Primate Conservation 2022 (36): 15-21

Resurveying Primate Populations: A Comparison of Methods to Monitor Change Over Time

Denise Spaan[1,2], Gabriel Ramos-Fernández[2,3,4] and Filippo Aureli[1,2,5]

[1]*Instituto de Neuroetología, Universidad Veracruzana, Xalapa, Veracruz, Mexico*
[2]*ConMonoMaya, Chemax, Yucatán, Mexico*
[3]*Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas, Universidad Nacional Autónoma de Mexico, Mexico City, Mexico*
[4]*Unidad Interdisciplinaria en Ingeniería y Tecnologías Avanzadas, Instituto Politécnico Nacional, Mexico City, Mexico*
[5]*Research Centre in Evolutionary Anthropology and Palaeoecology, Liverpool John Moores University, Liverpool, UK*

Abstract: Although long-term monitoring of wildlife populations is fundamental in understanding how populations respond to changes in their environment, particularly in areas affected by habitat disturbance, long-term monitoring programs are lacking for many species and sites. Using newer methods to estimate population density may limit comparison with estimates obtained in the past at the same study site. Our aim is to evaluate whether resurveys could be used to monitor changes in population trends over time by comparing population density estimates obtained in the past with subsequent population density estimates obtained using the same methods to collect and analyze the data. We performed line-transect surveys in mature and regenerating forest in the Otoch Ma'ax yetel Kooh protected area, Yucatán, Mexico, to determine the spider monkey (*Ateles geoffroyi*) population density in 1997–1998 and 2015. We estimated population density by calculating the size of the sampled area (effective strip width) using the Kelker, King and Maximum Perpendicular Distance methods. We compared population density estimates obtained using the same method in 1997–1998 and 2015. Although population density estimates differed across methods, each method consistently showed no change in population density over time in either mature or regenerating forest, suggesting that changes in population trends can be monitored using the same method over time. Given that large gaps remain in the distribution and size of populations for the majority of Neotropical primates and long-term monitoring programs are scarce, resurveys may be a useful method to provide updated information on populations surveyed in the past. Such updated information is urgently needed, especially in areas that have undergone landscape-scale modifications between survey periods.

Keywords: Long-term population monitoring, *Ateles*, line transect surveys, population density, spider monkeys

Introduction

Monitoring wildlife allows researchers to track population trends over time (i.e., whether a population is stable, increasing in size, or in decline), documenting the welfare and extinction risk of such populations (Kühl *et al*. 2008). Long-term monitoring, where surveys are performed at regular intervals in the same area (e.g., annually), is necessary to understand how changes in the environment or its management affect animal populations (Chapman and Lambert 2000; Magurran *et al*. 2010) and can therefore aid in conservation and management decision-making. Long-term monitoring is commonly practiced for large, charismatic fauna, such as elephants (*Loxodonta africana cyclotis* see Hoppe-Dominik *et al*., 2011; *L. africana* see Mtui, *et al*. 2017), and tigers (*Panthera tigris* Barlow *et al.* 2009; Majumder *et al*. 2017), but in primates it is restricted to a small group of species (e.g., Chapman *et al*. 2010, 2018; Rovero *et al*. 2015; Strier *et al*. 2017). In general, constraints imposed by time and funds lead to a larger number of short-term surveys (Dobson and Lees 1989; Struhsaker 2008), often only a few months in length (e.g., Allgas *et al*.

2018). Additionally, the long lifespan of many primate species makes long-term monitoring challenging as monitoring programs may need to span several generations of researchers or conservation practitioners and secure continuous funding to observe changes in population trends over time (Chapman and Lambert 2000; Estrada *et al*. 2017). One way to overcome such difficulties and obtain information on changes in population abundance over time when no long-term monitoring programs are in place is to resurvey a location surveyed in the past whenever possible (Marsh 1986; Moritz *et al*. 2008; Kopecký and Macek 2015). Such resurveys are usually separated by several years or decades, and although they are increasingly common in vegetation ecology (Verheyen *et al*. 2017), their application to primatology is limited (Marsh 1986; Aggimarangsee 2013; Alcocer-Rodríguez *et al*. 2021). As the most common measure of population trend is population density (i.e., the number of individuals or groups per unit area), comparisons of population density estimates based on resurveys may be unreliable if different methods to collect and/or analyze the data are used during the two survey periods.

