

Synthesis and perspectives of bibliographic information on *Tapirella bairdii* in Mexico

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Tapirella bairdii participates in the dynamics of tropical forests through herbivory and seed dispersal. The objective of the present study was to review and analyze the literature published on *T. bairdii* in México between 1865 and 2018 aiming to identify information gaps and advances in knowledge and propose future research perspectives. The literature references on *T. bairdii* in México published in periodic scientific journals between 1865 (year of description of the species) and 2018 were organized in the software Endnote Plus. Articles were arranged into 5-year periods to identify publication trends. Articles were grouped according to 1) the 11 main topics, 2) the Mexican state where the study was carried out, 3) country of origin (national or foreign) of the first author, and 4) country of origin of the journal (national or foreign). A total of 136 published articles were recorded, more than eighty-eight percent between 1995 and 2018. Eighty-one percent of studies were carried out by Mexican researchers. These articles were published in 43 foreign and 11 national journals. Seventy-three percent of the studies were carried out in Chiapas, Oaxaca, and Campeche. A total of 233 records of occurrence of *T. bairdii* in México have been documented. The topics most frequently addressed include ecology, taxonomy and phylogeny, and distribution. No research has been published on physiology and ethology. The most productive years of research (1995-2018) can be explained by the increase in the number of Mexican researchers, with more funds allocated to research projects, information dissemination about the tapir, and the greater economic, scientific, and technological developments in different areas. The participation of national researchers is highlighted, with most articles published in foreign journals. The compilation of published information highlights the need to continue preserving Natural Protected Areas (NPAs), the Mesoamerican Biological Corridor, and unprotected regions that are home to tapir populations. Also, the connectivity between tapir populations should be improved, and the availability of tapir habitats in the country should be warranted. Research is needed to cover information gaps on basic aspects of the biology of the species, including physiology, ethology, diseases and parasitism, genetics, anatomy, reproduction, and evolutionary history, among others. Our findings reveal that no research on the physiology and ethology of tapirs has been conducted. Finally, the formation of a collaborative network to define and prioritize efforts and set guidelines is a priority.

Tapirella bairdii participa en la dinámica de los bosques tropicales al realizar procesos de herbivoría y dispersión de semillas. La finalidad de este trabajo fue revisar y analizar la bibliografía publicada entre 1865 y 2018 sobre *T. bairdii* en México para identificar los avances y sesgos en su conocimiento, y proponer perspectivas de investigación hacia el futuro. La bibliografía sobre *T. bairdii* en México publicada en revistas científicas entre 1865 (año de la descripción de la especie) y 2018 se organizó en el programa Endnote Plus. Se elaboraron archivos por lustros para identificar tendencias en la producción. Los trabajos se agruparon de acuerdo a: 1) 11 temas principales, 2) las entidades federativas donde se desarrolló el estudio, 3) el país de origen (nacional o extranjero) del primer autor, y 4) el origen de la revista (nacional o extranjera). Se registraron 136 publicaciones, con más del 88 % entre 1995-2018. El 81.6 % se realizaron por autores mexicanos. Se publicaron en 43 revistas extranjeras y 11 nacionales. El 73 % de los trabajos se desarrollaron en Chiapas, Oaxaca y Campeche. Se cuantificaron 233 registros de ocurrencia de *T. bairdii* en México. Los temas más abordados fueron sobre ecología, taxonomía y filogenia, y distribución. Hay nula investigación sobre fisiología y etología. Los años más productivos (1995-2018) pueden ser explicados por un incremento de investigadores mexicanos, del financiamiento de proyectos de investigación, de la divulgación sobre el tapir y por un mayor desarrollo económico, científico y tecnológico. Resalta la participación de investigadores nacionales con la mayoría de las publicaciones en revistas de origen foráneo. La síntesis de información indicó que es necesario continuar con la protección de las Áreas Naturales Protegidas (NPAs), del Corredor Biológico Mesoamericano, y de las regiones no protegidas que alberguen poblaciones del tapir; también se debe mejorar la conectividad entre ellas, para garantizar la disponibilidad de sus hábitats en el país. Se requieren incrementar los estudios sobre enfermedades y parasitismo y cubrir huecos de información sobre aspectos básicos de la biología de la especie como la fisiología, genética, anatomía, reproducción, historia evolutiva, entre otros. Se deben iniciar esfuerzos para estudiar la fisiología y la etología donde hay nula investigación. Finalmente, es prioritaria la formación de una red de colaboración para definir, priorizar esfuerzos y plantear directrices.

