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Research Article

Ecology and Conservation of Baird's tapir in Mexico

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ABSTRACT
Baird's tapir (*Tapirus bairdii*) is endangered primarily because of habitat loss and fragmentation, and overhunting throughout its distribution range (ca. 21,000 km^2) in the Mexican states of Campeche, Chiapas, Quintana Roo, Oaxaca, Veracruz, and possibly Yucatan and Tabasco. The number of tapirs occurring in Mexico is estimated around 2,600 individuals, which are also threatened by factors such as forest fires, large-scale infrastructure projects (building of dams and highways), disease transmission from domestic animals, pollution of water bodies, and global climatic change effects. A strategy for tapir conservation in Mexico should include: 1) protection and management of extant habitat; 2) creation and maintaining of corridors among isolated forest fragments containing tapirs; 3) community-based control of poaching; 4) development of economic alternatives for people living near tapir habitat; 5) captive breeding programs with educational, scientific, and conservationist purposes; 6) environmental education and communication programs in rural and urban areas near tapir habitat; and 7) research on distribution, abundance, habitat use and availability, population status, movement patterns, feeding habits, genetic variability, interactions with domestic species, diseases, and responses to habitat fragmentation, hunting, and global climatic change.
Key words: population status, research needs, *Tapirus bairdii*, threats.

RESUMEN
El tapir (*Tapirus bairdii*) está en peligro de extinción debido principalmente a la pérdida y fragmentación de su hábitat, y a la cacería sin control en su área de distribución en México (ca. 21,000 km^2) en los estados de Campeche, Chiapas, Quintana Roo, Oaxaca, Veracruz, y posiblemente Yucatán y Tabasco. Las poblaciones mexicanas de tapires se estiman en alrededor de 2600 individuos, que están en riesgo por los incendios forestales, grandes obras de infraestructura (presas hidroeléctricas y autopistas), transmisión de enfermedades de animales domésticos, contaminación de cuerpos de agua, y efectos del cambio climático global. Una estrategia nacional para conservar a esta especie debe incluir: 1) protección y manejo del hábitat remanente; 2) creación y mantenimiento de corredores entre poblaciones aisladas; 3) control comunitario de la cacería; 4) desarrollo de alternativas económicas en áreas de distribución; 5) programas de reproducción en cautiverio con fines educativos, científicos y conservacionistas; 6) programas de educación y comunicación ambiental en áreas rurales y urbanas cercanas al hábitat del tapir; y 7) investigación sobre distribución, abundancia, uso y disponibilidad de hábitat, estado de las poblaciones, patrones de movimiento, hábitos alimentarios, variabilidad genética, interacciones con especies domésticas, enfermedades y respuestas a la fragmentación del hábitat, cacería y cambio climático global.

Palabras clave: amenazas, estado poblacional, necesidades de investigación, *Tapirus bairdii*.

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Introduction

Baird's tapir (*Tapirus bairdii*),also known as Central American or Mesoamerican tapir, is the largest terrestrial native mammal in the Neotropics. This species is globally endangered because of habitat loss and overhunting throughout most of its distribution range [1, 2]. Most Baird's tapir populations have not been quantified and monitored yet. However, it is very likely that numbers are declining everywhere as a result of high deforestation rates, forest fragmentation, and illegal hunting [3, 4]. Tapirs play an important role in the dynamics of tropical ecosystems through the processes of herbivory, seed dispersal, and seed predation [5-8]. In addition, these mammals have been used for a long time as a food source by many ethnic groups in Mesoamerica [9, 10].

Baird's tapirs tend to be solitary and may be active both at night and during the day; however, they become almost completely nocturnal when heavy hunting pressure is present [11]. The primary predators for tapirs are humans, jaguars, pumas, and large crocodiles [9, 12, 13]. Females are able to mate when they are 3-4 years old, and their gestation period lasts about 13 months [14]. Minimum periods between litters are 17 months, and the single young born stays with its mother for about a year [12, 15].

Compared to other Neotropical mammals, tapirs have been little studied in the wild, largely because of their low densities and their secretive behavior. Although we still do not know many aspects of Baird's tapir ecology and behavior, a number of studies conducted in Central America and Mexico provide a reasonable amount of information on this matter. This work presents a review of the most remarkable results from those studies, as well as a series of recommendations and information needs for tapir conservation in Mexico.

Methods

Between 1992 and 2007, available articles, books, theses, reports, and unpublished documents containing information on Baird's tapir ecology and conservation were compiled and reviewed by the author in institutions of Costa Rica (Instituto Nacional de Biodiversidad and Universidad Nacional), Mexico (El Colegio de la Frontera Sur and Universidad Nacional Autonoma de Mexico), and the United States (University of Florida and Colorado State University). Complementary information was obtained through searches in the internet, and through discussions with members of the IUCN's Tapir Specialist Group during international symposia held in Central and South America since 2001. Unpublished field data generated by the author and his collaborators in southeastern Mexico since 1994 were also integrated in this review. Population densities were estimated through distance sampling (Buckland et al. 1993 [16]; Thomas et al. 2005 [17]), in which tapirs sightings

were recorded along more than 2000 km of line transects of variable width and length in both protected and unprotected areas of southern Mexico (see Naranjo and Bodmer [18] for a detailed description). Tapir population size estimates were obtained through extrapolation using conservative densities and habitat extension remaining in Mexico [3, 19; E.J. Naranjo, unpublished data]. Habitat extension was estimated from recent satellite images available in Google Earth 4.3 (http://earth.google.com), measuring compact forest tracts remaining in areas with verified tapir presence.