Survey and data-analysis methods have undergone major developments over the past two decades—the introduction of distance sampling (Buckland *et al*. 2001), spatially explicit mark-recapture (Efford *et al*. 2009) and occupancy modelling (Mackenzie *et al*. 2005). New methods may not be easily applied to long-term monitoring programs that span the careers of several researchers because the original data can be lost over time, leaving only survey estimates published in scientific articles. The lack of original survey data may, therefore, prevent the reanalysis of such data using newer methods, and thereby limit the comparison of population density estimates and population trends over time.

Given that information on population trends and the factors affecting them is vital for the elaboration of conservation management plans, we aimed to evaluate whether resurveys could be used to monitor changes in population trends over time. We did so by comparing population density estimates obtained in the past with newer population density estimates obtained using the same methods to collect and analyze the data. We compared Geoffroy's spider monkey (*Ateles geoffroyi*) population density estimates obtained in the Otoch Ma'ax yetel Kooh (OMYK) protected area in 1997–1998 with estimates obtained in 2015. We did so by using three methods to estimate the effective strip width: the King method (Link *et al*. 2010; Meyler *et al*. 2012; de Luna and Link 2018), the Kelker method (Kelker 1945), and the Maximum Perpendicular Distance method (Defler and Pintor 1985; Chapman *et al*. 1988). All three methods were popular at the time of the 1997–1998 survey but decreased in popularity with the advent of newer methods, such as Conventional Distance Sampling, which accounts for imperfect detection (Buckland *et al*. 2001). Performing this study is relevant because all species of spider monkeys are threatened with extinction (Ramos-Fernández and Wallace 2008). In addition, despite having been surveyed at different sites across their range using a variety of methods to estimate population density from line transect data (Estrada and Coates-Estrada 1996; Estrada *et al*. 2004; Serio-Silva *et al*. 2005; Weghorst 2007; Link *et al*. 2010; Aquino *et al*. 2012; Marsh *et al*. 2016; Spaan *et al*. 2019, 2020), data on spider monkey population trends over time are lacking. As such, comparisons based on resurveys could provide important insights into the current trends of different spider monkey populations. An evaluation of the appropriate methodology is therefore essential.

Methods

Study design

We carried out spider monkey population surveys in 1997–1998 and 2015 in OMYK, Yucatán, Mexico. OMYK (5367 ha; 20°38'N, 87°38'W: 14 m above sea level) was decreed a Flora and Fauna protected area in 2002 (Bonilla-Moheno and García-Frapolli 2012). See Ramos-Fernández *et al.*, 2018 for further details on the study site.

We surveyed the southern section of OMYK with four transects in 1997–1998 and resurveyed the same section in 2015, using three transects that were in approximately the same location as the transects used in 1997–1998 (Spaan *et al*. 2021). Transect locations in 2015 were determined with the help of maps of the original transects and a member of the local community who was part of the 1997–1998 surveys. The total length of all transects equaled 19.6 km in 1997–1998 and 12.5 km in 2015. Most of the transect length was composed of regenerating forest (forests in differing stages of succession <50 years old): 13.2 km in 1997–1998 (67%) and 7.9 km in 2015 (63%). The rest of the transect length consisted of mature forest (forest >50 years old).

Data collection

We replicated the 1997–1998 survey data collection methods as closely as possible in 2015. Upon sighting monkeys, we counted all independently moving individuals, marked their compass bearing with respect to the transect centerline and estimated the distance between the observer on the transect centerline and the individual (Spaan *et al*. 2019). We also marked the location of the sighting using a hand-held GPS device (see Spaan *et al*. 2021, for further details).