Keywords: bibliography; database; history; journals; México; Tapiridae; ungulate.

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Introduction

Tapirella bairdii is the largest terrestrial ungulate in the Neotropics, being one of the four species in the family Tapiridae and the only species of tapir in Mesoamerica, endemic to a region stretching from southern México to northern Colombia (García et al. 2016). It plays a crucial role in the

dynamics of tropical forests through herbivory and seed dispersal, contributing to the regeneration of tropical forests (Camargo-Sanabria and Mendoza 2016).

Tapirella bairdii is listed as endangered by the International Union for the Conservation of Nature (IUCN, García et al. 2016), included in Appendix I of the Convention on Inter-

national Trade in Endangered Species of Wild Fauna and Flora (CITES 2018), and listed as endangered of extinction by the Secretariat of the Environment and Natural Resources (NOM-059-SEMARNAT-2010; SEMARNAT 2010). It is also considered a priority species for conservation. The major threats to the conservation of the tapir are deforestation and habitat fragmentation, poaching, forest fires, drought, incidental encounters with humans, and disease transmission (Cruz-Aldán et al. 2006; Contreras-Moreno et al. 2013; Naranjo et al. 2015). A 50 % reduction in tapir populations has been estimated for the past 30 years (García et al. 2016). Its current geographic distribution in México includes the states of Campeche, Chiapas, Oaxaca, Quintana Roo, and southwest Veracruz (Mendoza et al. 2013; Botello et al. 2014; Naranjo et al. 2015); although there is no current evidence, large tapir populations may also thrive in Yucatan and Tabasco (March and Naranjo 2005; Naranjo et al. 2015).

The biology and ecology of the tapir are essential in forest environments; however, a single literature review is currently available (March 1994). This points to the need of an updated review and analysis of the published literature to identify the approaches and prospects in Mexico, as well as the biases and advances in knowledge, to propose the perspectives for future research. The objective of this work was to review and analyze the bibliographic references on *Tapirella bairdii* in Mexico, using the literature published in scientific journals over 153 years (1865-2018).

Materials and Methods

Information gathering, selection, and organization. The bibliography concerning *Tapirella bairdii* in México and published between 1865-2018 was gathered based on publications by Ramírez-Pulido et al. (1986), Ramírez-Pulido and Castro-Campillo (1990), Ramírez-Pulido and Castro-Campillo (1994), Ramírez-Pulido et al. (2000), and Ramírez-Pulido et al. (2017a), which include lists of the published literature on mammals of Mexico. In addition, we conducted a comprehensive search of electronic literature through the Google Scholar and the following databases: Biological Abstract, BioOne 1 Journals, BioOne 2 Journals, Current Contents Connect, ELSEVIER Science Direct – Journals, SciELO Mexico, Wiley-Blackwell Current Protocols, and Wiley-Blackwell Full Collection. The search was carried out considering the entire text (including the title), using specific and combined keywords including “tapir”, “Tapirus”, “Tapirella”, “bairdii”, “Tapiridae”, and “Mexico”. We reviewed the literature cited in each article on the subject. The only publications included were formal contributions published in scientific journals, expressly referring to the tapir in Mexico, excluding references of this species in other countries. The studies included date back to the year 1865 when the species was first described. For practical reasons, the year 2018 was selected as the last year, considering that the 153-year period adequately reflects the work conducted on this mammal.

The information contained in the references was analyzed and organized for incorporation into a database

including several files produced using the literature management program Endnote Plus for PC version X 7.5 (Niles & Associates, Inc.). The fields used were the following: Author, year, title, journal name, volume, pages, main theme, state of Mexico, country of publication (Mexico, foreign), and nationality of the first author (Mexican or foreign).