Results and Discussion

Distribution

Baird's tapir distribution in Mexico is restricted to extensive tropical and montane forests remaining in the states of Campeche, Chiapas, Oaxaca, Quintana Roo, Veracruz, and possibly Tabasco and Yucatan, at altitudes between 0 and 2000 m [9]. The areas with verified tapir presence are: Calakmul, Balam-Ku and Balam Kin Reserves, and eastern Campeche; Sian Ka'an Biosphere Reserve, central and southern Quintana Roo; El Ocote, El Triunfo, La Sepultura, Lacantún, and Montes Azules Reserves, Lacandon Forest and Sierra Madre, Chiapas; Uxpanapa, Veracruz; Chimalapas, Chacahua National Park, Sierra Veinte Cerros, and Sierra Mixe, Oaxaca [9, 11, 20, 21; Fig. 1].

Fig. 1. Current verified distribution of Baird's tapir (*Tapirus bairdii*) in Mexico. Map based on Lira and Naranjo [20], March and Naranjo [9], and Naranjo and Bolaños [57]. Historic distribution included all tropical, subtropical, and cloud forests of southern Mexico and Central America [22, 23].

Baird's tapir virtually had a continuous distribution from southeastern Mexico to northwestern Colombia, ranging from coastal forests and wetlands at sea level through montane forests and paramos above 3600 m [22, 23]. High rates of deforestation and habitat fragmentation in Mesoamerica have restricted current tapir distribution to mostly protected and/or remote areas in all countries, except El Salvador, where it has disappeared [4]. In Mexico, basically all areas with tapir presence have at least 100 km^2 of habitat in good condition. However, there is no guarantee that any of them is large enough to maintain a viable tapir population in the long term (>1000 individuals *sensu* Traill et al. [24]). The areas with highest potential to shelter large populations are: Calakmul-Balam Ku-Balam Kin in Campeche; Sian Ka'an-central Quintana Roo; Montes Azules-Lacantún in Chiapas; and Chimalapas in Oaxaca. Although there are no recent records, the existence of small and isolated tapir populations is possible in Pantanos de Centla Biosphere Reserve and Tabasco's border with Guatemala. Other potential sites for tapir presence that should be verified are the remaining large forest fragments along the western coast of Oaxaca and eastern coast of Guerrero, Los Petenes and Laguna de Terminos coastal forests in Campeche, the southern tip of Yucatan, and the Yum Balam and El Eden Reserves in northern Quintana Roo.

Abundance and Population Size

A very few estimates of Baird's tapir abundance are available (Table 1). In Mexico, only three published studies provide such estimates: Naranjo and Cruz [11] did line transect sampling in La Sepultura Biosphere Reserve, Chiapas, calculating tapir abundance indices of 0.24 tracks and 0.38 fecal groups per kilometer traveled. Using similar sampling techniques, Lira et al. [25] estimated a density of 0.07 tapirs/km^2, as well as indices of abundance of 0.67 tracks and 0.25 fecal groups per 100 kilometers traveled. Naranjo and Bodmer [3] reported densities of 0.24 ± 0.09 tapirs/km^2 and 0.05 ± 0.04 tapirs/km^2 in slightly hunted sites (Montes Azules Biosphere Reserve, MABR) and persistently hunted sites (communities adjacent to MABR) of the Lacandon Forest, Chiapas. The same authors also estimated indices of abundance of 1.07 and 0.5 tapir tracks per 100 kilometers traveled. If conservative densities between 0.5 and 0.20 tapirs/km^2 depending on habitat quality are extrapolated to areas of available habitat for tapirs in Mexico (around 21,000 km^2, including areas with different levels of hunting pressure; E.J. Naranjo, unpublished data), then it is reasonable to expect a population size of about 2,600 individuals in the country (Table 2). Based on these conservative estimates, the largest local tapir populations in Mexico would be: Calakmul-Balam-Ku-Balam Kin (N=800); MABR-Lacantún (N=600); Sian Ka'an-central Quintana Roo (N=450); and Chimalapas (N=450; Table 2). Considering Traill et al.'s [24] criteria, none of these populations would be viable in the long term by itself. Nevertheless, they still have some degree of connectivity with other areas where tapirs exist (i.e., the corridors Calakmul-Sian Ka'an, Chimalapas-Uxpanapa-El Ocote, and Montes Azules-Sierra del Lacandon, Guatemala) which increases their survival probabilities.

Reliable estimates of Baird's tapir density are indeed very hard to obtain because of the difficulties in observing this species in the field [11]. Although such estimates have been obtained through different calculation methods from line transect sampling or radiotelemetry data, all of them indicate low densities ranging between 0.05 and 1.6 tapirs/km^2 (Table 1). These values concur with densities obtained for the lowland tapir (*Tapirus terrestris*) in South America [26, 27]. As said earlier, it is clear these densities imply that only a few large reserves in Mexico and Mesoamerica might shelter viable tapir populations. As shown in Table 1, tapir density and abundance may vary among localities. These variations may rely on factors such as topography, moisture, dominant vegetation

type, food and water availability, presence of domestic animals, and human activity, among others.

