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# Long-term changes in landscape and in small mammal and raptor assemblages in central Chile

Cambios de largo plazo en el paisaje y los ensambles de micromamíferos y rapaces en Chile central

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**ABSTRACT**

San Carlos de Apoquindo, a piedemont area to the east of Santiago city, is a site with 30 years of data on vertebrates. Using LANDSAT satellite imagery for the years 1975, 1989 and 2003, we studied the spatio-temporal trajectory of land use and its putative effects on vegetation, small mammals and raptors. On the basis of a landscape-level analysis, we interpreted long-term trends in the abundance of small mammals and in the diet of raptors. Satellite imagery reveals an accelerated expansion of the urban area in detriment of agricultural land and native scrubland. Native mammal species of small and medium size do not display large variation of abundance during the 30 years study period, but larger-sized native mammals show reduced population numbers. The European rabbit (*Oryctolagus cuniculus*) currently is among the most abundant mammal species in the area, and seems to be favored by the temporal transition from dense to sparse scrubland. In the diets of Chilean Eagle (*Geranoaetus melanoleucus*) and of native Harris' Hawk (*Parabuteo unicinctus*) there is a marked decrease of the native rodent prey *Octodon degus* and a concomitant increase of the exotic prey *Oryctolagus cuniculus*. In addition, there is a decreasing trend in richness and abundance of raptors throughout the study period, which is associated to both urban expansion and scrubland fragmentation and reduction. We propose that urban encroachment, together with areal reduction and fragmentation of native scrubland, has resulted in a decrease of the *Octodon degus* population, and in its subsequent decrease in the diet of both native eagles and hawks, which in turn has determined increased predation on exotic rabbits.

**Key words:** invasive species, landscape ecology, native species, temporal trends.

**RESUMEN**

San Carlos de Apoquindo, en la precordillera de Chile central, es una localidad con estudios de larga data en vertebrados (ca. 30 años), situación favorable para el análisis de procesos de largo plazo que operan sobre dichos ensambles. En este contexto estudiamos la trayectoria del uso del suelo mediante imágenes satelitales LANDSAT, correspondientes a 1975, 1989 y 2003 y su presunto efecto sobre la vegetación, micromamíferos y aves rapaces. El análisis de las imágenes satelitales revela una expansión acelerada del área urbana en desmedro del suelo agrícola y matorrales naturales. Las especies de micromamíferos nativos de talla reducida y media no evidencian grandes variaciones de abundancia durante el período de estudio pero las de mayor tamaño redujeron sus poblaciones. El conejo europeo (*Oryctolagus cuniculus*) es una de las especies más abundantes del área, y estaría siendo favorecido por la modificación del paisaje. En la dieta del águila (*Geranoaetus melanoleucus*) y del peuco (*Parabuteo unicinctus*) se observó una disminución sostenida de la principal presa nativa, el degú (*Octodon degus*) y un aumento de la presa exótica, el conejo. Además se observó una tendencia a la disminución de la riqueza y abundancia de aves rapaces durante el período de estudio, la que se asociaría a la expansión urbana y al deterioro del matorral natural. Postulamos que la expansión urbana y la pérdida y fragmentación del matorral han producido una disminución de la población de degú, con su consecuente disminución en la dieta de águilas y peucos, lo que a su vez ha potenciado un incremento de depredación sobre conejo.

**Palabras clave:** ecología del paisaje, especies invasoras, especies nativas, tendencias temporales.

## INTRODUCTION

The five Mediterranean regions of the world stand out due to their rich biota and high degree of endemism.

Mediterranean central Chile is considered among the 34 critical areas for conservation, due to its high environmental value and because it is subjected to a strong anthropic pressure (Meyers et al. 2000, Conservation International 2007). Former Chilean vegetation was dominated by sclerophyllous forests (Gajardo 1994), which have been degraded to a fragmented scrubland.

