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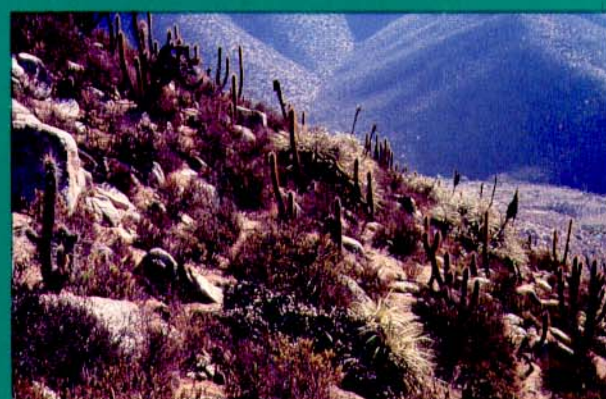

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CONSERVATION OF THE LAST WILD CHINCHILLA (*Chinchilla lanigera*) ARCHIPELAGO: A METAPOPULATION APPROACH

JAIME E. JIMÉNEZ[1], Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida 32611 U.S.A. (Tel: 1-904-392-4851; FAX: 1-904-392-6984)

ABSTRACT

The last wild Chilean chinchilla (*Chinchilla lanigera*) populations persist in 42 discrete colonies around Aucó (31°30'S, 71°06'W), a semi-arid locality in northcentral Chile. The species almost went extinct due to overexploitation for its valuable fur. Although well-protected within the boundaries of the 4,570-ha Chinchilla National Reserve (CNR), the number of wild chinchillas appears still to be declining. I examined the spatial and shape attributes of this chinchilla archipelago as well as those of the protected area using a metapopulation approach. Most chinchilla colonies are currently unprotected, although they occur relatively close to the CNR. Colonies are located primarily on steep north-facing slopes, and range in size from 1.5 to 113.5 ha. Most have less than 50 individuals; none has more than 500. Colonies within the CNR are closer to each other compared to those outside the protected area. In addition, they have more edge than unprotected colonies. The edge of the CNR is about twice as long compared to the ideal circular form, which makes it highly susceptible to the effects of external threats. I analyzed the potential impacts of human settlements around the CNR, such as the presence of domestic predators and herbivores, as well as disturbances caused by local vehicle traffic and found that they can be significant. I also compared spatial relationship of predators and chinchilla colonies. In order to protect more colonies and to keep natural processes operating, such as the metapopulation dynamics, I propose that the CNR be enlarged.

KEY WORDS: biogeography, Chile, chinchilla, *Chinchilla lanigera*, metapopulation, population dynamics, reserve design

RESUMEN

Las últimas poblaciones de chinchilla chilena (*Chinchilla lanigera*) silvestre persisten como un grupo de 42 colonias en los alrededores de la localidad semiárida de Aucó (31°30'S, 71°06'O), en Chile centronorte. La especie fue casi extinguida debido a sobreexplotación por su apreciada piel. A pesar de encontrarse bien protegidas en las 4.570 ha de la Reserva Nacional Las Chinchillas (CNR), el número de chinchillas parecen seguir disminuyendo. En un contexto metapoblacional, examiné variables espaciales y de forma de este archipiélago de chinchillas, así como del área protegida. La mayoria de las colonias de chinchilla se encuentran sin protección, pero cercanas a la CNR. Ellas ocupan principalmente las laderas de exposición norte con bastante pendiente. El tamaño de las colonias varía entre 1,5 a 113,5 ha, teniendo la mayoría de ellas menos de 50 individuos y ninguna más 500. Las colonias al interior de la CNR se encuentran más cercanas entre sí, pero presentan más borde relativo al área, comparadas con aquellas no protegidas. La CNR tiene cerca del doble del borde esperado para una forma ideal circular, lo que la hace altamente susceptible al efecto de agentes externos. Al respecto, analicé impactos potenciales de asentamientos humanos en la periferia de la CNR, tales como la presencia de depredadores y herbívoros domésticos y perturbaciones producto del tráfico vehicular local, todos los cuales pueden tener efectos negativos en las chinchillas. También comparé relaciones espaciales entre predadores y colonias de chinchillas. Con el propósito de proteger un mayor número de colonias y de mantener procesos naturales, tales como la dinámica de la metapoblación, sugiero ampliar la CNR.

