

Latin American deer diversity and conservation: A review of status and distribution¹

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Abstract: We reviewed the scientific literature published from 1940 to 2002 on Latin American (Mexican and Central and South American) deer (Mammalia: Cervidae), focusing on conservation status and prediction of geographic distributions. The extant Latin American deer are the most diverse deer assemblage in the world (Cervinae: one genus, one species: Elk [*Cervus elaphus*]; Odocoileinae: six genera, 18 species: White-tailed deer [*Odocoileus virginianus*], mule deer [*O. hemionus*], marsh deer [*Blastocerus doctotomus*], pampas deer [*Ozotoceros bezoarticus*], huemul [*Hippocamelus bisulcus*], taruca [*Hippocamelus antisensis*], greater pudu [*Pudu mephistophiles*], lesser pudu [*Pudu pudu*], and six recognized species of brocket deer [*Mazama americana*, *M. gouazoubira*, *M. nana*, *M. bricenii*, *M. chunyi*, and *M. rufina*] as well as three recently proposed species [*M. pandora*, *M. rondoni*, and *M. bororo*]). Within this group, three genera (*Odocoileus*, *Hippocamelus*, and *Blastocerus*) have been well studied, whereas the genus *Mazama*, *P. puda*, *P. mephistophiles*, and *H. antisensis* have received little attention. The marsh deer, pampas deer, taruca, huemul, lesser pudu, and two *Mazama* species (*Mazama nana* and *M. bororo*) are the most endangered species. They are each listed as Convention International for the Trade of Endangered Species Appendix I and are considered by the International Union for Nature Conservation to be near threatened or endangered. We updated or created distribution maps for these species. Current research predominantly centres on easily available species (e.g., white-tailed deer in Mexico) or endangered species (e.g., marsh deer in Brazil). In contrast, the ecology and conservation status of the pudu, taruca, and *Mazama* sp. remain largely unknown.

Keywords: conservation, deer, distribution, Latin America, neotropics.

Résumé : Nous avons procédé à une revue de la littérature scientifique publiée entre 1940 et 2002 et traitant des Cervidae (Mammalia) de l'Amérique latine (Mexique, Amérique centrale et Amérique du Sud). Nous avons concentré nos recherches sur l'état des populations et sur les méthodes de prédiction des répartitions géographiques. Les cervidés de l'Amérique latine constituent l'assemblage de cerfs le plus diversifié au monde (Cervinae: un genre, une espèce : le wapiti (*Cervus elaphus*); Odocoileinae : six genres, 18 espèces : le cerf de Virginie (*Odocoileus virginianus*), le cerf mulot (*O. hemionus*), le cerf des marais (*Blastocerus dichotomus*), le cerf des pampas (*Ozotoceros bezoarticus*), l'huemul (*Hippocamelus bisulcus*), le cerf andin ou guemal (*Hippocamelus antisensis*), le pudu du Nord (*Pudu mephistophiles*), le pudu du Sud (*Pudu pudu*) et six espèces reconnues de mazamas ou daguets (*Mazama americana*, *M. gouazoubira*, *M. nana*, *M. bricenii*, *M. chunyi* et *M. rufina*) ainsi que trois autres espèces récemment proposées (*M. pandora*, *M. rondoni* et *M. bororo*). À l'intérieur de ce groupe, trois genres (*Odocoileus*, *Hippocamelus* et *Blastocerus*) ont été bien étudiés. Par contre le genre *Mazama*, de même que *P. puda*, *P. mephistophiles* et *H. antisensis* n'ont fait l'objet que de peu d'attention. Le cerf des marais, le cerf des pampas, le guemal, l'huemul, le pudu du Sud et deux espèces de mazama (*Mazama nana* et *M. bororo*) sont toutes des espèces en danger de disparition. Elles figurent dans l'Annexe 1 de la Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction et elles sont considérées comme menacées ou en danger de disparition par l'Union internationale pour la conservation de la nature (Union internationale pour la conservation de la nature). Nous avons mis à jour ou établi les cartes de répartition de ces espèces. Les recherches en cours s'intéressent essentiellement aux espèces facilement accessibles, comme le cerf de Virginie au Mexique, ou aux espèces en danger de disparition, comme le cerf des marais au Brésil. En contrepartie, l'écologie et le statut des populations du pudu, du guemal et des espèces de mazama demeurent bien peu connus.

Mots-clés : Amérique latine, cerf, conservation, répartition, zone néotropicale.

Nomenclature: Wilson & Reeder, 1993.

Introduction

Latin America is one of the most biologically rich regions in the world. It harbours three of the so-called "mega-diversity" countries and has the largest deer diversity in the world, with seven genera and 18 species described to date (Medellin & Ceballos, 1994; Wemmer, 1998.)

In North America (including Mexico) contemporary deer population depletion commenced during the 18th century with the introduction of modern weapons. Most will agree that indigenous hunting had minimal impact upon deer number before European settlement. However, some argue that at least part of the megafauna extinction process in South America (including that of deer) started much earlier during the Pleistocene and was strongly linked with indigenous human hunting (Eisenberg,

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1987; 1989; Redford & Eisenberg, 1989; Robinson & Bennett, 1999).

Deer biology studies began in Brazil in the early 1900s with Goeldi (1902) and de Miranda Ribeiro (1919), while in the 1940s studies extended elsewhere in South America (Cabrera, 1943; 1960; Cabrera & Yepes, 1961). In the late 1950s, deer research extended to Mexico (Leopold, 1959). Central America (with the possible exception of Costa Rica) has not yet had a local school of deer biologists (Mendez, 1984; Vaughan & Rodriguez, 1994).