Information Analysis. To explore the trend in the production of scientific articles, these were grouped considering 5-year intervals, except for the most recent one, which covered four years. This pooling allowed the identification of production trends and topics addressed in the publications over the 153 years of the study.

Published works were classified in one of the 11 main themes (Feeding, Anatomy and Morphology, Behavior, Conservation, Distribution, Ecology, Diseases and Parasitism, Physiology, Miscellaneous, Reproduction, Taxonomy and Phylogeny; Table 1), following the proposal of Guevara-Chumacero et al. (2001). The 11 themes in this proposal contain 100 biological topics as used by Carleton et al. (1993). Ethnozoology was incorporated into the Miscellaneous category. Publications were grouped according to the state of México where each study was conducted. Author nationality (Mexican or foreign) was assigned considering the first author of each publication.

A database of records of occurrence of *T. bairdii* in México was built in Excel based on data from the Global Biodiversity Information Facility (GBIF, <http://data.gbif.org>, accessed in June 2018); georeferences were reviewed and validated through geographic information. This information was mapped using the software ArcView 3.2.

Table 1. Topics included in this study. From Guevara-Chumacero et al. (2001).

Main topics	Topics used by Carleton et al. (1993)
Feeding	Diet, digestion, feeding habits, and nutrition.
Anatomy and Morphology	Determination of age, allometry, dentition, growth changes locomotion, molting, morphometry, sexual dimorphism size, weight.
Behavior	Activity, communication, territoriality, movement, shelters, pheromones, odor marks, social structure, vocalization.
Conservation	Cinegetic species, endangered, threatened, rare, hunting, status.
Distribution	Biogeography, zoogeography, ecogeography.
Ecology	Activity patterns, population censuses, demography, density, dispersal, habitat, home range, territoriality, migration, mortality, photoperiod, Predation, radiotelemetry, sex ratio.
Diseases and Parasitism	Parasites, injuries, pathology.
Physiology	Development, energy, function, immunology, metabolism, thermoregulation, hibernation, torpor.
Miscellaneous	Longevity, histology, orientation, echolocation, synopsis of works in congresses, ethnozoology.
Reproduction	Breeding, gestation, lactation, reproductive patterns, litter size, parturition, sexual maturity.
Taxonomy and Phylogeny	Chromosomes, cladistics, classification, cytogenetics, description, electrophoresis, evolution, fossils, genetics, geographic variation, heterozygosis, hybridization, karyotype, systematics.

Results

A total of 136 works on *T. bairdii* were recorded for Mexico, published between 1865 and 2018 (Appendix I). A low productivity was observed between 1865 and 1994, with just 15 scientific articles (Figure 1). From 1995, scientific production increased, peaking between 2010-2018. Of the total number of publications, 111 (81.6 %) were conducted by Mexican scientists and 25 (18.4 %) by foreigners. In the period of low productivity for the species (1865-1994), Mexican and foreign researchers contributed to the same extent. However, between 1995 and 2018, the ratio between Mexican and foreign authors was 5:1.

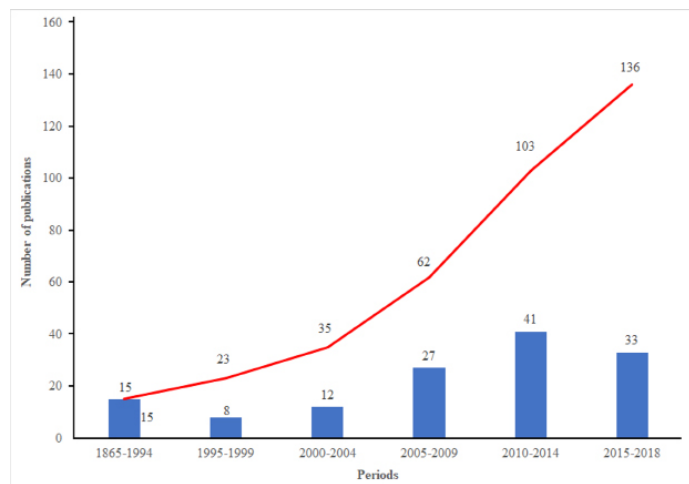


Figure 1. Number of publications on *Tapirella bairdii* in México between the years 1865-2018. Blue bars represent the number of publications per five year-intervals, while the red line marks the cumulative number of publications.

