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Park size and the conservation of Chilean mammals

Tamaño de parques y la conservación de los mamíferos chilenos

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ABSTRACT

We assessed whether national parks and other protected lands of Chile offer areas large enough to maintain viable populations of nine species of large mammals. For herbivores, 79% of the parks are larger than the minimum area required to support populations of 500 individuals. However, only 45% of the parks are adequate for carnivores. Size inadequacies of protected areas may determine local extinctions of mammals despite being protected from human interference.

Key words: Chile, conservation, extinction, mammals.

RESUMEN

Nosotros evaluamos si los parques nacionales y otras unidades de conservación chilenas ofrecen áreas suficientes para que se mantengan poblaciones viables de nueve especies de mamíferos grandes. Para herbívoros, un 79% de los parques tienen superficies mayores al mínimo requerido para sostener una población de 500 individuos. Sin embargo, sólo un 45% de los parques son adecuados para carnívoros. Lo pequeño de los parques chilenos podría gatillar extinciones locales de mamíferos, aun cuando estén protegidos de actividades antrópicas.

Palabras clave: Chile, conservación, extinción, mamíferos.

INTRODUCTION

The terrestrial mammals of Chile comprise 99 species, 51 of which are of conservation concern (Glade 1988, Contreras & Yáñez 1995). The most frequent threatening causes are illegal hunting and habitat destruction (Miller et al. 1983). In protected areas, mammals are expected to be free of the decimating factors that affect their survival. An implicit assumption is that areas provided by these parks and reserves are large enough to ensure the existence of viable populations within their boundaries. Otherwise, protected populations will become extinct due to the demographic vagrancies faced by small populations even if free from anthropogenic decimating factors (Schaffer 1981).

The potential loss of species from protected areas, as suggested by Soulé et al. (1979) for mammals in African parks, has indeed ocurred in several African and western North American parks. Species such as *Canis lupus* and *Ursus arctos* have vanished from parks since their establishment, particularly from the smallest ones (Miller & Harris 1977, Newmark 1986, 1987, 1995; species nomenclature after Wilson & Reeder 1993). In Latin America, several protected areas in Amazonia seem insufficiently large to preserve viable populations of large mammals, such as *Puma concolor*, *Leopardus pardalis, Panthera onca* or *Tapirus terrestris* (Redford & Robinson 1991). Therefore, a decline in mammalian biodiversity could be expected if no management action is undertaken.

A preliminary analysis of potential faunal collapse for mammalian species in Chilean parks and reserves suggests that 10-15% of large mammal species (body mass > 1 kg) may become extinct within the next 500 years, particularly from the smallest protect-

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ed areas (Mella 1994). In fact, local extinctions have occurred within protected areas. Two large bodied mammals, *Lama guanicoe* from Fray Jorge National Park and *Hippocamelus bisulcus* from Villarrica National Park became extinct before park establishment (CONAF, Corporación Nacional Forestal 1987, 1992). Here, we estimate the area required to support viable populations of Chilean mammals and compare it with the size of the conservation units wherein these species are found. Such a comparison should enable us to determine which species are most likely to become extinct even if protected in wildlife preserves.

METHODS

Two previous studies (Newmark 1985, Redford & Robinson 1991) have assessed parks suitability to sustain mammalian populations. They use a figure of 500 individuals per population. For comparative purposes, we also estimated whether Chilean parks provide an area large enough to sustain populations of 500 individuals of different taxa. The minimum area required to support such a population was estimated as the ratio between the population size (500) and the population density. If more than one density evaluation was available, we estimated both the minimum and maximum area required. This approach assumes that the whole park is suitable habitat for the species, which renders our analysis a conservative one.