Most studies on Latin American deer to date have concentrated on gathering only baseline information. For example, from 1975 to 1995 diet studies and population survey methodology formed the core of deer research in Mexico (Galindo-Leal & Weber, 1998). For some species, even gross geographical range maps are lacking, and no previous literature review has attempted to produce them. In fact, the last literature review is now 5 y old and was not comprehensive, due to the difficulty of obtaining the literature and first-hand information in the region (Wemmer, 1998).

Our aims with this review were to compile the available biological information on deer; update the distribution maps of the species, focusing on their geographic ranges and main populations; and discuss the conservation status and research trends of the 18 Latin American deer species described to date.

Methods

We reviewed the available literature, including that published locally or nationally from 1940 to 2002 in the form of books, proceedings, dissertations, theses, project reports, and memoirs of workshops and meetings. Such sources were often hard to locate in such a large area as Latin America, so in many cases we contacted authors or people involved with ongoing research. Therefore, though we try to keep these to a minimum level, several personal communications are quoted. We divided the continent into three major geographical regions (Mexico, Central America, and South America) and evaluated the information on a species by species basis.

A major aim of our work was to update (or, for some species, create for the first time) distribution maps of the 18 species of Latin American deer. To accomplish this, we followed the International Union for the Conservation of Nature - Species Survival Commission (IUCN-SSC) criteria for extent of occurrence and area of occupancy (Wemmer, 1998), using published information and museum records for historical distribution maps. For predicted and current distribution maps, we used published and unpublished information (so-called grey literature) and personal communications with local and regional experts. We also developed potential distribution maps based on regional habitat. We used ArcView®GIS and the World Wildlife Fund World Eco-Region maps at continental and country scales. Based on available data of the presence of a species in a given habitat and expert knowledge on the extent of this habitat at

regional levels, we predicted and/or updated the distribution maps accordingly.

Given the lack of knowledge about many deer species, we focused on documenting current levels of disturbance (*e.g.*, deforestation and overgrazing) of the different habitats, basing our predictions on deer distribution largely on estimations of suitable habitat extent. Clearly, at such large scales, accuracy is compromised, and therefore our maps should be considered to depict potential distribution rather than actual distribution. However, for many species, this is the first attempt to put together this information and to predict gross distributions. Finally, we predicted generalized regional deer diversity patterns (species richness) based on our potential regional distributions maps.

Results

The current conservation status (Convention on the International Trade of Endangered Species [CITES]), geographic range, habitat, and some biological parameters of the 18 species of deer currently known to science in Latin America are summarized in Table I. In the following sections, we provide a species-by-species account and then discuss some deer diversity patterns and research trends by region. Given the lack of consensus on deer subspecies, we keep our discussion at this taxonomic level to the minimum. Distribution maps of the 18 species are summarized in Figures 1-4. Individual maps for each species can be obtained by contacting the authors.

SPECIES ACCOUNTS

WAPITI (*CERVUS ELAPHUS NELSONI*)

As a result of over-hunting, the Mexican subspecies of elk (*C. e. merriami*) became extinct in the early 1920s in the U.S.A. and Mexico (Leopold, 1959). It once roamed from southern New Mexico and Arizona to northern Sonora, Chihuahua, and Coahuila states in Mexico (Leopold, 1959), having spread from a very restricted original distribution in the oak-pine forests of the Sierra Madre of Mexico. The Rocky Mountain subspecies (*C. e. nelsoni*) has since been reintroduced at private properties in Sonora, Coahuila, Chihuahua, and Durango in northern Mexico (Weber & Galindo-Leal, in press). This is not to be confused with the European red deer (*C. e. scooticus*) introduced for deer farming in several Latin American countries, such as Argentina, Chile, Uruguay, and more recently Mexico (Figure 1). The outlook for this species is difficult to assess since the few remaining herds are all in private properties belonging to wealthy ranchers.

MULE DEER (*ODOCOILEUS HEMIONUS*)

The distribution of the mule deer in Latin America is restricted to northern Mexico, where there has been an estimated 60% reduction in the historic distribution (Figure 1). It is now well managed for sport hunting in some private properties in Sonora and Chihuahua, Mexico (Weber & Galindo-Leal, in press).

Five subspecies of mule deer are recognized in Mexico: *O. h. cerrocensis*, *O. h. crooki* (syn. *O. h. ermicus*), *O. h. fuliginatus*, *O. h. peninsulae*, and *O. h. sheldoni* (Hall, 1981). Most research has been carried out with three subspecies (*O. h. crooki*, *O. h. peninsulae*, and

TABLE I. Summary information of the 18 species of Latin American deer.