Articles on *T. bairdii* were published in 54 different journals, 43 foreign (53.3 %) and 11 Mexican journals (46.6 %). Although articles were published in a greater diversity of foreign journals, the 3 with the highest number of publications were Mexican journals (*Acta Zoológica Mexicana*, *Revista Mexicana de Biodiversidad*, and *Revista Mexicana de Mastozoología*). The most important national and foreign journals in terms of the number of studies published on the tapir in México are shown in Table 2. Seventy-three percent of the works were conducted in three states: Chiapas (32.4 %), Oaxaca (21.8 %), and Campeche (18.8 %). The states with the lowest number of studies were Tabasco (2.3 %) and Guerrero (1.2 %; Figure 2a).

Table 2. List of the main Mexican and foreign journals based on the number of articles published. Number of publications (NP)

Mexican journals			Foreign journals		
	NP	%		NP	%
1. <i>Acta Zoológica Mexicana</i>	16	11.8 %	1. <i>Tapir Conservation</i>	8	5.9 %
2. <i>Revista Mexicana de Biodiversidad</i>	13	9.6 %	2. <i>Revista de Biología Tropical</i>	5	3.7 %
3. <i>Revista Mexicana de Mastozoología</i>	12	8.8 %	3. <i>Tropical Conservation Science</i>	5	3.7 %
4. <i>Therya</i>	8	5.9 %	4. <i>Conservation Biology</i>	3	2.2 %

The topics addressed more frequently were Ecology (29.9 %), Taxonomy and Phylogeny (20.4 %), and Distribution (15.3 %). Some subjects were either scarcely addressed,

including Feeding (1.5 %), Anatomy/Morphology (0.7 %), and Reproduction (0.7 %), or were not addressed as main themes (Physiology and Ethology; Table 3).

Table 3. Number of papers published according to the main topic. Main topic (MT); number of works (NW).

MT	NW (%)	MT	NW (%)
Ecology	41 (29.9 %)	Diseases and Parasitism	9 (6.6 %)
Taxonomy and Phylogeny	28 (20.4 %)	Feeding	2 (1.5 %)
Distribution	21 (15.3 %)	Anatomy and Morphology	1 (0.7 %)
Miscellaneous	20 (14.6 %)	Reproduction	1 (0.7 %)
Conservation	14 (10.2 %)	Behavior	□
		Physiology	□

For the period 1884-2018, 233 records of occurrence of *T. bairdii* in México were obtained from the GBIF, corresponding to seven states (Oaxaca, Veracruz, Campeche, Tabasco, Chiapas, Yucatan, and Quintana Roo). Of these, 126 (54.5 %) records were observations, 59 (25.1 %) are of unknown origin, and 48 (20.4 %) were collections. Chiapas is the state with the largest number of records (106; 45.5 %), followed by Campeche (34; 14.6 %), and Oaxaca (31; 13.3 %), while Yucatan and Tabasco each reported two occurrence records.

Discussion

This study is the first work that compiles and assesses the current knowledge on *Tapirella bairdii*, a species that had been scarcely studied in México since its description (Gill 1865) to 1995, with just 15 scientific works published. Prior to the 20th century and following its description, the early studies where the tapir was mentioned were species listings for Tabasco, Oaxaca, and Chiapas, the aim of which was to record the local distribution of the fauna (Sumichrast 1881; Roviroso 1885). In the period 1890-1949, the absence of works for this species was evident; only Alvarado (1915) mentioned the tapir in his work entitled "Sinonimia vulgar y científica de los mamíferos mexicanos" (Common and Scientific Synonymy of Mexican Mammals). After 1950 and until the decade of 1970, most of the studies published ($n = 7$) referring to *T. bairdii* were also taxonomic or distribution listings of mammals. The exception was the study by Álvarez del Toro (1966) that provided data about tapir breeding in the Tuxtla Gutiérrez Zoo, including observations on various reproductive aspects of the tapir in captivity. In the decade of 1980, two works that mentioned the tapir were published: Sánchez-Herrera (1986) included the tapir in the list of new records of mammals for Quintana Roo, and March (1987) mentions the tapir as one of the animals traditionally hunted and consumed as bushmeat by Mayan Lacandons in the state of Chiapas.