There are few estimates of population densities for Chilean mammals of conservation concern (Table 1). A total of nine species were included in this analysis. Of these, *Hippocamelus bisulcus* and *Oncifelis geoffroyi* are endangered; *Vicugna vicugna, Lama guanicoe, Pudu puda Puma concolor* are vulnerable; *Pseudalopex culpaeus* and *P. griseus* are inadaquetely known, and *Conepatus humboldtii* is out of danger (Glade 1988).

To assess the suitability of protected areas to sustain these mammalian species, we tallied the protected areas wherein each one of the species has been recorded. Data regarding mammalian presence in different protected areas (hereafter, parks) was obtained from Internal Reports issued by CONAF, the institution responsible for administrating Chilean protected areas. All reports are on file at the Library of CONAF. We also relied on available published reports (Johnson et al., 1990; Zunino, 1990). The area of the conservation units was obtained from IUCN (1992). To assess size suitability we calculated the ratio between the minimum area required to support a viable population (MA) and the area of the parks (PA). For the sake of comparisons, we are assuming that all park area is suitable habitat. This may certainly be false, but there is no detailed information in order to develop habitat suitability models (e.g., Verner et al. 1986). If MA/PA < 1, park areas are above the minimum required. If MA/PA > 1, the area to sustain a viable population is larger than currently provided by parks, suggesting size inadequacy. This ratio allows us to determine which species would go extinct in a given park. We tailled this information to determine the frequency of parks loosing species and the identity of the species that could go extinct.

RESULTS

To sustain a population of 500 individuals, the area required varies according to population densities. Based on maximum densities, which determines the lowest area requirements, *L. guanicoe* has the smallest area requirement (33 km^2), and *P. concolor* has the largest with 12,500 km^2 (Table 1). On average, carnivores require areas 21 times larger than herbivores. The five carnivores studied require 2,727 km^2 (range 49 to 12,500 km^2) to sustain a viable population whereas the four herbivores demand, on average, 127 km^2 (range 33 to 278 km^2; Table 1).

The proportion of parks that provide areas large enough to sustain viable populations of Chilean mammals ranks from 3% to 86% depending on the species. Only 45% of the Chilean parks are suitable for carnivores whereas 79% of them have areas large enough to support viable populations of herbivores (Table 1).

TABLE 1

Areas required to sustain viable populations of Chilèan mammals. Area is the land (km^2) required to sustain a population of 500 individuals; PSA is the percentage of parks where such area is offered; n is the number of parks where a given species is currently present; MA/PA is the ratio between the minimum area required to sustain a viable population (MA) and the area provided by parks (PA).

Areas necesarias para mantener poblaciones viables de mamíferos chilenos. Area es la superficie (km^2) requerida para mantener una población de 500 individuos; PSA es el porcentaje de los parques que ofrecen dicha área, donde n es el número de parques donde se encuentra cada especie; MA/PA es la razón entre el área mínima requerida para mantener una población viable (MA) y el área del parque (PA).

Species	Density (ind/km^2)	source (km^2)	Area	PSA		MA/PA	
				n	%	mean	range
Vicugna vicugna	0.63 - 4.15	1	119-833	5	80	0.29	0.06 - 1.06
Lama guanicoe	0.45 - 15.00	2-3	33-1,000	14	86	1.46	<0.01 - 18.23
Hippocamelus bisulcus	0.02 - 1.80	4-6	278-25,000	13	69	2.44	0.01 - 23.05
Pudu puda	3.85 - 6.25	7	79-128	16	81	11.40	<0.01 - 177.78
Pseudalopex culpaeus	0.13 - 1.37	8-9	357-5,000	38	52	14.19	0.02 - 231.01
Pseudalopex griseus	0.31 - 4.37	7,10	114-1,667	30	60	13.83	<0.01 - 255.56
Conepatus humboldtii	6.25 - 10.30	11	49-79	8	75	4.12	0.03 - 30.38
Puma concolor	0.02 - 0.04	12-13	12,500-25,000	30	3	97.23	0.72 - 581.39
Oncifelis geoffroyi	0.08 - 0.74	14	714-6,250	3	33	3.11	0.37 - 7.22

1. Cattan & Glade (1989); 2. Raedeke (1979); 3. Torres en Marcheti et al. (1992); 4. Wilson (1984); 5. Colomés (1978); 6. Povilitis (1986); 7. Redford & Eisenberg (1992); 8. Crespo & de Carlo (1963); 9. Abello (1979); 10. Durán et al. (1985); 11. Fuller et al. (1987). 12. Currier (1983); 13. Young & Goldman (1946); 14. Johnson & Franklin (1985).