Table 1. Estimates of Baird's tapir (*Tapirus bairdii*) densities and indices of abundance in southern Mexico and Central America. Densities are given in numbers of individuals (ind) per squared kilometer.

Location	Method	Estimated Abundance / Density	Authors
Barro Colorado Island, Panama	Direct sightings	0.53 tapirs/km^2	Glanz [62]
Santa Rosa National Park, Costa Rica	Home range estimates	0.21 tapirs/km^2	Williams [41]
Chiquibul Forest, Belize	Direct sightings	0.10 tapirs/km^2	Fragoso [29]
Corcovado National Park, Costa Rica	Direct sightings Track counts	0.60 tapirs/km^2 0.66 tracks/km	Naranjo [32]
Corcovado National Park, Costa Rica	Home range estimates	1.6 tapirs/km^2	Foerster [31]
La Sepultura Biosphere Reserve, Mexico	Track counts Fecal counts	0.24 tracks/km 0.38 fecal groups/km	Naranjo and Cruz [11]
La Sepultura Biosphere Reserve, Mexico	Direct sightings Track counts Fecal counts	0.20 ± 0.24 tapirs/km^2 1.37 tracks/km 0.75 fecal groups/km	Cruz [42]
Northeastern Honduras	Track counts	0.15 tracks/km	Flesher [52]
El Triunfo Biosphere Reserve, Mexico	Direct sightings Track counts Fecal counts	0.07 ± 0.03 tapirs/km^2 0.67 tracks/km 0.25 fecal groups/km	Lira et al. [25]
Lacandon Forest (slightly hunted sites), México	Direct sightings Track counts	0.24 ± 0.09 tapirs/km^2 1.07 tracks/100km	Naranjo and Bodmer [3]
Lacandon Forest (persistently hunted sites), México	Direct sightings Track counts	0.05 ± 0.04 tapirs/km^2 0.50 tracks/100km	Naranjo and Bodmer [3]

Habitat Preferences

From track and feces counts carried out at El Triunfo and La Sepultura Biosphere Reserves, Lira et al. [25] as well as Naranjo and Cruz [11] concluded that tapirs preferred densely forested areas with permanent streams and ponds (tropical subdeciduous forest and montane cloud forest), rather than drier, opener, and more disturbed habitats (pine forests and grasslands). In the Lacandon Forest, Muench [28] found that tapirs preferred palm swamps, riparian forest, and successional vegetation (caused by natural disturbance) over mature rainforest and open areas. In fact, available field data on habitat preferences suggest that Baird's tapir prefers habitat types which have: (1) greater availability of permanent water bodies; (2) a more diverse and dense understory (which implies more food); (3) larger extensions of riparian vegetation; (4) less incidence of fires; and (5) less hunting pressure and human presence [11, 28-33] (Fig. 2). It is interesting to note that in La Sepultura Reserve, a significant number of tapir feces were found along narrow oak-forest strips covering the top of medium-altitude mountains [11]. This suggests that oak-forest strips are used by tapirs as both marking sites and corridors between different habitat types, in a similar manner that small creeks seem to be used in MABR, and in Corcovado National Park (CNP), Costa Rica [18, 32].

Fragoso [30] observed tapirs only in logged forests and floodplains, but not in unlogged and sapling forests in the Chiquibul Reserve of Belize. He explained this behavior by considering the greater abundance of food plants for tapirs in the first two habitat types. Similarly, tapir evidences were more abundant in lowland, second-growth forests and *Raphia taedigera* or *Bactris* sp. palm swamps than in drier, higher areas in both CNP and MABR [18, 28, 32, 34]. These results were also attributed to more abundant and better quality food and water sources, as well as more appropriate resting sites and gentler slopes in preferred habitats. In addition, tapir signs observed in CNP were positively correlated with distance from perennial water bodies and rain intensity, while there was a negative correlation between signs and slope steepness. It has to be noted that gentler slopes imply both better conditions for observing tracks and greater numbers of ponds and other water bodies, where tapirs get relief from both high temperatures and parasites. Hunting and other human activities may be discarded as factors influencing these results, since they are under control by park guards at CNP [32].

Table 2. Estimated sizes and threats of Baird's tapir (*Tapirus bairdii*) populations known in Mexico. Areas were estimated from recent satellite images available in Google Earth 4.3 (http://earth.google.com/), measuring compact forest tracts remaining in areas with verified tapir presence.

Region	Estimated tapir habitat (km^2)	Habitat quality[a]	Expected density[b] (n/km^2)	Estimated population size[c] (N)	Main threats[d]
Calakmul (Campeche)	8,000	medium	0.10	800	1, 2, 3, 5, 6, 7
Quintana Roo forests (Quintana Roo)	4,500	medium	0.10	450	1, 2, 3, 5, 6, 7
Lacandon Forest (Chiapas)	3,000	high	0.20	600	1, 2, 3, 4, 8
Los Chimalapas (Oaxaca)	3,000	medium /high	0.15	450	1, 2, 3, 8
Sierra Madre (Chiapas)	1,500	medium /high	0.15	225	1, 2, 3, 4, 7
El Ocote (Chiapas)	≤ 300	low	0.05	≤ 15	1, 2, 3
Sierra de Juarez (Oaxaca)	≤ 300	low	0.05	≤ 15	1, 2, 3
Uxpanapa (Veracruz)	≤ 200	medium /high	0.15	≤ 30	1, 2, 3, 4
Chacahua (Oaxaca)	≤ 200	medium	0.10	≤ 20	1, 2, 3, 8
Total	21,000			2,605	

[a] Habitat quality assessed by considering dominant vegetation types, water availability, and threats present in the area.
[b] Densities based on available estimates for Mexico (see Table 1), as well as habitat quality.
[c] Population sizes obtained by multiplying available habitat areas by expected tapir densities.
[d] Threats: 1=habitat loss/fragmentation, 2=poaching, 3=fires, 4=floods, 5=drought, 6=hurricanes, 7=road construction, 8=drug trafficking.