PALABRAS CLAVE: biogeografia, Chile, chinchilla, *Chinchilla lanigera*, dinámica poblacional, metapoblación, diseño de reservas

RESUMO

As últimas populações de chinchila chilena (*Chincilla lanigera*) silvestre persistem como um grupo de 42 colônias ao redor da localidade semiárida de Aucó (31°30'S, 71°06'O), no centro-norte do Chile. A espécie foi quase extinta devido à sobre-explotação por sua apreciada pele. Apesar de se encontrar bem protegida nas 4.570 ha da Reserva Nacional Las Chincillas (CNR), as chinchilas parecem seguir diminuindo. Em um contexto metapopulacional, examino variáveis espaciais e de forma deste arquipélago de chinchilas, assim como da área protegida. A maioria das colônias de chinchilas se encontram sem proteção, mas perto da CNR. Elas ocupam principalmente as ladeiras de exposição norte com bastante pendente. O tamanho das colônias varia entre 1,5 a 113,5 ha, tendo a maioria delas menos de 50 individuos e nenhuma mais de 500. As colônias no interior da CNR se encomtram mais perto entre si, mas apresentam mais borda relativa à área, comparadas com aquelas protegidas. A CNR tem aproximadamente o dobro da borda esperada para uma forma circular ideal, o que a faz altamente suscetível ao efeito de agentes externos. Ao respeito, analiso impactos potenciais de assentamentos humanos na periferia da CNR, tais como a presença de predadores e herbívoros domésticos e perturbações produto do tráfico automotor local, todos os quais podem ter efeitos negativos nas chinchilas. Com o propósito de proteger um maior número de colônias e de manter processos naturais, como a dinámica da metapopulação, sugiro ampliar a CNR.

PALAVRAS-CHAVE: biogeografia, Chile, chinchila, *Chinchilla lanigera*, dinâmica populacional, metapopulação, desenho de reservas

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The Chilean chinchilla is a medium-sized rodent currently classified as endangered (Glade 1988). Historically, the species was widely distributed throughout most of northcentral Chile (Jiménez, in press). Chinchilla fur is considered among the finest and softest in the world (Grau 1986, Mohlis 1983). Due to over-harvesting for its valuable fur, chinchilla populations were extirpated from most of their range and reduced to near extinction at the beginning of the century (Albert 1901). Despite a 1929 law protecting the species (Iriarte and Jaksic 1986), the rough topography of the region and inaccessibility of chinchilla habitats serious-

[1]Current address: Ecology Center and Department of Fisheries and Wildlife, Utah State University, Logan, Utah 84322-5210 U.S.A. (Tel: 1-801-797-2459; FAX: 1-801-797-1871; E-mail: sltyn@cc.usu.edu)