Different species require, on average, from 0.3 to 97 times the areas available in parks in order to attain a population of 500 individuals. *Vicugna vicugna* is protected in five parks, four of which provide enough area. On average, these four parks provide 10.5 times the area required to sustain a viable population, assuming that all habitats are suitable (Table 1). Two of the 14 areas where *L. guanicoe* occurs are smaller than the required area. On average, *L. guanicoe* requires 9% of the area of the 12 suitable parks to attain a viable population. Similarly, for *P. puda*, three of the 16 parks are smaller than the area required, whereas the other 13 parks are large enough, offering 5.6 times the minimum area required. For *H. bisulcus*, nine of the 13 areas are above the minimum size. In these latter parks, *H. bisulcus* could attain a viable population in 24% of the area provided.

The scenario for carnivores is more dramatic. Fewer areas are large enough to support a population of 500 individuals. As for *C. humboldtii*, six out of eight parks are above the minimum area required. On average, these parks provide 6.3 times such an area. Twelve out of 30 parks where *P. griseus* occurs are below 115 km^2, the minimum area required by this species. The remaining 18 offer 2.7 times that area. For its congener, *P. culpaeus*, 20 out of 38 parks are large enough to support a viable population, and they provide 2.3 times the minimum area required by this species. The situation of *P. concolor* and *O. geoffroyi* is more critical. Just a single park where they occur has sufficient area to support a population of 500 individuals of these species. On average, parks are 97 and 3 times smaller than required to sustain a viable population of *P. concolor* and *O. geoffroyi*, respectively. The single park that may sustain a population of 500 *P. concolor* provides only 1.38 times the minimum area, assuming all is suitable habitat.

The nine species considered occur in a total of 49 parks, which average 1,726 km^2. Few parks could sustain their current mammalian fauna. Actually, 38 parks could loose from one to five of those species, depending on park size and species composition (Fig. 1). Seventeen parks may lose one species (most frequently *P. concolor*). However, 10 parks may lose two species (both *P. concolor* and *P. culpaeus* on four cases, and *P. culpaeus* and *P. griseus* on two). Another nine parks may lose up to three species (*P. concolor, P. culpaeus* and *P. griseus* in four ocassions). Finally, one park (Pali Aike National Park, 30 km^2) may lose four species (*P. concolor, P. griseus L. guanicoe* and *C. humboldti)*, one park (Lago Cochrane National Reserve, 84 km^2) may lose five species, where *P. concolor* and the two *Pseudalopex* species would become locally extinct along *O. geoffroyi* and *H. bisulcus*. The mayority of potential extinctions (63 out of 73 cases) will be carnivore species, particularly *P. concolor* (45 out of 63 cases). The most threatened herbivore is *H. bisulcus*, which accounts for four out of 10 extinction of herbivores (Fig. 1). If extinctions do occur, the present geographical distribution of each species will be restricted. The central and southern part of Chile will be the most affected regions by local extinctions (Table 2).