More than 88 % of the articles about this species were published in the period 1995-2018, with 2010 to 2018 as the most productive years, concentrating over 55 % of research articles (Figure 1). This productivity pattern can be attributed to various factors including the formation of

new Mexican researchers that completed post-graduate programs in México and abroad, plus an increase in communications about the importance of the tapir in Mexico. An additional factor is the increased financing of research projects and the boost in economic, scientific, and technological development, consistent with the trends observed by [Ramírez-Pulido et al. \(2017b\)](#) in their analysis of the bibliographic synthesis of the Mexican mammalogy.

The most remarkable increase in the number of published works on the tapir started in 1995, mainly in foreign journals, although not synchronized with the overall pattern for the mammals of Mexico, for which the greatest increase took place from the 1950s ([Guevara-Chumacero et al. 2001](#)). This lack of synchrony may be due to the historical difficulties that are intrinsic to the study of the tapir in its natural habitat, including low population densities, evasive behavior, and presence restricted to remote and inaccessible areas ([Matola et al. 1997](#)). It is until recent decades that new observation, population quantification and sampling techniques have emerged ([Silveira et al. 2003](#); [Lyra-Jorge et al. 2008](#); [Tobler et al. 2008](#)).

The increase in the number of studies about the tapir in recent decades is also explained by the larger number of specialists and the diversity of projects in institutions such as the Universidad Nacional Autónoma de México (National Autonomous University of Mexico), the Center for Tropical Research at the Universidad Veracruzana, El Colegio de la Frontera Sur, the Africam Safari Zoo, Universidad McGill, the Miguel Álvarez del Toro Zoo, the DGPA Environmental Consultancy, and the Protected Natural Area (NPA) National Commission ([Mendoza-Ramírez and Carbajal-Borges 2011](#)).

In recent years, the knowledge about the tapir has focused on three main topics: ecology, taxonomy and phylogeny, and distribution. Investigations on ecology have been a priority in the generation of knowledge, involving a broad range of subjects such as density (e.g., [Botello et al. 2014](#)), population activity patterns and habitat preference (e.g., [Lira-Torres et al. 2014](#)), and ecological role in seed dispersal (e.g., [O'Farrill et al. 2013](#)), among others. However, the main topic addressed has been the relative abundance of the species (e.g., [Carrillo-Reyna et al. 2015a](#); [Naranjo et al. 2015](#); [Pérez-Irineo and Santos 2016](#); [Sandoval et al. 2016](#)), which is essential for the development of proper management plans. Photo-trapping is a valuable tool that has played a fundamental role in the conduct of these studies in recent decades, reducing the time and effort of observers in the field ([Carbajal-Borges et al. 2014](#); [Carrillo-Reyna et al. 2015a](#); [Mandujado 2019](#)).

The studies with a focus on taxonomy and phylogeny include updated listings of mammals at national and state levels (e.g., [Ceballos and Arroyo-Cabrales 2012](#); [Guzmán-Soriano et al. 2013](#); [Rivero and Medellín 2015](#)).

A key taxonomic aspect for this species was the proposal to change the generic name (*Tapirus bairdii*) to *Tapirella*. The genus *Tapirus* was proposed by [Brünnich \(1772\)](#),

while *Tapirella* was a new generic name assigned by [Palmer \(1903\)](#) to replace the name *Elasmognathus* coined by [Gill \(1865\)](#) to name a new genus of the family Tapiridae based on two skulls found in the Isthmus of Panama showing morphological differences with specimens from South America (named *Elasmognathus bairdii*). However, this name was changed because the latter generic name had already been used in the order Hemiptera of the class Insecta ([Fieber 1844](#)). The generic name *Tapirella bairdii* was recovered by [Groves and Grubb \(2011\)](#), who reviewed the taxonomic relationships of the Perissodactyla and Artiodactyla based on morphological, cytogenetic, and molecular traits.