Data analysis

We used the compass-bearing and distance from the transect centerline to each individual spider monkey to calculate the perpendicular distance between the transect centerline and each individual. We corrected for error in estimating distances following Spaan *et al*. (2019). Population density refers to the number of individuals in a particular area (Plumptre *et al*. 2013), where the area is calculated as 2-times the transect length × the effective strip width (ESW). ESW is the distance from the transect centerline within which it is assumed that all individuals have been detected (Struhsaker 1981). We did not account for bias in our population density estimates that could have resulted from missing individuals that were in fact present in the subgroup encountered. A previous study revealed that 1.7% of adult females and 12.3% of young can be missed during line transect surveys in this forest (Spaan 2017). Although such bias may be overcome in primates that live in groups of stable composition and size by calculating the distance to the group center point, this measure is not applicable to spider monkeys due to their high degree of fission-fusion dynamics (Aureli *et al*. 2008) and can introduce other biases.

We estimated the population density of spider monkeys in mature and regenerating forest for both study periods using three methods: the King method (Link *et al*. 2010; Meyler *et al*. 2012), the Kelker method (Struhsaker 1981) and the maximum perpendicular distance (MPD) (Defler and Pintor 1985; Chapman *et al*. 1988). These methods differ in how the ESW is estimated. All methods use the perpendicular distances from the individual detected during surveys to the transect centerline to estimate ESW. Therefore, the number of individuals and the area included in the calculation of population density varied between methods (Spaan *et al*. 2019).

For the MPD, the ESW is assumed to be the maximum perpendicular distance recorded during surveys (Chapman *et al*. 1988). Although the King method was originally based on radial distances (animal-observer distances; de Andrade *et al*. 2019), it has been modified to use perpendicular distances in previous spider monkey surveys (Link *et al*. 2010; de Luna and Link 2018) as well as surveys of other primate species (Meyler *et al*. 2012). Population density is estimated using the mean perpendicular distance (Link *et al*. 2010; de Luna and Link 2018). All 102 and 76 individuals sighted in mature forest and 26 and 7 individuals sighted in regenerating forest in 1998 and 2015, respectively, were included in the population density estimates using the King and MPD methods.

The Kelker method is a histogram inspection technique (Chapman *et al*. 2000; Hassel-Finnegan *et al*. 2008; Meyler *et al*. 2012). The effective strip width is determined as the perpendicular distance from the transect centerline after which there is a dramatic decline in the number of individuals sighted. We used a 50% fall-off distance, where the number of individuals drops >50% from one bin compared to the previous bin, to estimate the ESW (see Spaan *et al*. 2019 for further details). We selected the histogram (and bin size) that excluded the least number of sighted individuals after the 50% fall-off distance was applied (Spaan *et al*. 2019). We grouped perpendicular distances into histograms with bins of 4, 5, 6, and 7 m for mature forest, and chose the histogram with the 4 m and 6 m bins for 1998 and 2015, respectively. For regenerating forest, we grouped perpendicular distances into histograms with bins of 3, 4, 5 and 7 m, and chose the histogram with the 5 m and 7 m bins for 1997–1998 and 2015, respectively. These histograms included 89 and 76 sighted individuals in mature forest and 25 and 7 individuals in regenerating forest for 1997–1998 and 2015, respectively. We calculated 95% confidence intervals following Meyler *et al*. (2012), but we were unable to do so for mature forest in 1997–1998 as only one transect included mature forest.

Results

We recorded distance measurements for all spider monkeys sighted in the two vegetation types for a total survey effort of 219.7 kms and 128.5 kms, during the 1997–1998 and 2015 surveys, respectively.

Spider monkey population density estimates calculated with each method in either mature or regenerating forest for 1998 and 2015 are similar (Table 1). The population density estimates obtained using the King method and the MPD method with the 1998 data fell within the 95% confidence interval of the corresponding 2015 data for mature forest (Table 1). The 1998 population density estimate obtained using the Kelker method fell just outside of the 2015 confidence interval but was very close to the upper limit. In addition, the 1998 and 2015 95% confidence intervals overlapped for all three methods for regenerating forest (Table 1).

