII, Consejo Nacional de Ciencia y Tecnología, Paraguay. FT, HQ, RH, PGC, ALD and JAM study was funded by Panthera Foundation.

B. Specific project description

Site description: Jaguar distribution range across Latin America.

Data compilation: The dataset is primarily composed of raw data, with availability restricted to the researchers and institutions directly involved in jaguar monitoring. All data were gathered via direct communication with research groups working throughout jaguar range.

Research methods:

The initial organization of this dataset aimed to evaluate jaguar movement ecology patterns in Brazilian biomes (Morato et al. 2016). From this initial collaboration, a new round of contacts with researchers and institutions was conducted to increase the scale of future studies. Datasets from distinct research groups were organized into a single standard format and locations were converted to Geographic Coordinate System WGS 84. When fix status and DOP information were available, the data were filtered to include only 3D fixes and locations with DOP < 10, which has a typical accuracy of 2-10 m (de la Torre et al. 2017a). Although some collars stored additional information such as elevation, we did not include those metrics as those data could be acquired from other reliable and standardized sources. For example, a 30-meter digital elevation model can be obtained at https://earthexplorer.usgs.gov. Finally, biometric data were compiled from capture records collected by participating researchers. The estimated age of each individual jaguar at time of capture was based on tooth wear and eruption (Van Horn et al. 2003).

Class III. Dataset status and accessibility

A. Status

Latest updates: February 2018

Latest archive date: February 2018

Metadata status: Last updated February 2018, version resubmitted

Data Verification: Data were double-checked for accuracy.

B. Accessibility

Storage location and medium: The original data files are held by the authors. This dataset, published in Ecology, is the first public release of these data. Updated versions will be available at datadryad.org (https://doi.org/10.5061/dryad.2dh0223) and https://github.com/LEEClab/jaguar_movement (https://doi.org/10.5281/zenodo/1219174)

Contact person: Queries about the entire dataset or individual specific studies can be initially directed to Ronaldo G. Morato, email: ronaldo.morato@icmbio.gov.br or directly submitted to the authors of individual studies (co-authors of this dataset).

Copyright and proprietary restrictions: None. When using the dataset, please cite this article to recognize the effort involved in gathering and collating the data and the willingness of the authors to make it publicly available.

Costs: None.

Class IV. Data structural descriptors

A. Dataset files

Identity: (1) jaguar_additional_information.csv
(2) jaguar_movement_data.csv

Size: (1) jaguar_additional_information.csv (56 KB)
(1) jaguar_movement_data.csv (12,4 MB)

Format and storage mode: Available as comma-separated values (*.csv).

Alphanumeric attributes: Mixed.

Special characters/fields: If no information is available for a given record, the field is filled with NA.

B. Data limitations and Enhancements

The elusive behavior and naturally low density of apex predators, along with logistic and equipment expenses, make monitoring these species very difficult. Despite the great distribution of study sites presented in this dataset – from Mexico to Argentina – there is a relatively high number of monitored animals in the Pantanal wetlands (n = 53, 45%) of Brazil. This large, seasonally inundated, and biodiverse floodplain (Junk et al. 2006) is home to one of the highest jaguar densities reported to date (Soisalo and Cavalcanti 2006). Such high jaguar densities likely enhanced capture success rate. In contrast, areas with low jaguar densities, such as in the Caatinga biome of Brazil (Silveira et al. 2010), exhibited low capture success rate, which increased the difficulty of conducting movement studies in such regions (Ribeiro Araujo 2016). Despite our efforts to include all available GPS collar data for jaguars, the dataset represents only five of the 18 extant Neotropical range countries (Quigley et al. 2017), with Brazil being represented the most (Figure 2). Many biomes where jaguars occur are currently underrepresented or absent, due to either the lack of data or of participation by research groups from those areas.

Various projects monitored individual jaguars with different GPS data network types (e.g., store on board; remote download; Argos; Globalstar; and Iridium). The different types of communication networks may influence the chance of successful data transfer, which then influence the fix success rate over time. For example, data transmitted via ARGOS are highly affected by forest coverage and humidity, thereby reducing fix success rate (Mantovani et al. 2003). Due to differences in project objectives and technological limitations, the scheduled location acquisitions varied from 0.5 h to 24 h. Monitoring periods were affected by equipment damage or failure, battery durability, or individual mortality, and ranged from 0.2 to 48.1 months (average = 9.8 months; see Figure 2). Consequently, researchers who use these data need to take these issues into account. We suggest that potential users contact, and ideally collaborate with, the project leaders regarding the characteristics of the data and how best to utilize them.