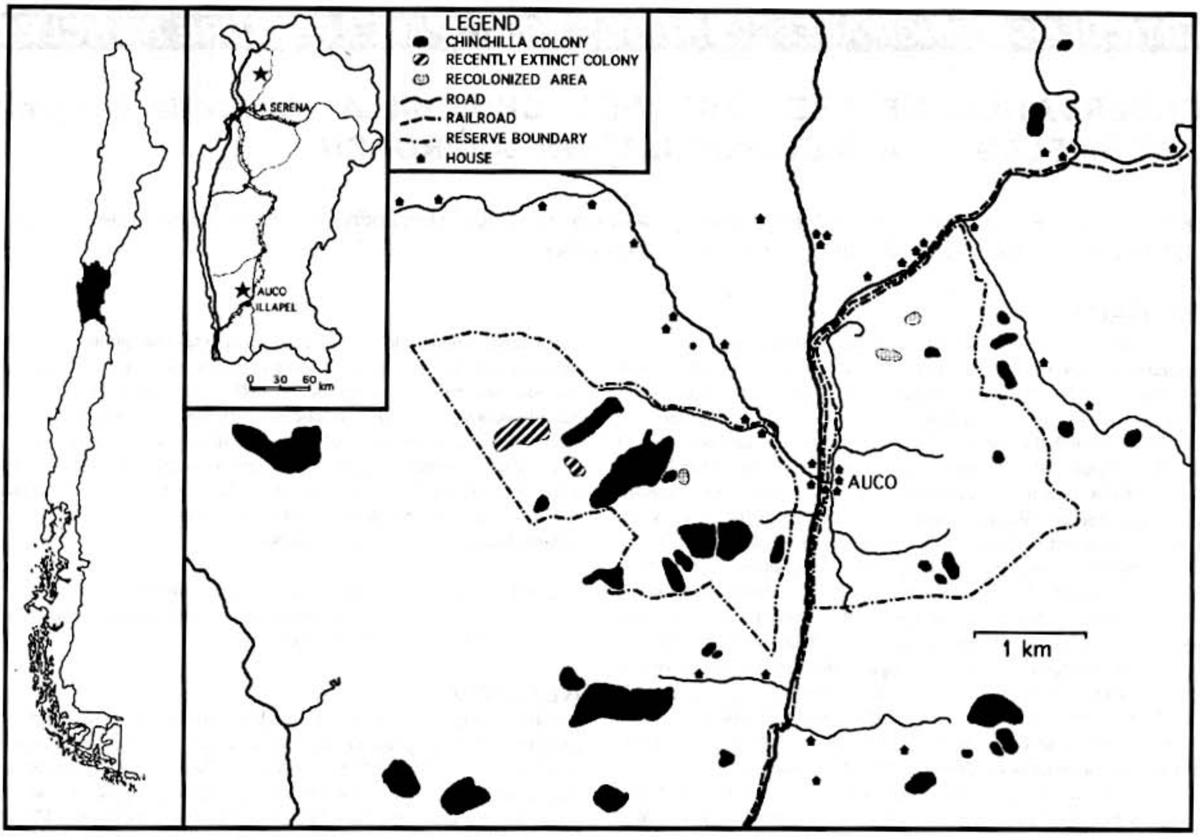

Figure 1. Spatial distribution of chinchilla (*Chinchilla lanigera*) colonies in the Aucó area and in the Chinchilla National Reserve. Stars indicate current known distribution of the species. Recently recolonized areas and local chinchilla extinction areas are shown.

ly handicapped enforcement efforts, and poaching continued at least until 1968 (Jiménez, in press).

By the 1950's the species was considered extinct in the wild (Mann 1978). However, in 1975 the combined efforts of CONAF (Chilean Forest Service), Connie Mohlis (US Peace Corps) and a knowledgeable chinchilla hunter led to the rediscovery of scattered populations close to the town of Aucó, in northcentral Chile (31°30'S, 71°06'W; Fig. 1; Mohlis 1983). CONAF established the Chinchilla National Reserve (CNR) in 1983, and excluded mining, cattle, goats, and other human activity. The protected area was fenced by 1987 (Jiménez 1990).

In contrast to captive stocks, the biology of the wild chinchilla is poorly known (Grau 1986, Jiménez, in press). Between 1985 and 1990, more isolated chinchilla populations were discovered around Aucó and a 46-ha isolated colony was found approximately 250 km north of Aucó (29°33'S, 71°04'W; see stars on Fig. 1). All of them were located outside the protected area.

The chinchilla currently is distributed in discrete colonies of various sizes in a naturally patchy environment. A recent study at Aucó showed that within the past decade the area covered by chinchilla colonies at CNR was reduced by 50%. Both the number and size of colonies are decreasing and becoming more fragmented (Jiménez 1990). However, while some colonies are disappearing, others are appearing in areas where colonies had formerly disappeared.

The topography of preferred chinchilla habitat is very rugged and naturally fragmented in a mosaic arrangement. Thus, chinchilla colonies occupy suitable habitat patches surrounded by a heterogeneous matrix of ecologically hostile habitat (Henderson *et al.* 1985). This spatial distribution creates an interesting scenario from the perspective of conservation and biogeography because it is an array of different-sized patches scattered throughout a heterogeneous landscape (Smith 1974).

A previous study (Jiménez 1990) suggested that most colonies are too small to be viable even on the short-term and are vulnerable to local extirpation (Lacy 1987, Thomas 1990). The dynamics of a metapopulation, located in interconnected patches with various degrees of isolation (Bleich *et al.* 1990, den Boer 1981, Fahrig and Merriam 1985, Henderson *et al.* 1985, Smith 1974) may explain the persistence of chinchilla in this heterogeneous landscape. This paper examines the size, distribution, and intercolony distances for chinchilla in the area of Aucó. I also explore potential impacts of human settlements, roads (Noss and Harris 1986, Wood and Samways 1991), the shape of chinchilla colonies, and of the CNR (Laurance and Yensen 1991, Saunders *et al.* 1991) on population persistence. I rely on a geographical information system (Aronoff 1991) to make crucial predictions which will guide management and conservation decisions for chinchilla populations in the wild using a metapopulation approach (Caughley 1994).