Species (common name)	Geographic range	Habitat (Considered to predict distributions)	Body size & feeding habits	IUCN-CITES conservation status
<i>Blastocercus dichotomus</i> (Marsh deer)	Argentina, Bolivia, Brazil, Paraguay, Peru, Uruguay†	Marshes and wet savannas with high grass and wooded island, damp forest edges	100-150 kg Browser	Vulnerable VU A4acde CITES I
<i>Cervus elaphus merriami</i> (Wapiti, elk)	Mexico†	Forest lowlands and mountains	75-340 kg Grazer & browser	Extinct (reintroduced)
<i>Hippocamelus antisensis</i> (Taruca)	Argentina, Bolivia, Chile, Ecuador†, Peru	Open Andean grasslands	45-65 kg Grazer	Data deficient-CITES I
<i>Hippocamelus bisulcus</i> (Huemul)	Argentina, Chile	Mountain forest dense shrub	45-65 kg Grazer & browser	Endangered EN C2a -CITES I
<i>Mazama americana</i> (Red brocket)	Mexico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Ecuador, Colombia, Venezuela, Trinidad, Guyana, Suriname, French Guyana, Brazil, Argentina, Bolivia, Paraguay, Peru	Tropical forest and woodlands, cloud forest, and cerrado	30-40 kg Browser & frugivore	Data deficient DD
<i>Mazama bororo</i> (Small red brocket deer or Brazilian Atlantic forest deer)	Brazil	Atlantic forest Brazil	25 kg	Data deficient DD
<i>Mazama bricenii</i> (Dwarf grey brocket)	Venezuela	Mountain cloud forest	Unknown	Not included
<i>Mazama chunyi</i> (Peruvian dwarf brocket)	Bolivia, Peru	Humid forest yungas	> 14 kg	Data deficient DD
<i>Mazama gouazoubira</i> (Grey or brown brocket)	Ecuador, Colombia, Venezuela, Trinidad, Guyana, Suriname, French Guyana, Brazil, Argentina, Uruguay, Peru, Bolivia	Forest, woodlands, dry deciduous forest, or savannas cerrado	20-30 kg Browser & frugivore	Data deficient DD
<i>Mazama nana</i> (Brazilian dwarf brocket)	Argentina, Brazil, Paraguay	Tropical rain forest	10-13 kg	Data deficient DD
<i>Mazama pandora</i> (Yucatan brown brocket)	Mexico	Tropical semi-deciduous and tropical flooding forests	15-20 kg Browser & frugivore	Data deficient DD
<i>Mazama rondoni</i> (Small gray brocket)	Brazil	Amazonian rain forest	15 kg	Not included
<i>Mazama rufina</i> (Colombian dwarf brocket)	Ecuador, Colombia	Mountain forest 3000-4000 m	15 kg	Lower risk- least concern
<i>Odocoileus hemionus</i> (Mule deer)	Mexico	Forest mountains, plains, and deserts	100-120 kg	Lower risk- least concern
<i>Odocoileus virginianus</i> (White-tailed deer)	Mexico, Coiba I, Panama, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Margarita I, Venezuela, Curaçao, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela, Brazil	Forest, woodlands, edge/ shrub, and open grassland	40-60 kg Grazer & browser	Not listed
<i>Ozotoceros bezoarticus</i> (Pampas deer)	Argentina, Bolivia, Brazil, Paraguay, Uruguay	Pampas, open grassland, and cerrado	20-40 kg Grazer & browser	Near threatened NT CITES I
<i>Pudu mephistophiles</i> (Northern pudu)	Colombia, Ecuador, Peru	Temperate forest and fringing grasslands 2000-4000 m	5.8-13 kg Grazer & browser	Lower risk-near threatened-CITES II
<i>Pudu puda</i> (Southern pudu)	Chile, Argentina	Humid <i>Notofagus</i> forest up to 1700 m	5.8-12 kg Browser	Vulnerable VU A1cde -CITES I

† Locally extinct.

O. h. cerrosensis, in that order) with little research effort focusing on the remaining two (Galindo-Leal, 1993; Weber & Galindo-Leal, in press). The status and future of the Tiburon Island mule deer (*O. h. sheldoni*) seems secure because of the isolation of the island and its well-protected status as a Nature Reserve. The Cedros Island mule deer is probably the most endangered subspecies (Figure 1).

WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*)

The white-tailed deer is by far the most extensively studied deer species in Latin America, particularly in Mexico, and it is also of the most polytypic, with around 20 subspecies described for the region (Folliot & Gallina, 1981; Vaughan & Rodriguez, 1994; Galindo-Leal & Weber, 1998). Most research work has been obtained on five to six subspecies, mostly from northern Mexico and

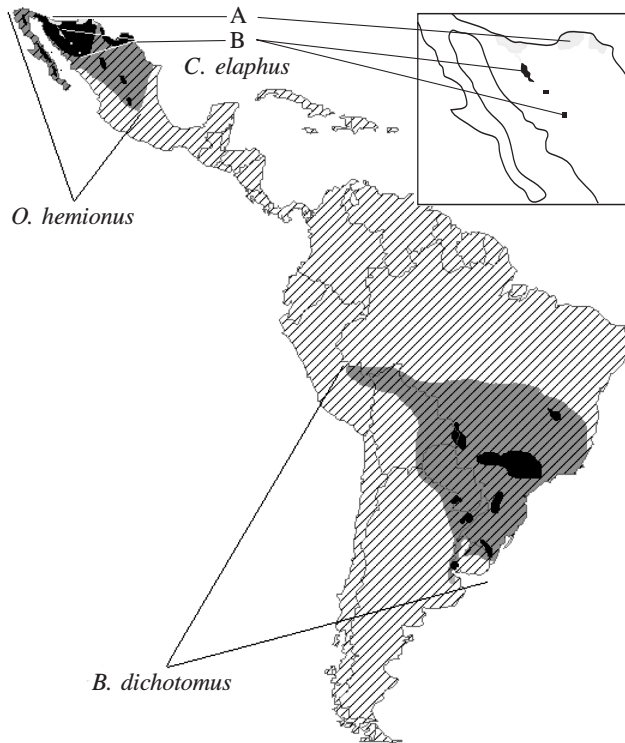


FIGURE 1. Historic distribution (grey) and predicted current distribution (black) of *Cervus elaphus*, *Odocoileus hemionus*, and *Blastoceros dichotomus* in Latin America. The inset zooms on *C. elaphus* (A) historic and (B) predicted distributions in Northern Mexico.

Costa Rica (Vaughan & Rodriguez, 1994; Weber & Galindo-Leal, 1994). Local extinctions due to over-hunting are common where it is one of the most sought-after game species (Figure 2). Although formal research on the white-tailed deer in Mexico started in the 1980s and has continued uninterrupted since then, most work has been carried out in just three or four states in the north of Mexico (Durango, Nuevo Leon, Chihuahua, and Jalisco), encompassing two or three subspecies that inhabit semi-arid shrub-land and/or oak-pine habitats. Until recently, deer biologists in Mexico have largely ignored the tropical subspecies of white-tailed deer (with the notable exceptions of Chamela tropical dry forest biological station, Jalisco, Mexico [Mandujano & Gallina, 1995] and the tropical rain forest of Calakmul, Campeche [Weber & Reyna-Hurtado, 1999]).