Baird's tapirs use different types of microhabitats within both the cloud forest and the paramo in the highlands of southern Central America. Tapirs have been observed in the Costa Rican paramo, particularly near ponds surrounded by dense bush of *Chusquea* sp. [22]. It is interesting to note that, lacking a dense hair cover like that of the Andean tapir (*T. pinchaque*), an extraordinarily thick skin and subcutaneous fat deposits probably help Baird's tapirs to resist the low temperatures prevailing in the paramos (down to -10º C). However, these ungulates seem to avoid the coldest season in the paramos of Chirripó National Park, Costa Rica by spending longer periods in neighboring cloud forest below 3,000 m (E.J. Naranjo, unpublished data).

An interesting aspect of habitat use by Baird's tapir relates to its defecation habits. Tapirs frequently defecate in shallow water bodies; however, they sometimes use particular sites on dry land, forming "latrines," where large concentrations of feces may be found [11, 35]. Ninety-four percent of 136 feces collected at CNP were located in permanent or seasonal water bodies, while only 6% were found on dry land. Most of observed defecation sites at both CNP and MABR were quiet, shallow pools along clear-water streams and rivers surrounded by dense vegetation [18, 36]. On the other hand, a significant proportion of all fecal samples observed in La Sepultura was found on dry land along mountain crests at 1,000-1,500 m high. These mountain crests are often covered by strips of oak forest, which are probably being used by tapirs as both marking sites and transit areas between tropical subdeciduous and montane cloud forest slopes [11].

Most tapir habitat in Mexico currently occurs within protected areas. However, it is unfortunate that good-quality tapir habitat remaining outside those areas is increasingly being transformed for human use because of its potential for agriculture, cattle grazing, and timber extraction. This is the case of large forest tracts, riparian vegetation, and water bodies (i.e., streams, rivers, and lagoons) in the surroundings of Biosphere Reserves such as Montes Azules, Lacantún, El Triunfo, La Sepultura, Selva El Ocote, Calakmul, and Sian Ka'an. Around these protected areas, loggers, farmers, and ranchers are taking every opportunity to get government subsidies promoting rural development and food production (i.e., PROGAN [37]), which by far surpass the budget devoted to environmental protection programs (i.e. PROARBOL [38]). In this sense, protected area managers should invest more time and resources in outreach and cooperation programs focused on avoiding further deforestation in neighboring communities.

Population Structure

The only available data on age structure for tapir populations in Mexico come from the study of Naranjo and Bodmer [18], who estimated proportions of adult (78.9%), juvenile (15.8%), and young (5.3%) individuals in the Lacandon Forest, Chiapas. These proportions appear normal given that age structure of slightly or non-hunted Baird's tapir populations generally have a large proportion of adults, while juveniles and young represent small fractions [39]. Proportions of adult, juvenile, and young tapirs were estimated at 88.5%, 3.8%, and 7.7% in CNP, respectively [32], which are not very different from the proportions estimated at MABR. The low numbers of juveniles and young do not seem to threaten tapir populations at MABR. This age structure may be explained by considering that: (a) Baird's tapir has a very low growth rate; (b) individuals are long-lived, up to 30 years; and (c) natural mortality rates tend to be very low in absence of human disturbance [4, 27].

Respecting Baird's tapir sex ratios, the only available estimation in Mexico comes again from Naranjo and Bodmer [18], who observed that female tapirs represented 57.1% of all

identified tapirs in MABR, while males constituted the remaining 42.9%. In fact, sex ratios of Baird's tapir populations do not seem to be significantly different from 1:1 everywhere. In CNP, Naranjo [32] reported that 13 out of 26 tapirs observed in his study were females (50%), while the remaining individuals were either males (42%), or unidentified young (8%). Using a different observation technique (*ad libitum*) in the Sirena area of CNP, Foerster [40] found slightly more males (58%) than females (42%).

In the near future, it will be important to generate information about the age structure and sex ratios of tapir populations in other areas of Mexico. Knowing these variables may help to detect habitat or population management needs for tapir conservation, especially in non-protected areas where hunting is persistent.

Fig. 2. Habitat, habits, and signs of Baird's tapir (*Tapirus bairdii*). A-C: tapirs in tropical rainforest of the Lacandon Forest, Chiapas. D: adult female tapir and her young in a waterhole of Calakmul, Campeche.