STUDY AREA AND METHODS

The study area was a 20 x 13 km rectangle centered at the locality of Aucó (31°30'S and 71°06'W), 17 km north of the town of Illapel in northcentral Chile (Fig. 1). The climate is semi-arid, and topography is rugged, with steep slopes intersected by deep ravines and a few interspersed flatlands at elevations ranging from 400 to 1900 m (Jiménez 1990, Jiménez *et al.* 1992). Topographic information was derived from IGM (Chile's Military Geographical Institute) maps from 1967 (1:50,000 scale).

Distribution of the colonies was documented by exploring the entire area on foot from 1988 to 1990 (Jiménez 1990) and monitoring presence of chinchilla droppings. Location, extension, and shape of each colony, as indicated by droppings, was recorded on topographic maps. According to slope and aspect of the landscape, six patch types (habitats) were recognized (Jiménez 1993). Non-horizontal surface area was calculated for each patch type according to each patch's mean slope angle.

I calculated colony population density (size) by multiplying the mean ecological density of chinchillas from trapping estimates (mean±1 SD = 4.37±1.09 ind./ha from three colonies; Jiménez 1990) by the area of each colony. I measured the distance of each colony to the nearest neighbor colony and calculated mean distance of each colony to its five nearest colonies. Finally, using a shape index (SI *sensu* Patton 1975) I calculated the departure from the ideal round-shaped form for the CNR.

Spatial analyses were performed with a PC ARC/INFO system (ESRI 1990). All information was manually digitized from maps, in several separate coverages (or layers; *e.g.*, colonies, roads, boundaries), previously transformed into the UTM format (Aronoff 1991). Coverages were overlaid to spatially relate different landscape elements (*e.g.*, houses and colonies). Distances were measured on the screen with the DISTANCE command in ARCEDIT and the MEASURE command in ARCPLOT. For creating impact zones around some map elements (*e.g.*, houses, roads) I used the BUFFER command. Both the areas and perimeters for polygons were obtained from the polygon attribute tables (PAT files) displayed and manipulated with DBASE.

Table 1. Slope and surface area of different habitat types in the Chinchilla National Reserve. Figures for slope are mean ± 1 standard deviation, and range (10 different locations in each habitat type). The first four habitat types are named according to slope aspect.

	SLOPE (°)		AREA (ha)[a]	
Habitat	Mean ± S	Range	Uncorrected	Corrected
North	24.0 ± 4.6	18.4-32.8	1820	1993
South	24.6 ± 6.2	17.1-38.7	754	829
West	21.5 ± 4.8	15.5-27.8	396	425
East	25.0 ± 5.5	16.0-35.5	239	264
Flatland	5.6 ± 3.8	0.8-14.0	631	634
Ravine	8.7 ± 2.4	4.8-14.0	420	425
TOTAL			4260	4570

[a]Uncorrected=horizontal surface area
Corrected=non-horizontal surface area

Statistical analyses were performed using SAS software (SAS Institute, Inc. 1988). Because assumptions for parametric tests were not met by the data, the PROC NPAR1WAY (SAS Institute, Inc. 1988) was used to test for differences between medians. For comparison between two samples, SAS uses the Wilcoxon rank-sum test (which is equivalent to the Mann-Whitney U test; SAS Institute, Inc. 1988:714) with normal approximation (one and two-tailed tests). Log-likelihood ratio tests or G-tests (Sokal and Rohlf 1995:688) were used for goodness-of-fit with discrete distributions.

RESULTS AND DISCUSSION

Colony Location

Nineteen of the 42 colonies (45.3%) occurred within the CNR, with one colony bisected by the reserve boundary (Fig. 1). In this analysis, the latter was considered within the protected area.

While the four aspect types had similar reliefs, the flatlands and ravines were almost horizontal with little slope (Table 1). In an area such as Aucó, with great topographic relief, the use of non-horizontal surface area is important because it increased the area depicted by a flat surface area projection by over 7%. In decreasing order of surface area the aspects were north-, south-, flatland, ravine, west-, and east-facing slopes (Table 1).