Of the 14 subspecies described in Mexico, research and conservation status evaluations have been carried out for about seven to eight races, with major gaps in the distribution and current status of the tropical (*O. v. oaxaque-nsis*, *O. thomasi*, *O. truei*) and western Pacific coast (*O. v. sinaloae*, *O. v. acapulcesis*, *O. v. oaxaquensis*) subspecies. Most ecological research has been carried out on three subspecies: the Coues deer (*O. v. couesi*), the Texas deer (*O.v. texanus*), and the Potosi white-tailed (*O.v. miquihuanensis*) (Weber & Galindo-Leal, 1994).

In central America, most research on white-tailed deer has been carried out in Costa Rica (Vaughan & Rodriguez, 1994), where it is one of the most important trophies for sport hunters, resulting in considerable effort being spent on managing the remaining populations (Vaughan & Rodriguez, 1994).



FIGURE 2. Historic distribution (grey) and predicted current distribution (black) of *Odocoileus virginianus*, *Hippocamelus antisensis*, *H. bisulcus*, and *Ozotocerus bezoarticus* in Latin America. Note that only current distribution is given for the white-tailed deer with possible range expansions pointed with question marks.

In contrast with Mexico and Central America, where the white-tailed deer has been relatively well studied, the South American subspecies have been largely ignored. The only notable exceptions are in Venezuela (Brooks, 1984) and in Suriname (Branan & Marchinton, 1985; Branan *et al.*, 1985). A recent paper (Molina & Molinari, 1999) proposed that Venezuelan and other Neotropical *Odocoileus* are not conspecific with *O. virginianus* and should be considered different species. Since this work was based on morphometrics, more studies using modern molecular genetics techniques are needed to test this proposal.

The species range seems to be expanding in the south as a result of deforestation, with some recent records of the species in Bolivia, Peru, and Brazil, where it was previously unknown.

MARSH DEER (*BLASTOCERUS DICHOTOMUS*)

The marsh deer is the largest neotropical cervid with morphological and ecological adaptations to wetlands and riparian habitats (Pinder, 1996; Wemmer, 1998). It was originally distributed in most riparian marshlands from south of the Amazon River to northern Argentina (Pinder, 1996; Tomas, Beccaceci & Pinder, 1997), though we now estimate a 65% reduction in its global distribution (Figure 1).

Total population numbers are unknown, but are certainly declining in all areas as a result of poaching, cattle diseases, habitat loss due to agricultural activities, and dam construction (Beccaceci, 1994; Pinder & Seal, 1994; Duarte, 2001). In Uruguay it is probably extinct since the last record is from 1958 (González, 1994).

The population of the Brazilian Paraná basin is losing habitat for the species at an alarming rate due to the many dams that were built recently (Duarte, 2001). The Argentinian Iberá population is estimated to be 1,000 individuals inhabiting 12,000 km² (Beccaceci, 1994). The central part of Iberá consists of swamps and shallow lagoons less than 5 m deep. Most of the basin is at least periodically flooded. The Iberá is the second largest wetland in South America (Pinder & Grosse, 1991).

The other Argentinian population is Delta Paraná, the southern population located at south of the Paraná in the Delta. This population is being affected by habitat fragmentation due to forestation with exotic tree species and poaching (Varela *et al.*, 2001). The estimated population is around 300 to 400 individuals in total (D. Varela, pers. comm.).

The marsh deer is an important component for several new eco-tourism enterprises in the Pantanal region, Brazil, though elsewhere development projects in the form of dams (especially in the Parana-Paraguay river basins) are a major threat to the conservation of several of the remaining habitat strongholds of the species (Beccaceci & Merino, 1994; Beccaceci, 1996; Pinder, 1996; Duarte, 2001).

Over the last 20 y, there has been considerable research in the form of population surveys and captive breeding (Tomas, Beccaceci & Pinder, 1997). Studies on marsh deer include population estimates using aerial censuses (Schaller & Vasconcelos, 1978; Beccaceci & Merino, 1994; Beccaceci, 1996; Pinder, 1996; Mourao *et al.*, 2000; Duarte, 2001) and studies of diet and foraging behaviour (Beccaceci & Merino, 1994; Beccaceci, 1996; Tomas & Salis, 2000), reproductive biology (Duarte, 1992; 2001), genetics (Duarte, 1992; González *et al.*, 2001), diseases (Duarte *et al.*, 2001), home range, activity patterns and captive breeding (Schaller & Vasconcelos, 1978; Duarte & Merino, 1997; Duarte, 2001).

In 1994 a Population and Habitat Viability Analysis (PHVA) workshop was held, and the viability trends of the main population from Brazil were analyzed. The analysis showed that the Sao Paulo population would decline at an alarming rate. Captive populations had a high mortality rate. Many of the PHVA recommendations were implemented in Brazil. It is important to analyze the population trends in the current conditions (Pinder & Seal, 1994).

PAMPAS DEER (*OZOTOCEROS BEZOARTICUS*)

The pampas deer formerly occupied a range of open habitats such as grassland, pampas, savanna, and cerrado (Brazil). However, the area encompassed by these habitats has been dramatically reduced to less than 1% of that present in the 1900s (González, 1994; 1999).

The largest extant populations from *O. b. bezoarticus* are found in Brazil in the northeast cerrado ecosystem, where about 2,000 individuals live, and in the Pantanal region. Merino *et al.* (1997) estimated an available area of 125,116 km² that could potentially support 20,000 to 40,000 individuals (Figure 2).