Although the population density estimates obtained with the King method were much higher than those calculated with the Kelker method and MPD method in both vegetation types and years, confidence intervals of the three methods overlap for regenerating forest in both years and for mature forest in 2015 (Table 1).

Discussion

We found no change in spider monkey population density estimates in either mature or regenerating forest over a 17-year period in OMYK, regardless of the method used to estimate population density. Similar results were obtained using spider monkey encounter rates (individuals per kilometer walked; Spaan *et al*. 2021). Our results suggest that the spider monkey population in the southern section of OMYK has remained relatively stable over a 17-year period. This is particularly interesting as the study area underwent several changes between the survey periods, including the creation of the protected area. However, the comparison of population density estimates between two surveys over a 17-year period could hide fluctuations in population size that occurred during that time. In addition, it must be noted that as spider monkeys are slow growing and slow reproducing animals (Shimooka *et al*. 2008; Ramos-Fernández *et al*. 2018), 17 years may not be enough time to observe marked changes in population size. When funding and resources permit, it is always favorable to perform surveys at more regular intervals rather than resurveying an area surveyed only once in the past.

Table 1. Population density estimates (individuals per km^2) for mature and regenerating forest in 1997–1998 and 2015 using different methods.

Vegetation type	Method	Year	ESW (km)	Length (km)	N	Population density	95% CI
Mature forest	King method	1998	0.008	72.9	102	77.3	
		2015	0.011	42.78	76	81.6	23.4 – 96.1
	Kelker method	1998	0.016	72.9	89	38.2	
		2015	0.03	42.78	76	29.6	8.5 – 35.1
	MPD	1998	0.029	72.9	102	24.1	
		2015	0.028	42.78	76	31.7	19.9 – 38.5
Regenerating forest	King method	1998	0.012	146.8	26	7.6	0.1 – 17.3
		2015	0.008	85.72	7	4.9	-2.9 – 9.0
	Kelker method	1998	0.015	146.8	25	5.7	1.4 – 10.2
		2015	0.014	85.72	7	2.9	-1.7 – 5.4
	MPD	1998	0.037	146.8	26	2.4	0.7 – 10.9
		2015	0.013	85.72	7	3.2	-1.9 – 5.8

Although population density estimates differed between methods, all methods show the same trend over time. One of the limitations comparing population density estimates over time is that original data from past surveys may no longer be available, with only the population density estimates published in the scientific or gray literature remaining. This may limit comparisons across time as newer methods to estimate population density cannot be applied to previous survey data, even if the same data collection protocol was employed during subsequent surveys. Our results suggest that if the same protocols are followed during data collection, the published population density estimates can be compared to estimates obtained during subsequent surveys in the same area, if the same method is used to estimate population density. Thus, published population density estimates can still lead to valuable insights on population trends when compared to newer population density estimates using the same data collection and analysis protocols.

The older methods used here to estimate population density have largely been replaced by newer methods (e.g., Conventional Distance Sampling) because the older methods may over- or under-estimate population density and do not account for imperfect detection (Meyler *et al*. 2012). For example, maximum perpendicular distance is influenced by visibility and terrain which can lead to underestimating spider monkey population density (Spaan *et al*. 2019). Although the Kelker method slightly under-estimated spider monkey population density in previous surveys in OMYK, it provided the most similar population density estimate to the actual density based on home range size and individually identified monkeys (Spaan *et al.* 2019). It is therefore likely the most accurate estimate we present here. We report large confidence intervals for some of the population density estimates. Large confidence intervals can make interpreting the conservation status of a species or population difficult. Here, they are likely attributed to the limited number of transects that were walked. Large confidence intervals are a common limitation in population surveys of primates, although often they are simply not reported. To overcome this limitation and to err on the side of caution, the IUCN recommends using the lower confidence interval of population estimates (IUCN 2012; Paim *et al.* 2019). Considering the limited resources and funds available to conservation and the sheer number of threatened species, however, improving the precision and accuracy of population surveys should be a priority.