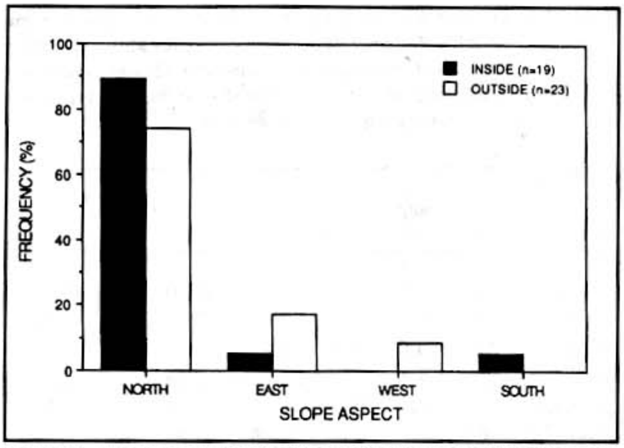

Figure 2. Frequency distribution of location of chinchilla colonies inside and outside the protected area at Aucó in relation to topographic aspect.

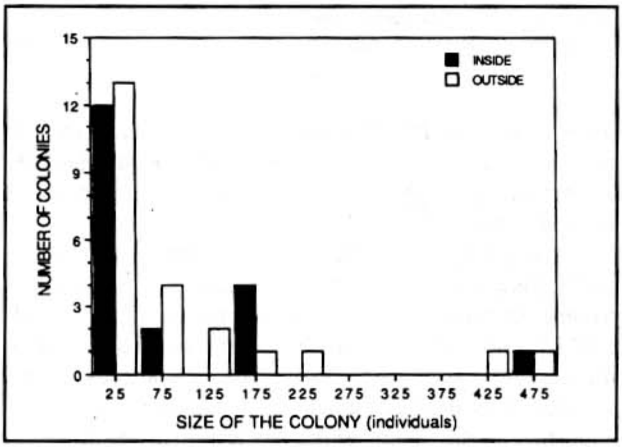

Figure 3. Size distribution of chinchilla colonies inside and outside the protected area at Aucó, Chile.

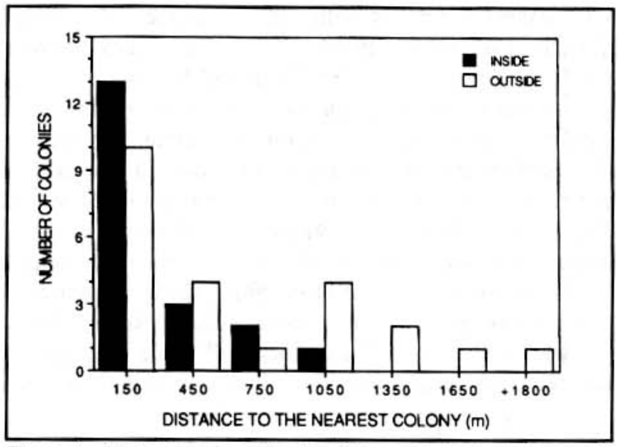

Figure 4. Distance of each chinchilla colony to the nearest colony inside and outside the protected area at Aucó, Chile.

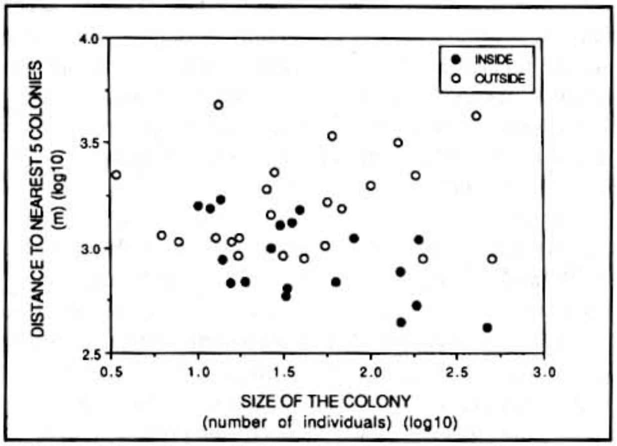

Figure 5. Size and mean distance of each chinchilla colony to the five nearest colonies at Aucó, Chile.

Chinchilla colonies did not occur in the different habitats as expected by their respective availabilities both inside (G=37.1, d.f.=3, P<0.001) and outside (G=38.5, d.f.=3, P<0.001) the CNR. The majority of colonies (81%) occurred on north-facing slopes (Fig. 2). Only one colony occurred on a south-facing slope, probably because the area had rocks and boulders that chinchillas use for establishing burrows (Jiménez 1990). No colony was found in ravines or flatlands. This agrees with the fact that north-facing slopes have less vegetation cover, more boulders, thorny bromeliads, and cacti than other habitat types, with which chinchilla are positively associated (Jiménez 1990).