In Argentina at the turn of the century over 500,000 km² of grassland habitat was available, and pampas deer

populations were likely very large (González, 1999). However, due to an increase in agricultural activities, today only two small populations remain.

In Uruguay, two remaining populations were described as two new subspecies (González, Álvarez & Maldonado, 2002). One of the subspecies, *O. b. arerunguaensis*, is located mainly in Salto Department, inhabiting an area of less than 120 km² with a population numbering fewer than 500 mature individuals (González, 1999). The other subspecies, *O. b. uruguayensis*, is located in Rocha Department, inhabiting an estimated 15 to 20 km² with an estimated 300 individuals.

With an estimated 98% reduction in historic distribution, the pampas deer is perhaps the most endangered tropical Latin American deer (González *et al.*, 1998). The main reasons for the fragmentation of the pampas deer population are extensive land use for cattle and agriculture (soy beans, sugar cane) and forestry projects such as the exploitation of pine and eucalyptus plantations (González, 1997; Merino *et al.*, 1997; González, Álvarez & Maldonado, 2002). Population trends from Uruguay and Argentina were analyzed in a PHVA workshop (González *et al.*, 1994). The small populations showed a high risk of extinction. As a result, considerable research is being invested in the study of pampas deer biology, ecology, and conservation in the fragmented populations of Uruguay, Argentina, and Brazil (Jackson, Landa & Langguth, 1980; Jackson, 1986; 1987; Jackson & Langguth, 1987; Jackson & Giuletti, 1988; Leeuwenberg *et al.*, 1997; Gonzalez *et al.*, 1998; Mathias, Girio & Duarte, 1999; Rodriguez & Monteiro-Filho, 2000; González, Álvarez & Maldonado, 2002).

THE ANDEAN DEER

TARUCA (HIPPOCAMELUS ANTISENSIS)

The taruca is by far the least known of the Latin American deer species and one of the least understood deer species globally. Though local extinctions as a result of over-hunting are common in the Peruvian and Bolivian Andes (Iriarte, Feinsinger & Jaksic, 1997; Regidor & Rosati, 2001), the taruca seems to persist in highly disturbed areas (H. Zevallos, pers. comm.). It has experienced at least a 60% reduction in global range (Figure 2). Its biology and ecology are poorly documented. A handful of reports on the distribution and social behaviour of this species have been published (Roe & Rees, 1976; Regidor & Rosati, 2001), but little is known about its ecology, reproductive biology, or any other biological aspect in the wild. Captive breeding is difficult, and the few attempts have proved unsuccessful (Redford & Eisenberg, 1989; Wemmer, 1998).

HUEMUL OR PATAGONIAN DEER (HIPPOCAMELUS BISULCUS)

The range of this species has contracted greatly, owing to habitat destruction for agriculture and cattle grazing (Iriarte & Jaksic, 1986; Diaz, 1993; Frid, 2001). We estimated at least a 70% reduction in its overall distribution, and this estimate is similar to estimates by local experts (Diaz & Smith-Flueck, 2000). At present, only a handful of protected areas in Argentina and Chile contain herds, and the species is practically extinct outside of these areas (Figure 2).

The social and foraging behaviour, reproduction, and distribution of these deer are well documented, with a number of studies carried out in Chile (Povilitis, 1983; 1984; 1998; Frid, 1994; 1999; 2001) but just a handful in Argentina (Smith-Flueck & Flueck, 1987; Serret, 2001). It is the national animal of Chile, where it has been actively protected for many years. The current bi-national protection agreement between Argentina and Chile is important in assisting the implementation of conservation measures (Serret, 2001).

NORTHERN PUDU (*PUDU MEPHISTOPHILES*)

Together with the taruca and some *Mazama* species, the northern pudu is one of the most poorly known mammals on the continent. The biology of the species is practically unknown, though it may be a habitat specialist (Eisenberg, 1989). It has been reported as highly susceptible to predation from feral dogs (Eisenberg, 1989). Considered "Near Threatened" by IUCN, the species is also listed in CITES Appendix II. It originally ranged from the Cordillera Central de Colombia to southern (Huacabamba region) and northern Ecuador, and northern and central Peru (Figure 3).

There are huge gaps in our knowledge on the basic biology and ecology of this species; even its presence or absence in some parts of the Northern Andes has never

been reliably documented. No information on the reproductive biology or any other aspect of the biology of the species is available other than the original taxonomic work by Hershkovitz (1982) in Eisenberg (1989).

SOUTHERN PUDU (*PUDU PUDA*)

Weighing less than 12 kg, the southern pudu is considered the smallest deer in the world (Eldridge, MacNamara & Pacheco, 1987). It is considered vulnerable by IUCN and is listed in CITES Appendix I. Although, it has been intensively studied in captivity, especially its endocrinology (Bubenik *et al.*, 2000), it remains poorly known in the wild. As is the case for the northern pudu, predation by dogs, competition with introduced species (such as red and Sika deer), and hunting are considered significant threats (Figure 3).

The southern pudu occurs in a wide variety of habitat types throughout its range in Chile and Argentina, but is characteristically found in thick forests dominated by *Nothofagus* spp., from sea level to 1,000 m. Bamboo thickets and paramo grassland are also favoured (Eisenberg, 1989). Other than this, little is known about the ecology of this South American species (Dellafiore & Maceira, 2001).

THE SOUTH AMERICAN BROCKET DEER SPECIES COMPLEX: A CONUNDRUM?

There has been considerable recent interest in the taxonomy and systematics of the genus *Mazama* since the discovery (or re-discovery) of two or three new species (Duarte & Jorge, 1996; Duarte & Merino, 1997; Medellin, Gardner & Aranda, 1998). The large variation in morphology at both the species and subspecies level in *M. americana* and *M. gouazoubira* has attracted considerable attention from geneticists and taxonomists in Latin America and elsewhere (Jorge & Benirschke, 1977; Smith *et al.*, 1986; Neitzel, 1987; Duarte, 1998).