Overall, although the population density estimates we present here may not be reliable in terms of the number of individuals that are found in the survey area (Meyler *et al*. 2012; Kun-Rodrigues *et al*. 2013; Spaan *et al*. 2019), our study shows that they may still provide valuable information on population trends between two survey periods. Resurveys can therefore provide insights into the welfare and extinction risk of animal populations living in an area previously surveyed, providing a powerful tool to investigate the effect of anthropogenic and climatic changes on population trends over time (Arce-Peña *et al*. 2019; Alcocer-Rodríguez *et al*. 2021). Given that large gaps remain in the distribution and size of populations for the majority of Neotropical primates (Freire Filho and Palmeirim 2020) and long-term monitoring programs are scarce, resurveys may prove a valuable tool to provide current information on populations surveyed in the past. Such updated information is urgently needed, especially in areas that have undergone landscape-scale modifications between survey periods.

Acknowledgments

We are very grateful to Braulio Pinacho-Guendulain, Juan de la Cruz Can-Yam, Nemencio Can Yam, Jorge Can-Yam and Cirilo Mukul for assistance with data collection. We also thank the Instituto Politécnico Nacional, Instituto de Ecología, A.C., and the Instituto de Neuroetología of the Universidad Veracruzana for their logistical support. This study was supported by the Consejo Nacional de Ciencia y Tecnología [CONACYT: CVU: 637705], CONANP [PROCER/DRPYyCM/2/2015], the National Geographic Society [9784-15], the National Autonomous University of Mexico (PAPIIT IA200720), and Chester Zoo. Research complied with protocols approved by the Secretaría del Medio Ambiente y Recursos Naturales [SEMARNAT: SGPA/DGVS/10405/15] and adhered to the legal requirements of Mexico. The Comisión Nacional de Áreas Naturales Protegidas (CONANP) gave us permission to conduct surveys in the protected area. We are very grateful to the reviewer for their most helpful comments.

Literature Cited

Aggimarangsee, N. 2013. Status monitoring of isolated populations of macaques and other nonhuman primates in Thailand. In: *Primates in Fragments: Complexity and Resilience*, L. Marsh and C. Chapman (eds.), pp.147–158. Springer, New York.

Alcocer-Rodríguez, M., V. Arroyo-Rodríguez, C. Galán-Acedo, J. Cristóbal-Azkarate, N. Asensio, K. F. Rito, J. E. Hawes, J. J. Veà and J. C. Dunn. 2021. Evaluating extinction debt in fragmented forests: the rapid recovery of a critically endangered primate. *Anim. Conserv.* 24(3): 432–444.

Allgas, N., S. Shanee, N. Shanee and H. Collongues de Palomino. 2018. Rapid survey of the primate density and biomass at Katakari, Pacaya Samiria National Reserve, Peru, *Primate Conserv*. (32): 1–10.

Aquino, R., F. M. Cornejo, E. Pezo and E. W. Heymann. 2012. Distribution and abundance of white-fronted spider monkeys, *Ateles belzebuth* (Atelidae), and threats to their survival in Peruvian Amazonia. *Folia Primatol* 84: 1–10.

Arce-Peña, N. P., V. Arroyo-Rodríguez, P. A. Dias, I. Franch-Pardo and E. Andresen. 2019. Linking changes in landscape structure to population changes of an endangered primate. *Landsc. Ecol.* 34: 2687–2701.

Aureli, F. *et al.* 2008. Fission-fusion dynamics: new research frameworks. *Curr. Anthropol*. 49(4): 627–655.

Barlow, A. C. D., C. McDougal, J. L. D. Smith, B. Gurung, S. R. Bhatta, S. Kumal, B. Mahato and D. B. Tamang. 2009. Temporal variation in tiger (*Panthera tigris*) populations and its implications for monitoring. *J. Mammal.* 90: 472–478.

Bonilla-Moheno, M. and E. García-Frapolli. 2012. Conservation in context: a comparison of conservation perspectives in a Mexican protected area. *Sustainability* 4: 2317–2333.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers and L. Thomas. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford, UK.

Chapman, C. A., S. R. Balcomb, T. R. Gillespie, J. P. Skorupa and T. T. Struhsaker. 2000. Long-term effects of logging on African primate communities: a 28-year comparison from Kibale National Park, Uganda. *Conserv. Biol.* 14: 207–217.