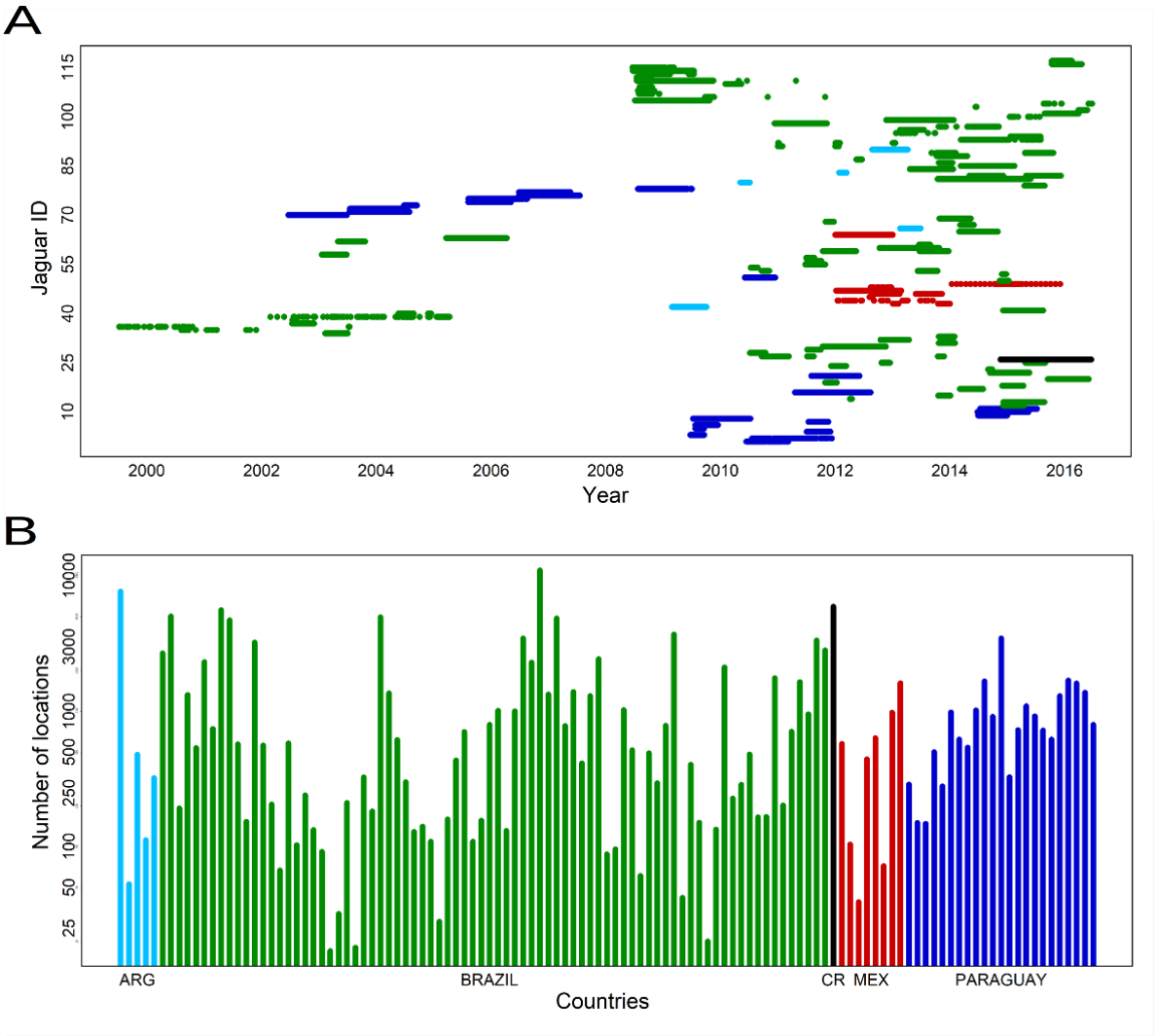

Fig. 2. A) Period of monitoring of jaguar individuals within different study sites, and; B) Number of locations per jaguar individuals monitored in different study sites . Argentina (n= 3, light blue), Brazil (n= 82, green), Costa Rica (n=1, black), Mexico (n= 8, red) and Paraguay (n= 23, dark blue).