Information on karyotypes has been produced for other tapir species or geographic areas (*Tapirus terrestris*; [Aguilera and Expósito 2009](#)), as well as for phylogenetic relationships (South America; [Holanda and Ferrero 2013](#)); no such information is currently available for populations in Mexico. [Zavala-Páramo et al. \(2017\)](#) identified a relatively high genetic diversity in populations of southeast Mexico, through the use of microsatellites and the mitochondrial control region; however, most samples were taken from captive individuals in zoos related to wild populations in Mexico. These authors highlight the need to conduct a study across the entire distribution range in Mexico, to identify critical conservation aspects and set the basis for a proper management plan suitable for the species.

Investigations on distribution have focused on recording new locations (e.g., [Sánchez-Herrera et al. 1986](#); [Peña-Azcona et al. 2015](#)) and, recently, on the application of models to determine its potential distribution (e.g., [Carrillo-Reyna et al. 2015a](#); [Schank et al. 2015](#); [Schank et al. 2017](#)). It is essential to continue using camera-traps in locations with documented records through fingerprints, skeletal remains, fur, or direct observations of tapir individuals, to provide evidence about the species in new geographic regions (e.g., [Lira-Torres and Briones-Salas 2011](#); [Lavariega et al. 2013](#)), and where assessments of the abundance and density would be required subsequently.

The states with the largest number of records of occurrence and where most of the studies have been conducted are Chiapas, Oaxaca, and Campeche, the NPAs of which show the highest population abundances estimated for the species ([Naranjo et al. 2015](#)). Yucatan, Tabasco, and Guerrero produced low or zero records of occurrence and turned out to be the least studied states (Figure 2b). Historically, the tapir had a continuous distribution throughout southeast Mexico; however, in recent years, the presence of this species in Yucatan and Tabasco is uncertain ([Naranjo et al. 2015](#)). In the particular case of Guerrero, no records of occurrence are available and only one study includes eight historical records, collected by J. A. Sutter in 1873 in Acapulco ([Nolasco et al. 2007](#)); this finding supported an extension of the historical distribution of the tapir in the Pacific slope in Mexico.

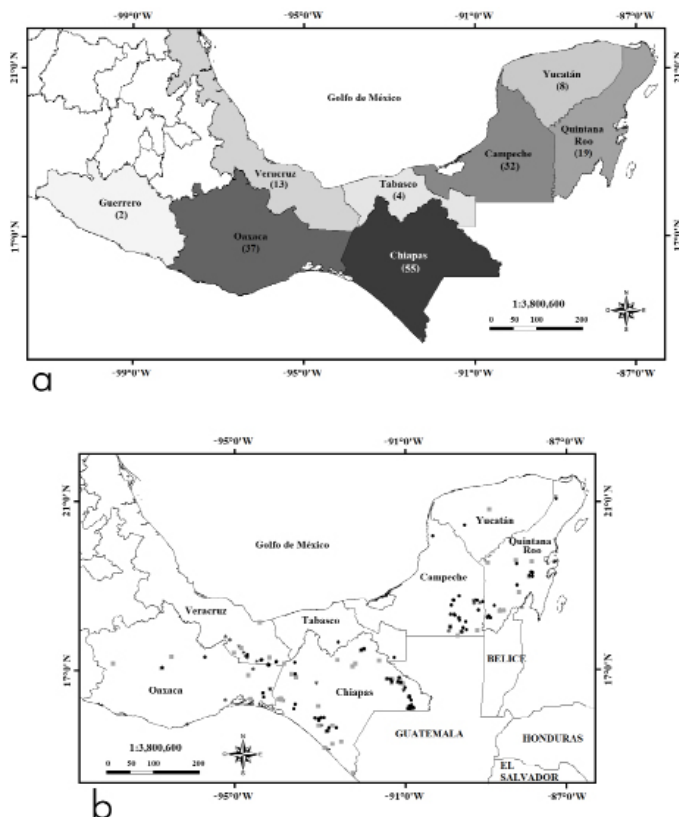


Figure 2. a) Map of the number of published works by state of Mexico. b) Map of records of occurrence of *Tapirella bairdii* in Mexico; black circles mark observed records observed; asterisks, collection records; gray boxes, unconfirmed records.