Chapman, C. A., S. Bortolamiol, I. Matsuda, P. A. Omeja, F. P. Paim, R. Reyna-Hurtado, R. Sengupta and K. Valenta. 2018. Primate population dynamics: variation in abundance over space and time. *Biodivers. Conserv*. 27: 1221–1238.

Chapman, C. A., L. M. Fedigan and L. Fedigan. 1988. A comparison of transect methods of estimating population densities of Costa Rican primates. *Brenesia* 30: 67–80.

Chapman, C. A. and J. E. Lambert. 2000. Habitat alteration and the conservation of African primates: case study of Kibale National Park, Uganda. *Am. J. Primatol*. 50: 169–85.

Chapman, C. A., T. T. Struhsaker, J. P. Skorupa, T. V. Snaith and J. M. Rothman. 2010. Understanding long-term primate community dynamics: implications of forest change. *Ecol. Appl.* 20: 179–191.

de Andrade, A.C., T. A. Marques and S. T. Buckland. 2019. Spider monkeys, the misunderstood assumptions of distance sampling and the pitfalls of poor field design. *Biodivers. Conserv.* 28: 4119–4121.

de Luna, A. G. and A. Link. 2018. Distribution, population density and conservation of the critically endangered brown spider monkey (*Ateles hybridus*) and other primates of the inter-Andean forests of Colombia. *Biodivers. Conserv.* 27: 3469–3511.

Defler, T. R. and D. Pintor. 1985. Censusing primates by transect in a forest of known primate density. *Int. J. Primatol.* 6: 243–259.

Dobson, A. P. and A. M. Lees. 1989. The population dynamics and conservation of primate populations. *Conserv. Biol.* 3: 362–380.

Efford, M. G., D. L. Borchers and A. E. Byrom. 2009. Density estimation by spatially explicit capture-recapture: likelihood-based methods. In: *Modeling Demographic Processes in Marked Populations*, D. L. Thomson,

E. G. Cooch and M. J. Conroy (eds.), pp.255–269. Springer, Boston.

Estrada, A. and R. Coates-Estrada. 1996. Tropical rain forest fragmentation and wild populations of primates at Los Tuxtlas, Mexico. *Int. J. Primatol.* 17: 759–783.

Estrada, A., L. Luecke, S. Van Belle, E. Barrueta and M. R. Meda. 2004. Survey of black howler (*Alouatta pigra*) and spider (*Ateles geoffroyi*) monkeys in the Mayan sites of Calakmul and Yaxchilán, Mexico and Tikal, Guatemala. *Primates* 45: 33–39.

Estrada, A. *et al.* 2017. Impending extinction crisis of the world's primates: why primates matter. *Sci. Adv.* 3: e1600946.

Freire Filho, R. and J. M. Palmeirim. 2020. Potential distribution of and priority conservation areas for the Endangered Caatinga howler monkey *Alouatta ululata* in north-eastern Brazil. *Oryx* 54: 794–802.

Hassel-Finnegan, H. M., C. Borries, E. Larney, M. Umponjan and A. Koenig. 2008. How reliable are density estimates for diurnal primates? *Int. J. Primatol*. 29: 1175–1187.

Hoppe-Dominik, B., H. S. Kühl, G. Radl and F. Fischer. 2011. Long-term monitoring of large rainforest mammals in the Biosphere Reserve of Taï National Park, Côte d'Ivoire. *Afr. J. Ecol.* 49: 450–458.

IUCN. 2012. *IUCN Red List Categories and Criteria: Version 3.1.* Second edition. IUCN, Gland, Switzerland and Cambridge, UK

Kelker, G. H. 1945. Measurement and Interpretation of Forces that Determine Populations of Managed Deer. PhD thesis, University of Michigan, Ann Arbor, MI.

Kopecký, M. and M. Macek. 2015. Vegetation resurvey is robust to plot location uncertainty. *Divers. Distrib.* 21: 322–330.