Colony Area and Size

The colonies ranged in area from 1.5 to 113.5 ha. Irrespective of their location (*i.e.*, inside or outside the CNR), colony sizes were similar (Z=0.25, P=0.80). However, the majority of colonies had relatively small populations; 59.5% of them had less than 50 individuals, whereas none had more than 500 individuals (Fig. 3). The upper-size limit appears to be dictated by habitat patch size (*i.e.*, the grain of the landscape topography).

Colony size (*i.e.*, number of individuals) is important because risks of local extinctions are inversely correlated with number of individuals in a unit (den Boer 1981, Smith 1980). Smaller colonies are more vulnerable to stochastic events and have a higher risk of extinction (Shaffer 1981, Soulé and Wilcox 1980, see also Thomas 1990). This is very important for a slowly-reproducing species inhabiting an extremely variable environment, as occurs with chinchi-

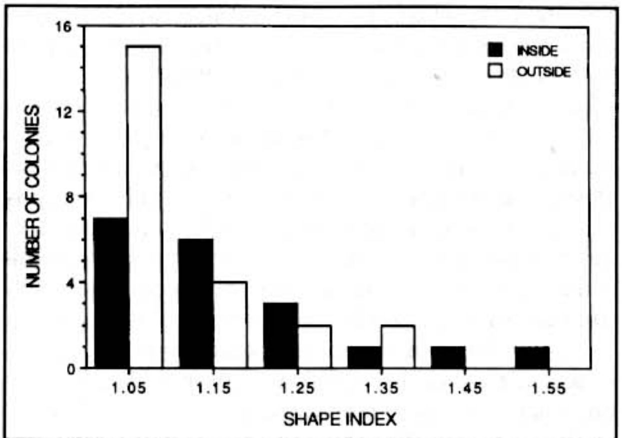

Figure 6. Frequency distribution of the shape index (SI) applied to chinchilla colonies. SI indicated the degree of deviation from circularity (a perfect circle has an SI = 1).

llas at Aucó (Jiménez 1990, Jiménez *et al.* 1992). In addition, colony size is also important because the ratio of edge to area increases inversely in relationship to patch size. Thus, the more abundant, small, chinchilla colonies will be relatively more affected by edge effect than larger colonies.

Colony Isolation

The relative isolation of chinchilla colonies, measured either as distance to the nearest neighbor or as mean distance to the five nearest colonies, revealed that, on average, colonies found inside the CNR were closer to each other than those located outside the protected area (Z =1.921, P=0.031, and Z=3.080, P=0.0019, respectively; Figs. 4 and 5). For instance, within the CNR there was no colony whose nearest neighbor was farther than 1,200 m, whereas outside the protected area four of the colonies were more than 1,200 m apart. Outside the CNR, there were seven colonies whose mean distance to the nearest five neighbors was greater than 2,000 m, whereas none were within the boundary. This pattern indicates that the CNR includes those colonies in the center of the archipelago.

All things being equal, the probability of colonization or movement of individuals (*i.e.*, gene flow) among colonies will decrease with distance (Smith 1980). Intercolony distances are therefore important. Theory also predicts that source size, as well as the target colony, may be important in the colonization process. However, there was no association between colony size and distances between colonies (Fig. 5).

The Importance of Shape

Shape is another important variable to consider when protecting a discrete patch. Shape relates the proportion of edge relative to area, to the extent that it is minimized in a circular form. Because most external disturbances permeate across the edge, the further the shape departs from a circular form, the more edge it has relative to the area, and hence more exposure to the altered surrounding (Laurance and Yensen 1991).

Instead of being continuous and circular (Diamond 1975) the CNR is split into two fragments, which have irregular shapes (Fig. 1). The proportion of edge to area is 27% and 46% higher for each protected fragment compared with the ratio for circular surfaces with the same area. Furthermore, when the CNR is considered as a whole, the proportion of edge increases to almost twice (SI=1.928 or 1.9 times more edge to area than a circular surface of the same area). Hence, by being split and having a clearly non-circular shape, the form of the CNR greatly departs from the ideal form if the goal is to minimize edge effects.

The same type of analysis can be done for the shape of the chinchilla colonies. On average, within the CNR, colonies had more edge relative to their area, whereas on the outside, they were rounder (Fig. 6; SI mean±SD: 1.18 ±0.14 and 1.12±0.09, respectively; Z=1.747, P=0.044). By having a more elongated shape, the protected colonies may be more exposed to risks coming from the surroundings, such as predators, diseases, etc.