The importance of the Central American tapir for rural communities of southeastern México has been reflected in the publication of several studies on ethnozoology (13.2 % of the total), showing that the species is hunted for food by different communities in Oaxaca, Chiapas, Campeche, and Quintana Roo (Contreras-Díaz and Pérez-Lustre 2008; Barrasa 2013; Lira-Torres et al. 2014). Occasional hunting in a few ejidos in Quintana Roo has also been documented (Reyna-Hurtado and Tanner 2005; Ramírez-Barajas and Naranjo 2007; Santos-Fita et al. 2012): this activity has been ruled out definitely because tapirs are usually difficult to locate (Jorgenson 1995). In the Lacandon town of Métabok in Chiapas, tapir hunting has been ruled out, as there have been no sightings in 15 years (Rodas-Trejo et al. 2016).

Zoarchaeological studies indicate that tapir consumption for food was a common practice among the Mayas in the Postclassic period in Yucatan; besides, tapir teeth may have been used as merchandise (Masson and Peraza Lope 2008). A study with strontium isotopes supports the hypothesis that the ancient Mayas traded body parts of the tapir (Kennedy-Thornton 2011).

In the most productive research period on the tapir, several themes have been poorly addressed, if at all. An illustrative example is parasitism. The presence of different genera of nematodes, protozoa, mites (Cruz-Aldán et al. 2006; Guzmán-Cornejo et al. 2006, 2011; Güiris-Andrade et al. 2009, 2018), and bacteria (Güiris-Andrade et al. 2007) has been reported. It is essential to continue exploring various

aspects, as the tapir is susceptible not only to diseases such as enteritis and tuberculosis (Cubas 1996) but also to infectious diseases such as equine infectious anemia from the horse (Cruz-Aldán et al. 2006; Lepe-López et al. 2018). Only one study addressing the anatomy/morphology of the tapir has been published. The aim was to provide a tool to evaluate the body condition of wild tapirs from the comparison of individuals captured by camera-traps versus morphometric measurements and images of anatomical regions of captive tapirs (Pérez-Flores et al. 2016). Dumbá et al. (2018) support the hypothesis of interspecific variation for different species of living and extinct tapirs using geometric morphometry. Further analyses of intraspecific geometric morphometrics are needed for *T. bairdii*, involving sampling across its geographic range; this information will contribute to advance our knowledge about the evolutionary processes in the tapir. In addition, the possibility of phenotypic variations cannot be ruled out, as is the case of other mammals (Mor-teo et al. 2017; García-Mendoza et al. 2018).

Our survey did not find studies addressing ethological or physiological aspects as main research subjects, although behavioral data have been reported as secondary topics. For instance, in the Calakmul Biosphere Reserve, Reyna-Hurtado et al. (2016), have reported home-range size estimates from the monitoring of movement patterns of one tapir for over four and a half years; a maximum dispersal distance of 10.5 km and home-range areas from 4 to 24 km² have been estimated, which are larger than those reported in previous studies (e. g., Foerster and Vaughan 2002). Sandoval et al. (2016), estimated the relative abundance of this species and evaluated the frequency of use of *aguadas* (water bodies formed by rain), concluding that these play a key role to determine the presence and abundance of the tapir in the Calakmul region. On the other hand, it is worth noting that there are no published studies on road-killed tapirs in México (Carrillo-Reyna et al. 2015b), and assessing whether it represents a new threat to the species is important, as is the case in Belize (Poot and Cleverger 2018).

The scarce or nil productivity in these areas can be explained by the low number of specialists in these academic fields and has been a general issue in scientific research of mammals (Guevara-Chumacero et al. 2001). In addition to the population decline of the tapir (Naranjo 2009; Naranjo et al. 2015), its elusive behavior with nocturnal and crepuscular habits, thriving in areas of difficult access (Naranjo and Cruz-Aldán 1998; Lira-Torres and Briones-Salas 2012) have been factors restraining its monitoring, tracking, and capture in the field.