Kühl, H. S., F. Maisels, M. Ancrenaz and E. A. Williamson. 2008. *Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations*. IUCN SSC Primate Specialist Group (PSG), Gland, Switzerland.

Kun-Rodrigues, C., J. Salmona, A. Besolo, E. Rasolondraibe, C. Rabarivola, T. A. Marques and L. Chikhi. 2013. New density estimates of a threatened sifaka species (*Propithecus coquereli*) in Ankarafantsika National Park. *Am. J. Primatol*. 76: 515–28.

Link, A., A. de Luna, F. Alfonso, P. Giraldo-Beltran and F. Ramirez. 2010. Initial effects of fragmentation on the density of three Neotropical primate species in two lowland forests of Colombia. *Endang. Species Res.* 13: 41–50.

Mackenzie, D.I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey and J. E. Hines. 2005. *Occupancy Estimation and Modelling: Inferring Patterns and Dynamics of Species Occurrence*. Academic Press (Elsevier), London.

Magurran, A. E., S. R. Baillie, S. T. Buckland, J. M. P. Dick, D. A. Elston, E. M. Scott, R. I. Smith, P. J. Somerfield and A. D. Watt. 2010. Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. *Trends Ecol. Evol.* 25: 574–582.

Majumder, A., Q. Qureshi, K. Sankar and A. Kumar. 2017. Long-term monitoring of a Bengal tiger (*Panthera tigris tigris*) population in a human-dominated landscape of Central India. *Eur. J. Wildl. Res.* 63: 1–11.

Marsh, C., A. Link, G. King-Bailey and G. Donati. 2016. Effects of fragment and vegetation structure on the population abundance of *Ateles hybridus*, *Alouatta seniculus* and *Cebus albifrons* in Magdalena Valley, Colombia. *Folia Primatol*. 87: 17–30.

Marsh, C. W. 1986. A resurvey of Tana River primates and their habitat. *Primate Conserv.* (7): 72–82.

Meyler, S. V., J. Salmona, M. T. Ibouroi, A. Besolo, E. Rasolondraibe, U. Radespiel, C. Rabarivola and L. Chikhi. 2012. Density estimates of two endangered nocturnal lemur species from northern Madagascar: new results and a comparison of commonly used methods. *Am. J. Primatol.* 74: 414–422.

Moritz, C., J. L. Patton, C. J. Conroy, J. L. Parra, G. C. White and S. R. Beissinger. 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. *Science* (80) 322: 261–264.

Mtui, D., N. Owen-Smith and C. Lepczyk. 2017. Assessment of wildlife population trends in three protected areas in Tanzania from 1991 to 2012. *Afr. J. Ecol.* 55: 305–315.

Paim, F. P., H. R. El Bizri, A. P. Paglia and H. L. Queiroz. 2019. Long-term population monitoring of the threatened and endemic black-headed squirrel monkey (*Saimiri vanzolinii*) shows the importance of protected areas for primate conservation in Amazonia. *Am. J. Primatol*. 81: e22988

Plumptre, A. J., E. J. Sterling and S. T. Buckland. 2013. Primate census and survey techniques. In: *Primate Ecology and Conservation: A Handbook of Techniques*, E. J. Sterling, N. Bynum and M. E. Blaire (eds.), pp.10–26. Oxford University Press, Oxford.

Ramos-Fernández, G., F. Aureli, C. M. Schaffner and L. G. Vick. 2018. Ecología, comportamiento y conservación de los monos araña (*Ateles geoffroyi*): 20 años de estudio en Punta Laguna, México. In: *La Primatología En Latinoamérica, 2 – A Primatologia na America Latina. Toma II Costa Rica – Venezuela,* B. Urbani, M. Kowalewski, R. G. T. Cunha, S. de la Torre and L. Cortés-Ortiz (eds.), pp.531–544. Ediciones IVIC. Instituciones Venezolano de Investigaciones Científicas, Caracas.