Home Range

Attempts to assess tapir home ranges in Mexico have not been very successful. A couple of females could be captured and radio-collared in MABR between 2000 and 2001, but only a few locations of one of them could be obtained during two months, indicating a home range of 0.67 km^2 [18]. Other estimates of Baird's tapir home ranges come from studies conducted by Williams [41] and Foerster [31], who observed individual areas of activity between 0.75 and 1.8 km^2 in CNP and Santa Rosa National Park, respectively. These home range variations may be due to differences in dominant vegetation types between CNP/MABR (tropical rainforest) and Santa Rosa (tropical dry forest), as well as a

considerably lower number of perennial water bodies in the latter [41]. Tapirs probably respond to the drier conditions of Santa Rosa by searching for appropriate water and food sources in a greater area.

Both Williams [41] and Foerster [31] found important variations among individual home ranges. The second author reported individual average travel distances from 379 to 720 m for nocturnal, 5- to 6-hour periods in CNP. Individual home ranges in the same area fluctuated between 0.62 and 2.32 km^2. Male tapirs showed somewhat larger but not statistically different average home ranges than females (1.60 and 1.02 km^2, respectively). Nevertheless, such home ranges were highly overlapped with those of both females and other males [31]. This pattern will have to be confirmed or rejected as more studies are conducted on *T. bairdii* in different study areas throughout its distribution range.

Feeding Habits

The information available on feeding habits of tapirs in Mexico comes from a few studies in which about 98 plant species of 50 families were recorded as consumed by this ungulate (Appendix 1). Naranjo and Cruz [11] compiled a list of over 40 plant species from 33 families consumed by tapirs in La Sepultura Reserve. This list was later expanded by Cruz [42] to about 68 species from al least 40 plant families. The best represented plant families in tapir feces collected in both studies were *Moraceae*, *Rubiaceae*, *Fabaceae*, *Asteraceae*, *and Solanaceae* [11, 42]. In the Lacandon Forest, Rivadeneyra [43] found at least 35 species from 22 plant families consumed by tapirs in MABR. The best represented families in tapir diet were *Solanaceae*, *Asteraceae*, and *Rubiaceae*. In this area, tapirs consume significant quantities of bark from trees such as *Vatairea lundelii* (Fig. 3) and vines like *Croton* spp., which often have visible marks of biting by these mammals (E.J. Naranjo, unpublished data; Appendix 1).

Tapirs are essentially browsers, spending up to 90% of their active hours on foraging. Baird's tapir selectively consumes a wide array of fruit, leaves, shoots, bark, and flowers [36, 41, 44-46]. Depending on the availability of food items, tapirs can shift their foraging strategy among habitat types and seasons. Plant species of the families *Moraceae*, *Rubiaceae*, *Arecaceae*, and *Euphorbiaceae* accounted for 33% of total plant species in tapir's diet in the lowland rainforest of CNP [36]. On the other hand, *Poaceae* (especially *Chusquea subtessellata*), *Asteraceae*, and *Ericaceae* seem to be the predominant plant families in the paramos of Chirripó National Park above 3,000 m high, Costa Rica [22].

The most noticeable changes in proportions of food items ingested by Baird's tapir throughout the year are those related to fruit consumption. Fruit usually constitutes a smaller proportion of tapir food than leaves and other fiber sources: Foerster [31], Naranjo [36], and Naranjo and Cruz [11] found average fruit proportions of 9.4%, 18.6%, and 7.1 % in tapir feces, respectively. Contrastingly, fruit only accounted for 1.4% and 2% of tapir feces analyzed in La Sepultura and MABR by Cruz [42] and Rivadeneyra [43], respectively. In spite of these small proportions found in tapir feces, it is very likely that fruits provide very important amounts of calories consumed by this ungulate, as shown by Bodmer [5] for the lowland tapir (*Tapirus terrestris*). This author found a considerably higher proportion of fruit (33%) in the diet of lowland tapirs in the Peruvian Amazon. He suggested that such a level of frugivory is maintained through an efficient exploitation of *Mauritia flexuosa* seeds. However, these voluminous seeds are chewed and spat but not ingested by tapirs. This pattern appears to be present in both CNP and MABR, where palm swamps composed primarily of *Raphia taedigera* and *Bactris balanoidea*, respectively, are regularly patrolled by tapirs and other ungulates (white-lipped peccaries in particular) in search of fruit. In both sites tapirs visit areas with abundant fallen fruits (i.e. *Brosimum alicastrum*, *Ficus*

spp., *Licania platypus*, *Manilkara zapota*, *Pouteria sapota*, and *Spondias mombin*), especially during the dry season [36, E.J. Naranjo, unpublished data]. Foerster [31] observed a higher proportion of fruit ingested by tapirs during the wet season in CNP. However, the same author asserts that this may be due to a very high intake of a single species (*Licania platypus*), which produces large amounts of fruit during a short period.

The role of tapirs in seed dispersal is far from being well understood. In Mexico, O'Farril et al. [47] demonstrated the importance of this mammal as disperser of *Manilkara zapota* seeds in Calakmul Biosphere Reserve, while Cruz [42] found high germination rates in seeds of *Acacia milleriana*, *Spondias mombin*, *Ficus* sp., and an unknown *Amarantaceae* collected from tapir feces in La Sepultura Reserve. Janzen [6, 45] found that, depending on the plant species, tapirs may be either seed dispersers or seed predators in the tropical dry forests of Costa Rica. Bodmer [48] and Fragoso et al. [49] discovered that lowland tapirs are efficient dispersers of palm species with large seeds, such as *Mauritia flexuosa* and *Maximiliana maripa*, which grow in extensive monospecific patches in Amazonia. According to Olmos [8], many seeds conserve—and even increase—their germinative power when they pass through the tapir digestive system. This may indicate that tapirs can be important dispersers for the flora of ecosystems where they live.