RED BROCKET DEER (*MAZAMA AMERICANA*)

The red brocket deer is the most widely distributed deer in Latin America (Figure 4), with 16 subspecies described to date, though many taxonomic riddles remain unresolved. It is highly variable in colour, size, and morphology across its range. It may be a habitat specialist in parts of its distribution, where a preference for pristine tropical rain forest is apparent (Leopold, 1959; Eisenberg, 1989; M. Weber, unpubl. data). The species has only recently been studied in the wild and in captivity in Suriname, Brazil, and Mexico (Branan, Werkhoven & Marchinton, 1985; Branan & Marchinton, 1987; Duarte, 1992; Weber, 2000). The red brocket has been recorded as far north as El Cielo Biosphere Reserve, Tamaulipas, in the north of Mexico and in the Yucatan Peninsula in the south (Weber & Reyna-Hurtado, 1999). An ongoing long-term project addressing aspects of red brocket deer biology and ecology in the wild is being carried out in the Calakmul Biosphere Reserve, Campeche, Mexico (Weber & Reyna-Hurtado, 1999; Weber, 2000). In spite of its relatively wide distribution throughout tropical environments in Mexico, the red brocket deer has been little studied and large gaps in knowledge of its biology and

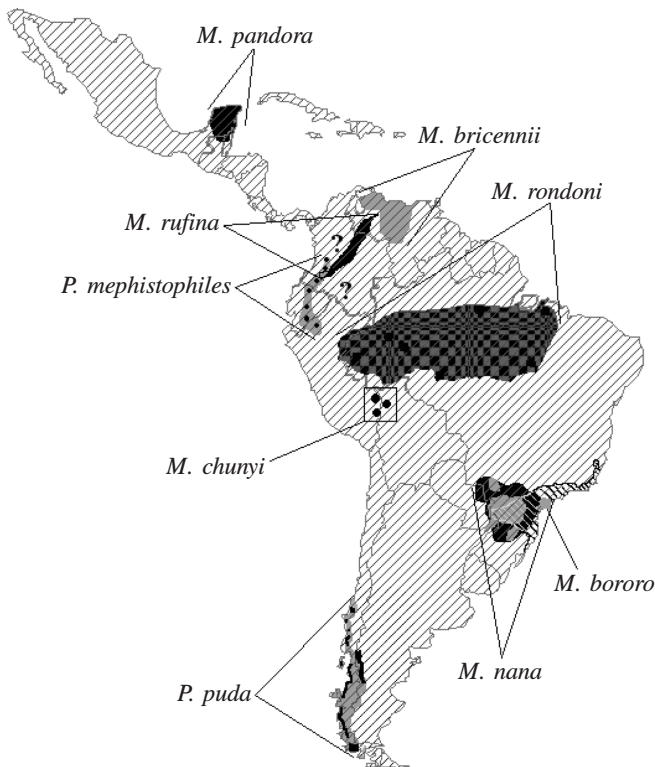


FIGURE 3. Historic distribution (grey) and predicted current distribution (black) of all the species of the genus *Mazama* with none overlapping in their distributions and the two species of pudu (*Pudu puda* and *P. mephistophiles*) in Latin America. For *M. rondoni* a combination of historic and current/predicted distribution (chess board pattern) is provided given the lack of biological information. The three historical records of *M. chunyi* available in the literature are plotted as distribution. The original distribution of the Brazilian Atlantic Forest (inverse diagonal lines) could be the historic distribution of *M. bororo*.



FIGURE 4. Predicted current distribution of *Mazama americana* (black blurred) and *Mazama gouazoubira* (grey solid) in Latin America. Note the large range overlap in north-central South America and compare with Figure 3 for overlapping with other species of the genus *Mazama*.

ecology remain unresolved in this country. No reliable information exists to assess its conservation status or even range changes, so we report only historical distribution.

There is no information on this species' conservation status for most Central American countries. Some baseline research on the conservation status and abundance has been carried out in Guatemala (MacNab, 1998) and Panama (Wright *et al.*, 2000). Poaching and subsistence hunting is pervasive in Central America, and local extinctions of the deer fauna may be occurring in many areas (Wright *et al.*, 2000) (Figure 4).

There is considerable variation in the body size of the red brocket deer (*e.g.*, > 60 kg in Argentina and 10 to 15 kg in northern Guatemala), colour (from a deep reddish in the northern subspecies to a more pale, almost yellowish colour in some South American races) and other traits (Eisenberg, 1989; Duarte, 1998).

Due largely to its solitary nature, its secretive habits, and the relatively inaccessible places it inhabits, the red brocket has been little studied in South America (Leopold, 1959; Wemmer, 1998). Most studies have simply relied on the information obtained from native hunters to document aspects of its biology such as diet (Branan, Werkhoven & Marchinton, 1985; Bisbal, 1994), herbivory (Bodmer, 1989), and reproductive biology (Branan & Marchinton, 1987).

GREY BROCKET DEER (*MAZAMA GOUAZOUBIRA*)

There are nine subspecies of grey brocket deer described, but the taxonomy of the group is unclear

(Hershkovitz, 1959; Eisenberg, 1989), and there could be more species masked by the grey brocket complex. It is a habitat generalist, highly resistant to hunting and habitat modification (Redford & Eisenberg, 1989; Dellafiore & Maceira, 2001), but subject to high hunting pressure throughout its range (Yanosky & Mercoli, 1994). It has been studied in Argentina (Yanosky & Mercoli, 1994), Brazil (Pinder & Leeuwenberg, 1997; Duarte, 1998), the Bolivian and Paraguayan Chaco region, and Peru (Bodmer, 1991; J. L. Cartes, pers. comm.), but no information on its conservation status is available. An endemic subspecies of grey brocket deer (*M. g. permira*) is present on San Jose Island, Panama (Eisenberg, 1989) (Figure 4).