Due to its wide distribution and ecological requirements, the jaguar is a key 'umbrella' species for conservation planning in the Neotropics, and contributes to overall biodiversity conservation throughout its range (Sanderson et al. 2002, Rabinowitz and Zeller 2010, Watkins et al. 2015). To date, conservation planning for the jaguar has been primarily based upon presence-only data and/or expert opinion at the local (Rodríguez-Soto et al. 2011, De Angelo et al. 2013, Morato et al. 2014), regional (Paviolo et al. 2016), and range-wide scales (Rabinowitz and Zeller 2010, Sanderson et al. 2002). Our dataset has the potential to improve planning effectiveness by providing inferences into jaguar movements and space use which

can be incorporated into different scales for decision making (Chetkiewicz et al. 2006, Chetkiewicz and Boyce 2009, Colchero et al. 2011, Conde et al. 2010, de la Torre et al. 2017a).

As movement behavior may change in relation to landscape characteristics (Mysterud and Ims 1998), analyses of resource selection and space use are other obvious uses for these data. The data may also be used to build Individual Based Models (Grimm and Railsback 2005) which may contribute to a better understanding of movement behavior in regions not currently represented in the dataset. We foresee the potential to identify thresholds in landscape characteristics that disproportionately affect jaguar movement and space use. Furthermore, as the dataset includes site-specific data on concurrently monitored individuals, there is potential for analyses of social interactions and responses to prey availability where additional site data are available.

Finally, by making our dataset publicly available, we hope that other large carnivore research groups will also be motivated to share their data. Given the growing threats to these species, we believe that there is much to be gained from a more integrated approach to the research and conservation of large carnivores, with far more to be lost by not doing so.

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We are indebted to those who spent weeks – often months – capturing jaguars in the most challenging field conditions.

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TABLES

Table 1. Information for individual jaguars: Description of the available data for the 117 jaguars that were monitored using GPS telemetry in the Neotropics. If no information is available for a given record, the field is filled with NA.

Variables	Description	Levels	Example
ID	Unique individual identification	1.117	1
Sex	Sex of jaguars	Male, Female	Female
Estimated Age	Estimated age (years),	0. 11	5
Weight	Weight (kg)	32.130	32
Collar_type	Type of collar used	GPS Iridium, GPS remote download, Satellite-GPS collar, GPS Globalstar, GPS Argos	GPS Iridium
Collar_brand	Brand of collar used	Lotek, Sirtrack, Televilt, ATS Telonics	Lotek
Planned Schedule	Planned schedule to record the locations (in hours)	0.5 h, 1 h, 1.5h, 2 h, 4.8 h, 5 h, 6 h	1 h
Project Leader	Name of leader of each project	Several project leader names	Daniel Kantek
Contact	Email of project leader	List of project leader emails	daniel.kantek@icmbio.gov.br

Table 2. GPS locations for jaguars in Neotropics: Description of GPS location dataset for the 117 jaguars that were monitored using GPS telemetry in Neotropics. If no information is available for a given record, the field is filled with NA.

Variables	Description	Levels	Example
Event_ID	Sequential identification of each GPS location in the dataset	1. 134690	1
timestamp	Date and time of GPS location (GMT)	Format: month/day/year hour:min	2/14/16 20:00
location.long	Longitude (decimal degrees)		-57.49381
location.lat	Latitude (decimal degrees)		-16.88929
individual.taxon.canonical.name	Scientific name		Panthera onca
tag.local.identifier	Tag identification or serial number		0-333005
individual.local.identifier (ID)	Unique individual identification, which is used to link with individual information CSV file	1. 117	1
Study_name	Name of study, project, or region	List with study, project or region names	Paraguayan Pantanal
Country	Country where individuals were monitored	Argentina, Brazil, Costa Rica, Mexico, Paraguay	Costa Rica