Fig. 3. Upper left and right: tracks and feces of adult female and young. Lower left and right: bark of *Vatairea lundelii* bitten by a tapir and tapir captured and radio-marked in the Lacandon Forest.

Conservation Threats

Habitat Loss and Fragmentation

Human activity has been intense throughout southern Mexico, where an important fraction of the original cover (primarily tropical forests) was severely fragmented and defaunated during the second half of the twentieth century as a result of a dramatic human population increase [50, 51]. The effects of forest fragmentation on tapir populations have been studied in a few locations [52-54). The general pattern observed is that tapirs become progressively rarer as their habitats become fragmented. A clear example of this phenomenon was found in forest fragments adjacent to MABR, where tapir densities were considerably lower than within the boundaries of the protected area [3]. A similar situation occurs in the Sierra Madre of Chiapas, where most of the original cover of tropical and montane forests was systematically cleared for farming and cattle ranching during the twentieth century, leaving a landscape of forest patches surrounded by a matrix of coffee plantations (with some potential as tapir habitat), corn plots, and pasture lands.

The two largest forest fragments remnant in the Sierra Madre are the El Triunfo (1190 km^2) and La Sepultura (1790 km^2) Biosphere Reserves. By 1996, the area now protected as La Sepultura had lost about 38% of its original forest cover in only 20 years, and almost 80% of the entire area had some degree of human disturbance [55]. This situation illustrates well what has occurred during the last few decades in forested areas of other Mexican states currently or formerly sheltering tapir populations, such as Oaxaca, Quintana Roo, Tabasco, Veracruz, and Yucatan. In these areas, major threats for tapir habitat are forest clearings to create new grazing areas for cattle, slash-and-burn agriculture, soil erosion by rain and wind on steep slopes, pollution of water bodies by pesticides and fertilizers, and competition for food with domestic animals such as cows, horses, and pigs [56-57]. In general terms, land-use changes produce negative effects for tapir habitat such as: (1) reduction of water retention; (2) partial or total loss of suitable forest fragments; (3) fragmentation and isolation of tapir populations; and (4) temporary overpopulation of some other ungulate species (i.e., white-tailed deer and collared peccaries) in remaining forest fragments.

Effective habitat protection is one of the most important actions that can be taken to improve tapir survival probabilities. The creation of relatively large protected areas during the last three decades in southeastern Mexico is a positive sign. However, law enforcement to avoid environmentally unfriendly practices (i.e., overhunting, free-ranging cattle grazing, and intentional burning) within and around these protected areas is still weak, and tapir populations continue to increase their isolation from each other. Population isolation is particularly acute in areas such as the Sierra Madre of Chiapas, the forests of Oaxaca and Veracruz, and the northern Yucatan Peninsula. Extant and further isolation of these tapir populations may be mitigated by encouraging connectivity among forest fragments through close work with residents to establish community reserves and promoting environmentally-friendly productive practices such as agroforestry systems (i.e., organic cacao and shade coffee plantations), sustainable cattle grazing, and sustainable harvests of native plant species around protected areas. In particular, efforts to ensure tapir habitat protection should be made through improving cooperation among environmental authorities and protected-area managers of southeastern Mexico and their counterparts in neighboring Belize and Guatemala. These efforts would be very positive to help preserving the largest Baird's tapir population remaining in the wild.

Hunting

Poaching is still a common practice in most areas—protected or not—where tapirs remain in Mexico [51, 57]. Ungulate species such as peccaries (*Pecari tajacu* and *Tayassu pecari*) and deer (*Mazama americana* and *Odocoileus virginianus*) are important food sources for many rural communities [58, 59]. However, tapir hunting seems to be relatively rare at present, probably because of the low densities of the species, the preference of local hunters for other prey (tapir meat is not as tasty as other kinds of wild meat), and the difficulty of carrying an entire tapir back home [10, 59]. It has been shown that even a conservative harvest rate may affect tapir populations to the point of local extinction due to their extremely low productivity [27, 29]. This was confirmed by Naranjo et al. [59], who found that tapirs were overhunted in communities adjacent to MABR, even though most killings of these animals occurred during unexpected encounters with hunters on trails between agricultural plots and human settlements. Cruz [42], Carrillo et al. [60], Lira et al. [25], and Naranjo and Cruz [11], found similar trends in CNP, El Triunfo and La Sepultura Reserves, where tapirs were extremely rare outside the boundaries of the protected areas.