YUCATAN PENINSULA BROWN BROCKET DEER (*MAZAMA PANDORA*)

The recently rediscovered Yucatan Peninsula brown brocket (Medellin, Gardner & Aranda, 1998) is endemic to the Yucatan Peninsula (Mexico, Belize, and Northern Guatemala), where it occurs as a habitat generalist and highly adaptable deer. Its biology and ecology have been under study since 1996 in southeastern Mexico (Weber & Reyna-Hurtado, 1999; Weber, 2000). Although its historical distribution range is unknown, some data suggest that it may be stable in most of the habitat in which it is actually found (M. Weber, unpubl. data) (Figure 3).

In Guatemala, the Yucatan Peninsula brown brocket is probably present in small numbers (compared with the more abundant red brocket) in Tikal National Park and some other areas of the Maya Biosphere Reserve (R. B. MacNab, pers. comm.). No information is available for Belize, but the species is likely to be present in the Gallon Jug-Rio Bravo conservation and management area in the region bordering Mexico and Guatemala (M. Weber, pers. observ.) (Figure 3).

SMALL GREY BROCKET DEER (*MAZAMA RONDONI*)

The small grey brocket deer was described at the beginning of the last century and just recently confirmed by cytogenetics (de Miranda Ribeiro, 1919; Duarte, 1998). This deer is the subrogate form of *M. gouazoubira* in the Amazonian rainforest. The biology of this species is completely unknown, but it may be threatened by overhunting and habitat destruction in parts of its range, which is within the Amazon rainforest in Brazil, Peru, and perhaps also in Bolivia (Duarte, 1998) (Figure 3).

BRAZILIAN DWARF BROCKET DEER (*MAZAMA NANA*)

The biology and ecology of the Brazilian dwarf brocket deer are poorly documented, but its distribution is known to overlap that of the red and grey brocket deer and part of that of *M. bororo*. Wild populations are currently being studied in Argentina (Dellafiore & Maceira, 2001) and in controlled captive conditions in Brazil (Duarte, 1998). We estimate a 40% reduction in historic distribution based on current habitat destruction patterns in its normal habitat (Figure 3).

COLOMBIAN DWARF BROCKET DEER (*MAZAMA RUFINA*)

The taxonomy of the Colombian dwarf brocket deer is unresolved. Some authors consider it to be the same species as the Peruvian and Brazilian dwarf brockets or

even to be a subspecies of the more common and widespread red brocket deer (Eisenberg, 1989). Its biology and ecology are totally unknown, partly because it is distributed in an area with high social unrest that makes research difficult. There are no studies or research projects on this species to date (Figure 3).

PERUVIAN DWARF BROCKET DEER (*MAZAMA CHUNYI*)

The Peruvian dwarf brocket deer is the smallest brocket deer, with a body weight of less than 14 kg. This species was described by Hershkovitz (1959). Its biology is completely unknown as it is rarely seen. It was reported for the first time for the Yungas Province in Bolivia in 1996 (Yensen, Tarifa & Anderson, 1994; Ergueta & Morales, 1996), prior to which just a handful of museum records existed, so its geographic distribution remains unclear (Figure 3). One research project working on the region where the first record in Bolivia was obtained is trying to document baseline biology and ecology of the species (M. Pardo, pers. comm.).

GREY DWARF BROCKET DEER (*MAZAMA BRICENNII*)

The grey dwarf brocket deer is another brocket deer with unresolved taxonomy: some people claim that it is a distinct species, while others consider it to be continuous with the other three dwarf brockets (Eisenberg, 1989; Duarte, 1998). The biology of this species is totally unknown, but it probably is highly endangered by habitat destruction since it inhabits the mist forests of the Andean Venezuelan Cordillera (Eisenberg, 1987; 1989). There are no studies to date. For this species we developed a predicted distribution map based on potential habitat and historic records, but given the lack of information this map should be viewed with caution (Figure 3).

BRAZILIAN ATLANTIC FOREST DEER (*MAZAMA BORORO*)

In 1996 it was proposed based on cytogenetics that the Brazilian Atlantic forest deer is distinct from the red brocket deer (Duarte & Jorge, 1996; Duarte, 1996; 1998). Considered endemic to the Atlantic forest of Brazil, one of the most endangered forest ecosystems on earth, this species is likely to be highly endangered. If it is found only in the Atlantic forest, then it is one of the most endangered deer in the world, with its habitat reduced to less than 2% of its original size (Figure 3).

DIVERSITY PATTERNS AND RESEARCH TRENDS BY REGION

MEXICO

To date, almost all research in Mexico has focused on the white-tailed deer, with little effort made to study the two brocket species and the mule deer (Galindo-Leal, 1994; Weber & Galindo-Leal, 1994; Galindo-Leal & Weber, 1998). Most research has been in oak-pine forests and semi-arid environments, though there has been some deer work done in tropical environments (Mandujano & Gallina, 1995).

The highest deer diversity in Mexico is found in the southern tropical semi-deciduous forests of the Yucatan Peninsula (Peten region), where three sympatric species (*O. virginianus*, *Mazama americana*, and *M. pandora*) exist.

CENTRAL AMERICA

Almost all research in Central America has been carried out in protected areas and national parks in Costa Rica and Panama; the status of deer in Belize, El Salvador, Guatemala, Honduras, and Nicaragua remains almost unknown (Mendez, 1984). Subsistence hunting in countries like El Salvador and Panama might be responsible for extensive local extinctions of species in many areas (Wright *et al.*, 2000; F. Horgan, pers. comm.). Baseline research on distribution, abundance, and conservation management of species is urgently required in these countries. The highest deer diversity in the region is found in northern Guatemala (Peten region), with the same deer assemblage as in the Yucatan, Mexico.