The Metapopulation Approach

The most probable explanation for the long-term persistence of this population is its function as a metapopulation (Hanski and Gilpin 1991, Jiménez 1990). This is because of the disparate sizes, the great variability in distance between colonies, and the local extinction of colonies and recolonization of habitat patches. For the smallest colonies to persist in time, they must be interconnected by corridors that would enable them to maintain the local extinction-colonization dynamics (Bleich *et al.* 1990, den Boer 1981, Harris 1984, Lacy 1987, Noss and Harris 1986).

The empirical evidence for the metapopulation idea is supported by my observations during a 3.5-year study of chinchillas (Jiménez 1990). During that period, two colonies became extinct, while three others were recolonized after becoming extinct (Fig. 1). In addition, circumstantial evidence over a longer time period also supports the idea of connectivity among colonies. During a 10-year period, four colonies disappeared and five were recolonized (Jiménez 1990). Rapid mortality of chinchillas, as well as reproduction by founder individuals (chinchillas have one or two litters of one or two young a year; Jiménez, in press), does not account for these local and fast extinction/recolonization phenomena.

The maximum linear distance moved by 15 chinchillas was 65.8±19.6 m (mean±1 SD), as estimated by trapping data during several months in two colonies. Direct observations with spotlights and of radio-collared individuals also indicated that chinchillas are very mobile. Even though chinchillas can move quickly and continuously, they are highly philopatric, generally remaining in the same area for at least several months. Three individuals remained in the same spot for at least 6 years. However, some chinchillas moved linearly at least 250 m in one night (Jiménez 1990), which indicates that chinchillas can potentially move considerable distances. Additional evidence that supports colony movement comes from monthly transect studies of three colonies at different elevations on the slope. The temporal abundances of chinchilla feces indicated that entire colonies had seasonal altitudinal movements of at least 100 m (Jiménez 1990).

The Surrounding Matrix

In addition to shape, colony size and isolation, the nature and quality of the surrounding landscape matrix is important for conservation purposes (Janzen 1983, Lankester *et al.* 1991). For example, the matrix may play an important role in limiting movement of individuals among patches, or by serving as corridors that, while not suitable habitat, are permeable enough to permit chinchilla movement (Bleich *et al.* 1990, Henderson *et al.* 1985, Lankester *et al.* 1991, Smith 1974, Weddell 1989).

The quality of the environment in which chinchilla colonies occur has changed dramatically over time. Increased desertification of the entire region due to overgrazing by goats, inappropriate agricultural practices, woodcutting, and extensive mining activities has led to an impoverishment of the matrix (Bahre 1979, Fuentes and Hajek 1979). This may have altered the connectivity of the chinchilla archipelago by transforming previously suitable corridors into inhospitable barriers (Noss 1987) increasing intercolony isolation.

Chinchillas are Still Declining: Some Threats

So far, there is no clear explanation for the continued decline of the remaining wild chinchilla populations (Jiménez, in press). Several hypotheses regarding the major threats faced by chinchillas were offered by Jiménez (1990, 1993). By using GIS, it is now possible to explore those concerning spatial relationships.

Predators

Major predators of chinchillas include great horned owls (*Bubo virginianus*) and foxes (*Dusicyon* spp.) (Jaksic *et al.* 1992, Jiménez 1990). Spatial associations are explained by combining diet analyses with radio-locations, sightings, predator captures, and chinchilla colony locations. No information on habitat associations by owls exist for Aucó. For foxes, the situation is complicated because two sympatric species use the area: chillas (*Dusicyon griseus*) and culpeos (*D. culpaeus*) (Jiménez 1990, 1993).

Little is known about the biology of these canids. A 7-month study of trapping and radiotracking both fox species (Jiménez 1993) generated valuable spatial information. Contrary to the larger culpeo, the smaller chilla primarily uses flatlands more than ravines. Chilla live closer to human habitations than the culpeo. Both activity patterns and capture data showed that chilla, unlike culpeo, generally lived farther from the chinchilla colonies ($G=3.97$, $d.f.=1$, $P=0.046$). Three of four culpeo home ranges included all or part of a chinchilla colony within their borders, whereas no chilla were found near chinchilla colonies. The five chillas, and three of the four culpeos, captured within the CNR, moved outside the protected area at least once.