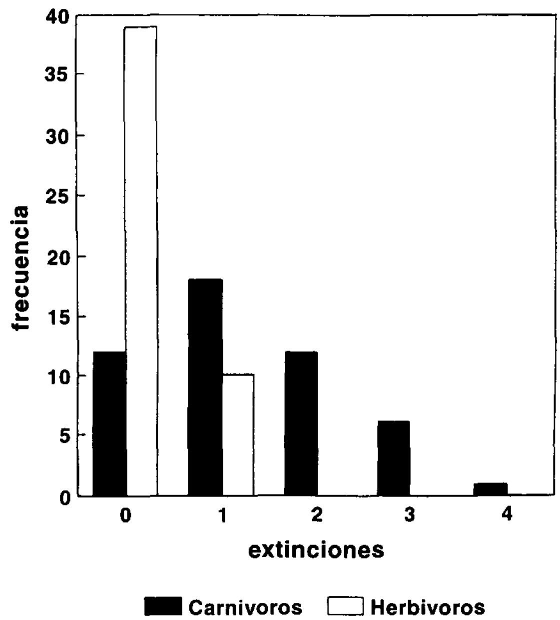

Fig. 1. Frequency distribution of potential extinctions of large Chilean mammals according to trophic status.

Distribución de frecuencias de extinciones potenciales de mamíferos chilenos según categorías tróficas.

TABLE 2

Geographic distribution of potential mammalian extinctions. Figures are the proportion of parks with areas smaller than required to sustain a population of 500 individuals and where extinctions are expected to occur (%EX), and n is the number of parks where the species is currently present. Parks are arranged in geographic regions: North (I to III Administrative Chilean Regions), Central (IV to VII Regions, including the Metropolitan Region), and South (VIII to XII regions).

Distribución geográfica de las potenciales extinciones de mamíferos. Los valores son el porcentaje de parques con áreas menores a las requeridas para sustentar una población de 500 individuos (%EX) y n es el número de parques donde la especie se encuentra presente actualmente. Los parques se han ordenado en regiones geográficas: Norte (Regiones Administrativas de Chile I a III), Centro (Regiones IV a VII, incluyendo la Región Metropolitana) y Sur (Regiones VIII a XII).

Species	North		Center		South		Total	
	%EX	n	%EX	n	%EX	n	%EX	n
Vicugna vicugna	20	5	-		-		20	5
Lama guanicoe	0	3	0	1	20	10	14	14
Hippocamelus bisulcus	-		0	1	33	12	31	13
Pudu puda	-		100	2	7	14	19	16
Pseudalopex culpaeus	0	4	89	9	60	15	48	38
Pseudalopex griseus	0	3	50	6	33	18	40	30
Conepatus humboldtii	-		-		25	8	25	8
Puma concolor	100	3	100	5	95	22	97	30
Oncifelis geoffroyi	-		-		67	3	67	3

DISCUSSION

Increasing evidence suggests that parks and other protected areas are inadequate to conserve large mammals owing to their small size (Miller & Harris 1977, Soulé et al. 1979, Frankel & Soulé 1981, Newmark 1987, 1995, Redford & Robinson 1991). Large-bodied species and carnivores occur at low density, requiring areas usually larger than that provided by parks in order to maintain viable populations. This pattern has been found in parks and other areas representative of both temperate and tropical biomes in North and South America, Europe, and Africa (Schonewald-Cox 1983). Chilean parks are no exception.

Low-density carnivores such as *P. concolor* and *O. geoffroyi*, while protected in parks are still in danger of extinction, because only a single park could sustain viable populations of these species. Lack of congruence between biotic requirements and size of parks seems the norm for *P. concolor* throughout the Americas. Viable populations in western North America as well as in Amazonia will require areas larger than those currently provided. For populations of 500 individuals, North American populations of *P. concolor* require 75,000 to 81,000 km^2, while similar-sized populations require from 5,000 to 17,000 km^2 in Amazonia. In Amazonia, 15 parks are large enough to support such populations, whereas none in the western U.S. has the minimum size (Redford & Robinson 1991, Newmark 1985, 1986; see also Beier 1993). Therefore, this species may be lost despite the protection afforded by parks.