SOUTH AMERICA

Most deer research in South America has concentrated on highly endangered species such as the pampas, huemul and marsh deer (Wemmer, 1998; Duarte, 1992; 1996; Duarte & Jorge, 1996; Duarte & Merino, 1997; Gonzalez *et al.*, 1998). Research has focused on taxonomy, genetics, population ecology, behaviour, survey methodology, and, in recent years, disease aspects concerning conservation medicine (Povilitis, 1983; 1984; Jackson, 1985; 1986; Spotorno, Brum & Tomaso, 1987; Duarte, 1992; Beccaceci, 1996; Pinder, 1996; Mathias, Girio & Duarte, 1999; Mourao *et al.*, 2000; Dellafiore & Maceira, 2001; Duarte *et al.*, 2001; Frid, 2001).

The brocket deer species were largely ignored until very recently, when the discovery of the Yucatan brown brocket and Brazilian Atlantic forest brocket attracted renewed attention to both the red and grey brocket deer complexes (Duarte, 1996; Medellin, Gardner & Aranda, 1998).

The largest diversity of tropical deer in the continent is found in the southern Brazil, northern Argentina, and eastern Paraguay region known as the Parana River Basin and Delta, where potentially as many as five species co-exist or may have co-existed in the past (but see overlap areas in Figures 1, 2, and 3). Another region with high deer diversity is found in Peru and Bolivia's Andean Yungas region, where originally there may have been as many as four or five sympatric species.

Discussion

DEER CONSERVATION CHALLENGES IN LATIN AMERICA

Intensive exploitation of South American cervids followed European settlement of the continent and was probably localized initially on the accessible Pampas grasslands and rangelands of Chile and Argentina. Pampas deer, for example, were hunted intensively during the 19th century and their hides were processed on a vast scale: over two million were exported between 1860 and 1870 (Thornback & Jenkins, 1982). Subsistence hunting is a major threat to all deer in the region (Galindo-Leal & Weber, 1998; Peres, 2000), whereas habitat destruction and fragmentation are important threats to tropical and Andean deer (Frid, 2001).

Recent studies in Latin America have demonstrated that subsistence hunting is still a major activity for rural

human populations (Robinson & Bennett, 1999; Escamilla *et al.*, 2000; Peres, 2000). Together with peccaries (*Tayassu* spp.) and some large caviomorph rodents (*e.g.*, *Agouti* spp.), deer are the most preferred targets of these hunters (Peres, 2000). In fact, deer are one of the most important sources of animal protein in rural Latin America (Weber, 2000). For example, data gathered during a three-month period in southeastern Mexico from a population of 155 peasant families in eight communities that regularly practiced subsistence hunting demonstrated that deer harvest accounted for 48% of the total biomass (10,095 kg) in a harvest bag comprising 13 wildlife species (Weber, 2000).

Considerable effort has been expended on studies of population ecology, behaviour, and captive breeding of some species, but there has been little management-oriented research (Weber & Galindo-Leal, 1994). We consider that manipulative (adaptive management) experiments (*e.g.*, changing hunting quotas and bags while researching their effects on population dynamics) with white-tailed, mule, and brocket deer would be useful for adapting management strategies while learning in the process (*e.g.*, on over-abundant white-tailed deer herds in northeast Mexico) (Galindo-Leal & Weber, 1998).

Biodiversity is currently being lost around the world at an alarming rate, and many deer in Latin America are among the species at risk. The most threatened genera are *Blastocerus*, *Hippocamelus*, *Ozotoceros*, *Pudu*, and *Mazama* (Wemmer, 1998). A number of deer are also prime examples of flagship and umbrella species, whose continued survival is related to the complex interplay of flora and fauna. Many species of deer are now under great threat of extinction, and the situation will not change for the better without a concerted effort.

Almost half of the Latin American native deer taxa are threatened to some degree (Table I). Hunting, deforestation, overgrazing, diseases, feral dogs, and competition with introduced deer and livestock are the main reasons of concern (Wemmer, 1998).

Although deer research in Latin America has accelerated considerably since the early 1980s, large gaps in knowledge on the biology of particular species still exist. Increased collaboration with deer scientists from developed countries for the study of native deer species should be encouraged. Priorities for species conservation programs include the pampas, marsh, and Andean (huemul, taruca, and pudus) deer, while priorities for species research programs include the Andean deer (mainly taruca and pudus) and both the red brocket and grey brocket deer complexes. Regional priorities for further research and conservation include (not in order of priority) Meso-America from the Yucatan Peninsula to Panama, the Andes, the Yungas region in Peru and Bolivia, the Parana-Paraguay river basins, and the Amazon River basin.

All Latin American countries with native deer populations should be supported in efforts to preserve large natural areas harbouring intact communities of wildlife. The promotion of conservation is a great challenge when countries also have to address critical socio-economic situations. Conservation initiatives for large flagship

species, such as endemic deer, will require incentives, encouragement, and financing.

RECOMMENDATIONS FOR FUTURE WORK

In order to develop ecologically sound conservation strategies for Latin American deer, we need to obtain reliable baseline biological information for poorly known species as soon as possible. Research needs to be focused on population estimation methodologies, habitat conservation, and sustainable use.

We need to encourage graduate students in conservation biology to get back to the study of deer natural history before we can even think of having deer managers. Multinational collaboration in the study of species with large distribution ranges should be a priority. The "Mazama riddle", as it is commonly called, deserves renewed attention, as the discovery of new species is likely.

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