Santiago City, the Capital of Chile, is located approximately 550 m above sea level, and shelters ca. 6 million inhabitants within its 15,800 km$^2$ area. Santiago occupies a large extension of the valley of the Metropolitan Region, which is one of the most representative areas of the Chilean Mediterranean ecosystem (di Castri 1968). Accelerated human population growth in absence of sustainable management resulted in a fast and chaotic expansion of the city towards the piedmont area of the Andean mountain range. Currently, urbanized areas have reached 1,000 m above sea level, causing an important loss of natural habitats and environmental problems such as atmospheric pollution due to dust, loss of soils, inundations, and shortage of green areas (Hajek et al. 1990, Romero et al. 1999, GORE-RM 2000[1])

There is scarce evidence on the impacts of the rapid and dramatic modification of the landscape of central Chile on the native fauna. However, Romero et al. (1999) and Romero & Órdenes (2004) indicated that the fast growth of Santiago City had polluted soils, water and air, and that it had affected the water retention and infiltration capacities of the soil, produced fragmentation of the natural vegetation, and the interruption of corridors for the native fauna. At a national scale, other studies have reveled important effects of landscape modifications (towards human use) on biodiversity, such as the southern cases of the urban area of Concepción (Pauchard et al. 2006) and Lake Budi (Peña-Cortés 2006). Currently, assigning conservation categories to native flora and fauna in Chile are fundamentally based on the concepts of populations and species (Glade 1988, Núñez et al. 1997, Cofré & Marquet 1999, Díaz-Páez & Ortiz 2003). This approach frequently results in a subjective evaluation of "endangered species" which does not take into account the actual situation of the environments those species inhabit.

In this study we assessed the potential effects of landscape transformation on the factors that sustain animal populations. To do this, we analyzed the change experienced by the piedmont landscape of Santiago during a period of ca. 30 years and determined population trajectories of small mammals and raptors recorded in a long term research carried out at San Carlos de Apoquindo, at the piedmont of the central Chilean Andes range.

[1] GORE-RM (2000) Proyecto de ordenamiento territorial ambientalmente sustentable para la Región Metropolitana. Primera etapa: Evaluación ambiental. Gobierno Regional de la Región Metropolitana - Universidad de Chile, Santiago.

## METHODS

### *Study Area*

For the landscape analysis, we arbitrarily defined a rectangular area of 52,620 ha on the east margin of the valley of Santiago, in the Metropolitan Region, incorporating the locality of San Carlos de Apoquindo (Fig. 1). This area includes the eastern section of Santiago City and the piedemont area up to 2,000 m above sea level. The northern boundary was defined by the Mapocho river and the southern boundary by the Maipo river, and its center was located approximately at 33°30' S and 70°30' W. The natural vegetation is Mediterranean shrubland of sclerophyllous type. However, there is less scrub cover at equatorial-exposed hillsides, which are instead dominated by cacti and bromeliads, and at lower elevations there is a savanna physiognomy dominated by *Acacia caven* (Mol.). Sclerophyllous forests dominate at the bottom of ravines and on hillsides with polar-exposure (often degraded to a dense scrub), and dominated by soap bark tree *Quillaja saponaria* (Mol.), litre *Lithrea caustica* (Mol.), boldo *Peumus boldus* (Mol.) and peumo *Criptocarya alba* (Mol.). Historically, this area has suffered a degradation succession from sclerophyllous forest to scrub due to a combination of fire, logging, and grazing. In recent times, the principal modeling factor of this landscape has been the expansion of the urban frontier towards the east (higher up the piedmont).

### *Spatial analysis*

We used LANDSAT satellite images of the years 1975, 1989 and 2003 for the analysis of vegetation cover and land use change in the study area (79 m pixels for the image of 1975 and 30 m pixels for the remaining images). Each image was georeferenced and each band was corrected geometrically and radiometrically. Thematic maps were made and stored in a system of geographic information, aided by the software ERDAS IMAGINE 5.8, and ARCVIEW 3.2. PATCH ANAYST extension was used for the spatial analysis (Elkie et al. 1999). We defined five categories of vegetation and land use using a supervised classification of the images: urban, agricultural, open scrub, dense scrub (corresponding to tree shaped scrub and sclerophyllous forest) and bare ground or snow cover. Each of these categories was characterized at two scales, type and landscape, for the years 1975, 1989 and 2003. For each type we calculated the total surface, number of patches, and mean size of patches as measures of characterization (McGraigal & Marks 1994). Shape complexity was estimated using fractal dimension (Mandelbrot 1984), a scale invariant indicator that enables to interpret variation in the regularity of shapes as a function of the surface/perimeter relationship.