The articles on conservation reviewed conclude that the main human activities with a negative effect on tapir populations are hunting, habitat loss, increasing human density, and extensive livestock (e.g., Escamilla et al. 2000; Naranjo and Bodmer 2007; Urquiza-Hass et al. 2009; Lira-Torres and Briones-Salas 2011). According to the findings reported by Mendoza et al. (2013), the Mesoamerican Biological Corridor, which runs from southeast México (Campeche, Chi-

apas, Quintana Roo, Yucatan, and Tabasco) to Panama, may potentially play a prominent role in the conservation of the tapir habitat; however, there is an urgent need to implement management plans that reinforce and complement this conservation initiative. Another area also requiring special attention is Selva de Zoque (that stretches from the Sierra Atravesada in Oaxaca to the Sierra Madre de Chiapas), which is home to one of the largest populations of *T. bairdii* in Mesoamerica; however, this could be in danger of local extinction if indiscriminate hunting continues (Lira-Torres *et al.* 2012). The existence of corridors to enable the connectivity between populations of tapirs, like those in the Sierra Madre de Chiapas (De la Torre *et al.* 2018), are essential elements in the conservation strategies for the species. Innovative species distribution models have been recently used for assessing the distribution and conservation status of the tapir throughout its range in the continent (*e. g.*, Schank *et al.* 2017). In the near future, these models will surely involve mobility patterns that will produce increasingly accurate results, necessary for improved conservation management aimed at reducing the loss of species in ecosystems.

The tapir is listed in the NOM-059-SEMARNAT-2010 as “endangered of extinction”, being a priority species for conservation (SEMARNAT 2010). The states of Chiapas, Oaxaca, Campeche, and Quintana Roo are the main reservoirs of tapir populations (Schank *et al.* 2015); this geographic region is critical to protect the species since it concentrates nearly 50 % of the total population worldwide (Naranjo 2009). It is essential to continue conducting long-term monitoring in this region, such as the one carried out in the Calakmul Biosphere Reserve, Campeche, which recorded the presence of the tapir in 14 *aguadas* between the years 2008–2010, involving a sampling effort of 3,470 trap-days, and recording 37.57 individuals/1,000 trap-nights (Pérez-Cortez *et al.* 2012).

It has been shown that Protected Areas are effective tools for the conservation of the tapir at regional and local levels (Porrás-Murillo *et al.* 2011), as these were addressed in 43.0 % of the studies. Nonetheless, future planning and development of research projects should also include sites where the status of the species remains unknown, or areas where its current presence is uncertain (Veracruz, Tabasco, and Yucatan).

Another key strategy for the conservation of the tapir involves agreements with local communities. In this sense, an agreement was recently signed by 14 communities in Reserva La Frailescana, in the Sierra Madre de Chiapas, that prohibited tapir poaching in this area (De la Torre *et al.* 2018), which will surely contribute to conserving the species in the region.

The most important foreign journals in terms of number of published articles were Tapir Conservation ($n = 8$), Revista de Biología Tropical ($n = 5$), Tropical Conservation Science ($n = 5$), and Conservation Biology ($n = 3$). Most of these journals focus on conservation; the treatment of this topic as a priority is encouraging, given the current threatened status of the tapir (ranking 34 in priority for conservation among more than 4,000 species of mammals, according to the Zoological Society of London – Isaac *et al.*

2007). The preservation of Natural Protected Areas and the Mesoamerican Biological Corridor, together with the conservation of unprotected natural areas that harbor tapir populations, should be considered in conservation programs; in addition, improving the connectivity between these regions is a top priority for ensuring the preservation of tapir habitats in the country.

The information generated to date is essential to develop alternatives for improving the management of the habitat and natural populations of this valuable species. The conservation of the tapir requires awareness raising in rural populations, avoiding poaching and uncontrolled logging to the extent possible, as these factors continue impacting the population size of tapirs. Also evident is the need to increase the number of studies on disease and parasitism, and fill the current information gaps on basic aspects of the biology of the tapir, including physiology, genetics, anatomy, reproduction, and evolutionary history. The formation of a collaboration network and the continued generation of information on this species are essential in order to advance the objectives of the Program of Actions for Conservation (Cruz-Aldán *et al.* 2009), which in general terms aims to achieve the conservation and management of this emblematic species in Mexico.

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Appendix I

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