Ramos-Fernández, G. and R. B. Wallace. 2008. Spider monkey conservation in the twenty-first century: recognizing risks and opportunities. In: *Spider Monkeys: Behaviour, Ecology and Evolution of the Genus* Ateles*,* C. J. Campbell (ed.), pp.351–376. Cambridge University Press, Cambridge.

Rovero, F., A. Mtui, A. Kitegile, P. Jacob, A. Araldi and S. Tenan. 2015. Primates decline rapidly in unprotected forests: evidence from a monitoring program with data constraints. *PLoS One* 10: e0118330.

Serio-Silva, J. C., V. Rico-Gray and G. Ramos-Fernández. 2005. Mapping primate populations in the Yucatan Peninsula, Mexico: a first assessment. In: *New Perspectives in the Study of Mesoamerican Primates*, A. Estrada, P. A. Garber, M. S. M. Pavelka and L. Luecke (eds.), pp. 489–511. Springer, New York.

Shimooka, Y., C. J. Campbell, A. Di Fiore, A. M. Felton, K. Izawa, A. Link, A. Nishimura, G. Ramos-Fernández and R. B. Wallace. 2008. Demography and group composition of *Ateles*. In: *Spider Monkeys – Behaviour, Ecology and Evolution of the Genus* Ateles*,* C. J. Campbell (ed.), pp. 329–350. Cambridge University Press, Cambridge.

Spaan, D., G. Ramos-Fernández, C. M. Schaffner, B. Pinacho-Guendulain and F. Aureli. 2017. How survey design affects monkey counts: a case study on individually recognized spider monkeys (*Ateles geoffroyi*). *Folia Primatol.* 88: 409–420.

Spaan, D., G. Ramos-Fernández, C. M. Schaffner, S. E. Smith-Aguilar, B. Pinacho-Guendulain and F. Aureli. 2019. Standardizing methods to estimate population density: an example based on habituated and unhabituated spider monkeys. *Biodivers. Conserv*. 28: 847–862.

Spaan, D., G. Ramos-Fernandez, M. Bonilla-Moheno, C. M. Schaffner, K. Slater, J. Morales-Mavil and F. Aureli. 2020. Anthropogenic habitat disturbance and food availability affect the abundance of an endangered primate: a regional approach. *Mamm. Biol.* 100: 325–333.

Spaan, D., G. Ramos-Fernandez, M. Bonilla-Moheno, C. M. Schaffner and F. Aureli. 2021. The impact of the establishment of Otoch Ma'ax Yetel Kooh protected area (Yucatán, Mexico) on populations of two Neotropical primates. *Parks* 27: 35–42.

Strier, K. B., C. B. Possamai, F. P. Tabacow, A. Pissinatti, A. M. Lanna, F. R. de Melo, L. Moreira, M. Talebi, P. Breves, S. L. Mendes and L. Jerusalinsky. 2017. Demographic monitoring of wild muriqui populations: criteria for defining priority areas and monitoring intensity. *PLoS One* 12: e0188922.

Struhsaker, T. T. 2008. Demographic variability in monkeys: implications for theory and conservation. *Int. J. Primatol.* 29: 19–34.

Struhsaker, T. T. 1981. Census methods for estimating densities. In: *Techniques for the Study of Primate Population Ecology,* pp.36–80. National Academy Press, Washington, DC.

Verheyen, K. *et al.* 2017. Combining biodiversity resurveys across regions to advance global change research, *BioScience* 67: 73–83.

Weghorst, J. A. 2007. High population density of black-handed spider monkeys (*Ateles geoffroyi*) in Costa Rican lowland wet forest. *Primates* 48: 108–116.

Authors' addresses:
Denise Spaan, **Filippo Aureli**, Instituto de Neuroetología, Universidad Veracruzana, Avenida Dr. Luis Castelazo, Xalapa, 91190 Veracruz, Mexico; **Gabriel Ramos-Fernández**, Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas, Universidad Nacional Autónoma de México, Circuito Escolar 3000, Ciudad Universitaria, Coyoacán 04510, Mexico City, Mexico.

Corresponding author: Denise Spaan
E-mail: <dspaan@uv.mx>

Received for publication: 26 August 2021
Revised: 2 November 2021