### *Small mammals*

We chose the location of San Carlos de Apoquindo

(33°23' S 70°31' O, 1,000-2,000 m above sea level) as a reference site for the analyses of historical series of small mammals, where studies have been conducted since 1976. For more information on the site refer to Jaksic (2001). Historical series were obtained from the studies made in 1976 (Jaksic & Yáñez 1978), 1978 (Jaksic et al. 1981), 1981 (Simonetti 1983b) and 1984 (Iriarte et al. 1989a). The selection criterion for the studies was the existence of annual census, because they provide a better representation of the small mammal assemblage by documenting intra-annual or seasonal fluctuations (Jaksic & Yáñez 1978, Jaksic et al. 1981, Iriarte et al. 1989a), and the sporadic presence of species (Simonetti 1983a, Iriarte & Simonetti 1986).

Additionally, during 2003, we captured small mammals in San Carlos de Apoquindo using Sherman traps (8 x 9 x 24 cm; H. B. Sherman Traps Inc., Tallahassee, FL, USA) baited with a mixture of oat, tuna fish and vanilla. The field protocol involved trapping during the four seasons of that year. To have comparable results, captures were standardized as percentage.

*Raptors*

We analyzed data published since 1973 on the presence of the native rodent Degu (*Octodon degus* Molina, 1782) and the naturalized European rabbit (*Oryctolagus cuniculus* Linnaeus, 1758) in pellets of Chilean Eagles (*Geranoaetus melanoleucus* Vieillot, 1819) and of native Harris's Hawks (*Parabuteo unicinctus* Temminck, 1824), at the location of San Carlos de Apoquindo and the neighboring site La Dehesa (33°21' S 70°32' O, 875 m above sea level). We considered the following studies for this analysis: for 1973, Schlater et al. (1980); for 1977, Yáñez & Jaksic (1978); for 1979, Jaksic et al. (1980); for 1985, Jiménez & Jaksic (1989, 1990, 1993); and for 1988, Pavez et al. (1992). This information was complemented with an analysis of pellets (Marti et al. 2007) of Harris' Hawks and Chilean Eagles collected during 2006 in La Dehesa and San Carlos de Apoquindo. Finally, we estimated the abundance of some raptor species at the foothills of Santiago during the study period, based on unpublished data by the authors (refer