On lesser grounds, all other species may become extinct within a significant fraction of the preserves wherein they were intended to survive. With exception of *V. vicugna,* all other species may be lost from more than one protected area due to size inadequacies. Large herbivores also need areas larger than those of existing parks and reserves. Ungulates use areas 0.01 to 7.0 times the size of parks in western North America (Newmark 1986). More area seems needed to maintain species such as Chilean cervids and camelids. However, the acquisition of new, large land tracts seems unlikely, including those surrounding existing national parks. Cooperative management of adjacent to parks is an alternative, but is not problem-free (e.g., Salwasser et al. 1987, Simonetti 1995, in press).

Extinctions within parks will be local extinctions. All nine species studied currently inhabit at least one park that offers them sufficient area to support a viable population. This spatial redundancy may prevent the extinction of any of these taxa nation-wide. However, the high species-specific extinction probability for species such as *P. concolor* and the two *Pseudalopex* foxes may render the surviving biota an impoverished and nested faunal subset. Large parks may not only sustain a more diverse biota than smaller parks, but the species of these species-poor parks will be a non-random set of the biota of species-rich parks (Mella 1994). In fact, extinction-dominated assemblages tend to exhibit highly nested species composition (Patterson 1987).

Parks from the central region of Chile would be the most affected by local extinctions, associated to their small sizes. All protected areas in this region have areas below 500 km^2. Only two are larger than 300 km^2, while the remaining have areas equal or smaller than 100 km^2. No single park would retain its original fauna, failing to fulfill its objective of perpetuating the local biodiversity. This situation is critical as this region is rich in number of species and endemics[1].

Besides local extinction, population declines may render a species "ecologically extinct" (Conner 1988, Estes et al. 1989). That is, while a given taxon may still be present, its low abundance entails that it no longer interacts significantly with other species. Consequently, several changes in community patterns and processes may be triggered by a given low abundance of the species despite being present (Redford 1992). Therefore, changes in biodiversity and community functioning could be expected even before the local extinction of mammals from parks is actually reached. Being at the top of food chains, the decline of carnivores may trigger quick and complex changes at the prey trophic level, and further.

Our estimates of expected extinctions are conservative. First, we calculated the area needed for attaining a population of 500 individuals. A group of 500 individuals normally implies a smaller effective population (Ne) size, because breeding individuals are usually a fraction of the total population, and because sex ratios, social structure and individual differences in number of progeny impinge on determining the size of the breeding population, among other factors (Franklin 1980). For Chilean mammals, a population of 500 individuals implies effective populations of 83 to 125 breeders (Mella 1994). Effective populations of this size may lost a significant fraction of their genetic information in less than 50 generations, diminishing their long term viability (Schonewald-Cox et al. 1983).

Migration reduces the effective population size required to maintain a genetically viable population (e.g., Samson et al. 1985). Therefore, movements between parks should be allowed or animal rellocations should be performed in order to increase the survival probabilities of large mammals protected, and eventually isolated, in parks. Second, our estimates are based on the species' highest density, which determines the lowest area requirements. Furthermore, densities usually are evaluated in small scale studies, which underestimate space requirements at larger scales (Schonewald-Cox & Buechner 1991, Schonewald-Cox et al. 1991). Third, our analysis assumes that the area provided by each park offers 100% suitable habitat for the focal species. Probably this is false for the majority of species, particularly in protected areas that contain glaciers and lakes. In fact, the area of Laguna San Rafael National Park decreases from 17.420 km^2 to 8.942 km^2 when the surface occupied by glaciers and lakes are excluded. Similarly, Río Pascua National Reserve diminishes from 11.965 km^2 to 8.930 km^2 and Torres del Paine National Park from 1.814 km^2 to 1.240 km^2 when such corrections are made. If these assumptions proved unrealistic, the estimated suitability of the parks would also decrease. Therefore, even under these very conservative conditions, the protection afforded by Chilean parks seems insuffi-

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cient to conserve viable populations of large mammals. Complementary approaches are urgently needed.

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