The evidence, however, does not support the hypothesis that increased predation pressure by foxes is the cause of the chinchilla decline (Jiménez 1993). Although previous studies indicated that chinchillas were preyed upon by foxes (Durán *et al.* 1987, Jaksic *et al.* 1992, Jiménez 1990), since 1990 no chinchilla parts were found in fox diets (Jiménez 1993).

Human Impacts

Since the CNR is not a true island (Janzen 1983, Wilcox 1980), there is a permanent threat from surrounding habitat (see also the edge effect below), both in terms of immigration and emigration of animals (*i.e.*, chillas and culpeos; Laurance and Yensen 1991, Mwalyosi 1991, Saunders *et al.* 1991). It is relatively easy to create buffer zones around human habitations, to mitigate the potential negative impacts of human settlements close to the CNR (Fig. 1). Although the CNR is fenced, this fence is not a barrier for small- and medium-sized domestic animals such as dogs and cats, both present in most houses in the area. Within the CNR boundaries, I have observed cats and dogs on four occasions, and have trapped two dogs at distances greater than 2,000 m from their owners' houses. By creating buffer zones around houses, I found that only 33% of the chinchilla colonies (14/42) were located >2,000 m from houses. This suggests the threat of having human settlements with domestic carnivores close to chinchillas.

Other indirect effects relate to habitat quality. Illegal trespassing for mining and firewood collection alter the landscape (Jiménez, pers. obs.). The fence provides an effective barrier against goats and other domestic livestock. However, intensive overgrazing occurs up to the wire mesh on all boundaries. This process keeps a highly altered landscape outside the boundary reinforcing the insular nature of the protected area. This represents another, less obvious, threat to chinchillas (Bahre 1979, Janzen 1983).

The road system can also be detrimental to the protected biota. Heavy traffic on public dirt roads (as well as a railroad) that bisect the area (Fig. 1) can have a great disturbance effect (*e.g.*, on average, one heavily-loaded mining truck passes hourly). Besides traffic noise and dust, roads may act as potential barriers to free movement and dispersion of chinchillas between the two protected fragments (Grinnell 1914, Harris 1984, Noss and Harris 1986), thus helping to maintain isolation between the two small protected areas.

The potential impact of both houses and roads close to the CNR can be significant. Following the "core-area model" (Laurance and Yensen 1991), indirect human impact such as potential effect of houses (by having carnivores and grazers and by firewood collection and developing agricultural practices) and roads close to the CNR edge, will leave only a small portion of the entire area unaffected (Fig. 1).

CONCLUDING REMARKS

Current distribution of the last wild population of chinchillas was analyzed in light of conservation goals. Several spatially-related concepts such as size, shape, isolation, and connectivity of targeted units, as well as the condition of the environment and human related threats, have been examined in context of the chinchilla's current status. Most concepts are related and interdependent, and appear to be crucial for long-term conservation of the species.

Evidence indicates that the archipelago of chinchilla colonies behaves as a metapopulation (Hanski and Gilpin 1991, Lankester *et al.* 1991). Thus, for conserving the species, it is important to preserve a minimum dynamic area (Pickett and Thompson 1978) containing chinchilla colonies, and a matrix of barriers with more permeable corridors, as well as buffer zones, to protect the colonies from external sources of disturbance (Ehrlich and Murphy 1987, Mwalyosi 1991). More than just preserving the species, we should try to keep biological processes operating; however, natural biological processes such as dynamics of local extinctions and colonizations may have been altered to the point that a metapopulation is no longer sustainable. Passive protection alone does not appear to be the solution for rescuing the chinchilla from extinction. Active management by mimicking recolonization through forced colonization or induced migration may also assure the persistence of the natural chinchilla archipelago.

External threats that permeate through the edge decreases as the patch shape approaches a circular form. A larger patch size also decreases the effect of surroundings, leaving a larger core area unaffected. Although shape and size of chinchilla colonies are difficult to manipulate, protected areas can be changed to make them more efficient in achieving its goal. In this regard, I propose to increase the size of the CNR to the south to protect the adjacent colonies. This would include several currently unprotected chinchilla colonies, and will also make the protected area more circular. The road and railroad, which bisect the CNR, are more difficult to remove because of conflicting interests with local communities. A buffer zone around the CNR should also be established and CONAF should discourage the establishment of new families close to the CNR border to achieve the purpose for which the Chinchilla National Reserve was created.

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