Implications for Tapir Conservation

Threats for Baird's tapir conservation are complex. However, there are alternatives of habitat and population management to improve the situation of this ungulate in Mexico. Maintaining of extant protected areas and improving connectivity among them are crucial to ensure habitat availability for tapirs in the country. In particular, it seems plausible to increase connectivity among tapir populations occupying the following areas: 1) the cluster Calakmul-Quintana Roo forests-Sian Ka'an with neighboring Maya Biosphere Reserve (Guatemala) and western Belize forests; 2) Chimalapas-Uxpanapa-Selva El Ocote; and 3) the cluster Montes Azules-Lacantun-Chan Kin with neighboring Sierra del Lacandon National Park (Guatemala). Community-based land use planning may be a useful tool to protect forest patches in communal lands with tapir presence, particularly in extensive *ejidos* of Campeche and Quintana Roo, as well as in indigenous territories of Chimalapas and the Lacandon Forest. A transition of conventional farming towards more environmentally friendly practices such as agroforestry, organic agriculture, and sustainable cattle ranching in tapir-distribution areas is also desirable to reduce pressure on remaining forests. However, it will be necessary to review persistent contradictions in public policies (i.e., subsidies for cattle grazing and for protecting remaining forest patches) conflicting within communities sheltering tapir habitat.

Effective enforcement of restrictions on tapir hunting [2] either in protected areas or community lands is needed to allow recovery of populations everywhere, but especially in isolated forest fragments where the likelihood of local extinction is higher. Selected residents of communities adjacent to protected areas containing tapirs may be trained and hired by federal or state government agencies for this purpose. Baird's tapir is definitely not a good candidate for sustainable hunting because of its life history traits (i.e., low reproductive output and low natural density), but sustainable harvests of species with higher productivity (i.e. armadillos, peccaries, and white-tailed deer) can be promoted to fulfill needs of communities for wild meat under a co-management system [61].

In spite of the challenging scenario set by the social and cultural complexity of rural communities in southern Mexico, it is of utmost importance to procure their involvement in tapir conservation actions. When local people become co-responsible and get economic and nutritional benefits from conserving tapir populations and their habitats, the chances for success may be considerably higher. For this purpose, it is necessary to explore alternative income sources for residents such as ecotourism, including observing tapir evidences (i.e.,

tracks and feces) and its habitat as part of the attractive natural elements for visitors. Although *in-situ* conservation strategies should prevail for Baird's tapir in Mexico, in regional zoos as well as in a few community wildlife management units authorized by the Ministry of Natural Resources (SEMARNAT) it may be feasible to establish rustic captive breeding units to both attract visitors and supplement or reintroduce tapirs to the wild. Guidelines for tapir captive breeding and reintroduction are well developed and available at the IUCN's Tapir Specialist Group website (www.tapirspecialistgroup.org). Additionally, alternative income sources such as sustainable harvests of non-timber products, beekeeping, butterfly and orchid nurseries, and wildlife-inspired handicraft markets can be fostered in communities where tapirs exist.

Human resource training as well as environmental education and communication are essential to succeed in conserving tapirs and their habitats in Mexico. Formation of human resources may be sponsored by academic institutions and non-governmental organizations, offering wildlife conservation and management courses for graduate and undergraduate students, staff of protected areas, and residents or rural communities. Environmental education and communication programs should be strongly sponsored and encouraged by federal and state education ministries through their elementary and high school systems in both urban and rural areas, particularly those located near tapir habitat.

Finally, a long list of basic and applied studies needed on tapirs is awaiting interested researchers in Mexico. Some of those studies include field verification and creation of current distribution maps, abundance, evaluations of habitat availability, population status (size, structure, growth rates, and threats), habitat use, movement patterns, feeding habits, genetic variability, interactions with domestic species, diseases, and responses to habitat fragmentation, hunting, and global climatic change.

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Appendix 1. Plant species and their parts consumed by Baird's tapir *(Tapirus bairdii)* in Mexico. Sources: 1=Naranjo and Cruz [11], 2=Cruz [42], 3=Rivadeneyra [43]. 4=E.J. Naranjo [unpublished data].

Family	Species	Parts consumed	Source
Acanthaceae	*Blechum* sp.	stems, leaves	2
Acanthaceae	*Odontonema* sp.	stems, leaves	2
Acanthaceae	*Justicia aurea*	stems, leaves	2
Acanthaceae	*Lagochilium schiedeanum*	stems, leaves	3
Amaranthaceae	*Amaranthus* sp.	fruit	1
Amaranthaceae	*Iresine arbuscula*	stems, leaves	2
Amaranthaceae	*Iresine celosia*	stems, leaves	3
Amaranthaceae	*Cyathula* sp.	stems, leaves	2
Anacardiaceae	*Spondias mombin*	fruit	1, 2, 3, 4
Annonaceae	*Annona diversifolia*	fruit	2, 4
Apocynaceae	*Stemmadenia* sp.	stems, leaves	1, 2
Aquifoliaceae	*Ilex guianensis*	fruit	1, 2
Araliaceae	*Dendropanax arboreus*	bark	3
Araliaceae	*Oreopanax* sp.	leaves	1
Arecaceae	*Attalea butyracea*	fruit	3, 4
Arecaceae	*Bactris balanoidea*	fruit	3, 4
Asteraceae	*Baccharis trinervis*	stems, leaves	2
Asteraceae	*Bidens* sp.	stems, leaves	1, 2
Asteraceae	*Clibadium arboreum*	stems, leaves	3
Asteraceae	*Clibadium surinamense*	stems, leaves	3
Asteraceae	*Cosmos* sp.	stems, leaves	2
Asteraceae	*Melanthera nivea*	stems, leaves	3
Asteraceae	*Perymenium grande*	stems, leaves	3
Bombacaceae	*Pachira aquatica*	brotes, fruit	3, 4
Boraginaceae	*Cordia alliodora*	stems, leaves	1
Bromeliaceae	*Billbergia* sp.	stems, leaves	2
Cactaceae	*Epiphyllum* sp.	fruit	1, 2
Capparidaceae	*Capparis flexuosa*	stems, leaves	1
Chenopodiaceae	*Chenopodium* sp.	fruit	1, 2
Chrysobalanaceae	*Licania platypus*	fruit	3
Cicadaceae	*Ceratozamia mexicana*	fruit	2
Clethraceae	*Clethra* sp.	stems, leaves	2
Commelinaceae	*Campelia* sp.	stems, leaves	1
Cyperaceae	*?*	fruit	1, 2
Escrofulariaceae	*?*	fruit	2
Euphorbiaceae	*Acalypha diversifolia*	stems, leaves	3
Euphorbiaceae	*Acalypha* sp.	stems, leaves	1
Euphorbiaceae	*Croton* sp.	bark	3, 4
Euphorbiaceae	*Euphorbia* sp.	stems, leaves	2
Fabaceae	*Acacia* sp.	fruit	3, 4
Fabaceae	*Acacia milleriana*	fruit	2
Fabaceae	*Desmodium* sp.	fruit	2

Fabaceae	*Dialium guianense*	fruit	3, 4
Fabaceae	*Erythrina goldmanii*	leaves	1
Fabaceae	*Inga* sp.	fruit, leaves	1
Fabaceae	*Pithecellobium* sp.	fruit	2
Fabaceae	*Vatairea lundellii*	bark	3, 4
Fagaceae	*Quercus* sp.	fruit	1, 2
Flacourtiaceae	*Casearia* sp.	stems, leaves	1
Flacourtiaceae	*Xylosma* sp.	stems, leaves	2
Hydrophyllaceae	*Wigondia urens*	stems, leaves	2
Lauraceae	*Phoebe chiapensis*	fruit, leaves	1
Malpighiaceae	*Bunchosia* sp.	stems, leaves	1
Malvaceae	*Malvaviscus arboreus*	stems, leaves	3
Meliaceae	*Cedrela odorata*	fruit	2
Meliaceae	*Guarea* sp.	stems, leaves	1
Meliaceae	*Trichilia havanensis*	stems, leaves	2
Moraceae	*Brosimum alicastrum*	fruit, leaves	1, 2, 3, 4
Moraceae	*Cecropia obtusifolia*	stems, leaves	4
Moraceae	*Ficus insipida*	fruit	4
Moraceae	*Ficus* sp.	fruit	1, 2, 3
Myricaceae	*Myrica cerifera*	stems, leaves	2
Myrsinaceae	*Parathesis* sp.	stems, leaves	1, 2
Myrtaceae	*Eugenia* sp.	stems, leaves	1, 2
Phytolaccaceae	*Phytolacca rivinoides*	stems, leaves	3
Phytolaccaceae	*Phytolacca purpurascens*	fruit, leaves	1, 2
Piperaceae	*Piper auritum*	stems, leaves	1, 2, 3, 4
Poaceae	*Panicum* sp.	leaves, fruit	1, 2
Polygonaceae	*Coccoloba hondurensis*	fruit	2
Polygonaceae	*Polygonum* sp.	fruit	1, 2
Portulacaceae	*?*	fruit	1, 2
Rubiaceae	*Hamelia patens*	stems, leaves	3
Rubiaceae	*Hoffmannia angustifolia*	stems, leaves	1, 2
Rubiaceae	*Psychotria limonensis*	bark	3
Rubiaceae	*Psychotria marginata*	bark	3
Rubiaceae	*Psychotria tenuifolia*	stems, leaves	3
Rubiaceae	*Psychotria* sp.	stems, leaves	1, 2
Rubiaceae	*Randia aculeata*	leaves, fruit	1, 2
Sapindaceae	*Cardiospermum grandiflorum*	stems, leaves	3
Sapotaceae	*Bumelia* sp.	fruit	2
Sapotaceae	*Manilkara zapota*	fruit	1, 2, 3, 4
Sapotaceae	*Pouteria sapota*	fruit	4
Solanaceae	*Cestrum nocturnum*	stems, leaves	3
Solanaceae	*Cestrum* sp.	stems, leaves	2
Solanaceae	*Lycianthes* sp.	stems, leaves	2
Solanaceae	*Physalis* sp.	fruit	1, 2
Solanaceae	*Solandra grandiflora*	stems, leaves	2
Solanaceae	*Solanum americanum*	stems, leaves	2
Solanaceae	*Solanum houstonii*	stems, leaves	3
Solanaceae	*Solanum nigrum*	stems, leaves	3
Sterculiaceae	*Byttneria aculeata*	stems, leaves	3
Symplocaceae	*Symplocos flavifolia*	stems, leaves	2

Tiliaceae	*Heliocarpus appendiculatus*	stems, leaves	3
Ulmaceae	*Celtis iguanaea*	stems, leaves	3
Ulmaceae	*Trema micrantha*	fruit	1, 2
Urticaceae	*Boehmeria ulmifolia*	stems, leaves	3
Verbenaceae	*Citharexylum* sp.	stems, leaves	1, 2
Vitaceae	*Vitis* sp.	fruit	1, 2