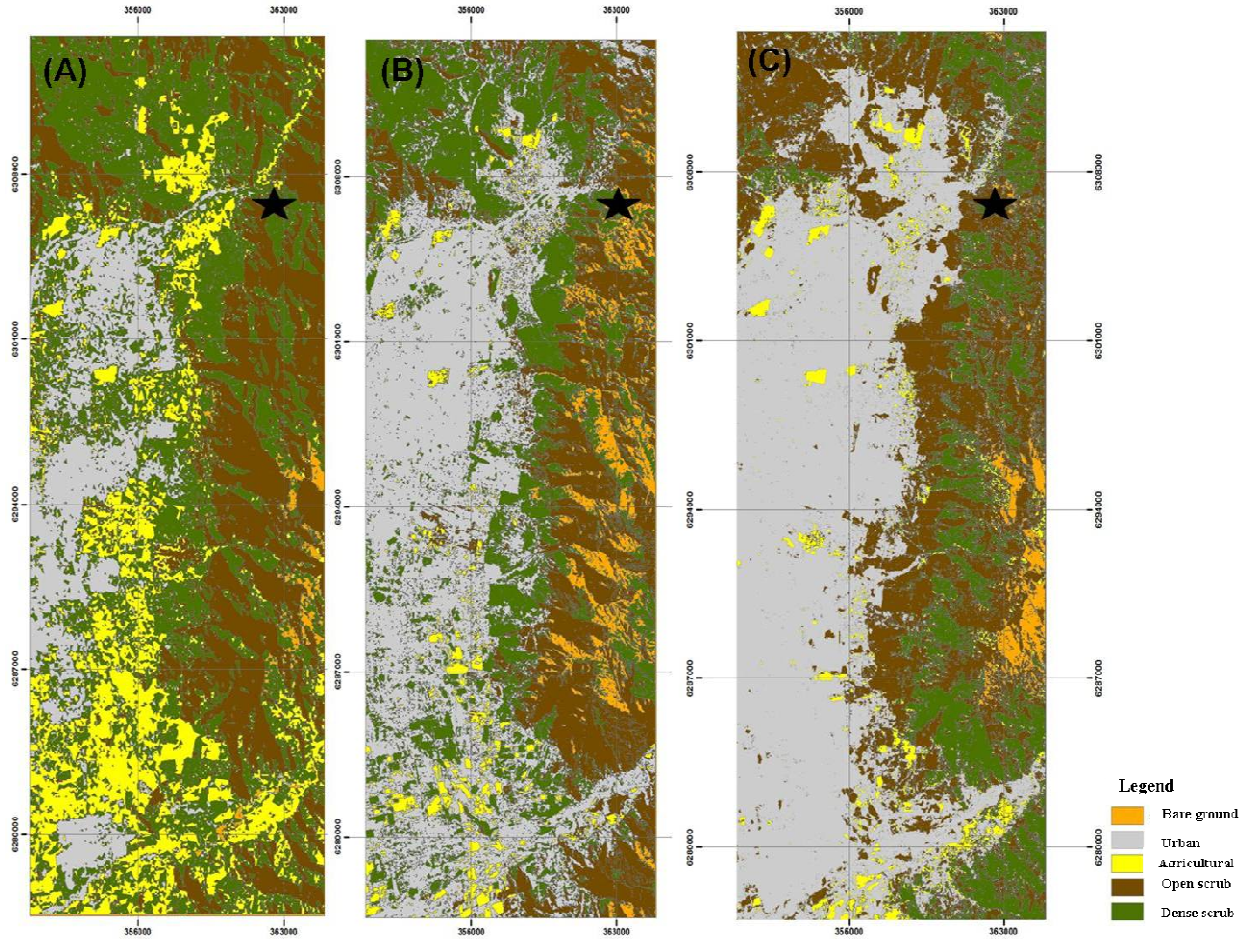


*Fig. 1:* Landscape dynamics in the Santiago piedmont between 1975 and 2003. A = 1975, B = 1989, C = 2003. The star shows the location of San Carlos de Apoquindo.

Dinámica del paisaje en la precordillera de Santiago entre 1975 y 2003. A = 1975, B = 1989, C = 2003. La estrella muestra la localización de San Carlos de Apoquindo.

to Jaksic et al. 2001 for a similar effort).

## RESULTS

### *Landscape dynamics*

Satellite image analysis for the years 1975, 1983 and 2003 reveals an expansion of the urban area in detriment of natural vegetation and of agricultural land use, principally at the southern section of the study area (Fig. 1). The natural landscape was characterized as a mixture of open and dense scrub (in many cases corresponding to degraded forests). Both vegetation categories reduced their cover in the study area (Fig. 2).

Loss of scrub cover has been accompanied by a remarkable increase in the number of patches, a reduction of mean patch size, and an increase of the fractal dimension (Fig. 3), all of which denotes reduction, fragmentation, and deterioration of habitat quality of the scrub for the native fauna. The larger impacts on these environments occurred during the years 1975 and 1989. Between 1989 and 2003 the change has been smaller, in part due to restrictions imposed on the further expansion of the urban sector due to physical factors such as steep hillside slopes, and legal factors such as a ban to build above 1,000 m above sea level.

### *Small mammals*

Currently, the small mammals assemblage in the study area is composed of eight native species, four of them considered endemic. Species such as Bridge's Degu (*Octodon bridgesi* Waterhouse, 1844) and the Tunduco (*Aconaemys fuscus* Waterhous, 1841) occupied central Chile by the late Holocene and apparently got extinct due to anthropic effects, including the developing agricultural and livestock activities (Saavedra & Simonetti 2003).

Data on percent variation during the study period have to be regarded with caution, given that species composition may vary in response to particular factors such as number of trapping days and of traps, or due to global factors such as the incursions of El Niño Southern Oscillation (Jaksic & Lima 2003). Nonetheless, these percent figures inform about tendencies in the variation of species abundance over the years.

Among species present in the study site, the Long-tailed Mouse (*Oligoryzomys longicaudatus* Bennett, 1832), the Long Haired Mouse (*Abrothryx longipilis* Waterhouse, 1837) and the Mouse Opossum (*Thylamys elegans* Waterhouse, 1838) were trapped in larger proportion in dense scrub. Of the alien invasive species, the abundant European rabbits were scarcely represented, probably due to the trapping method (Miller & Rottmann 1976, Jaksic et al. 1979), while the first record of the invasive Black Rat (*Rattus rattus* Linnaeus, 1758) was documented in 1981 (Simonetti 1983a). Since then, two other invasive Murids have been recorded: the House Mouse *Mus musculus*

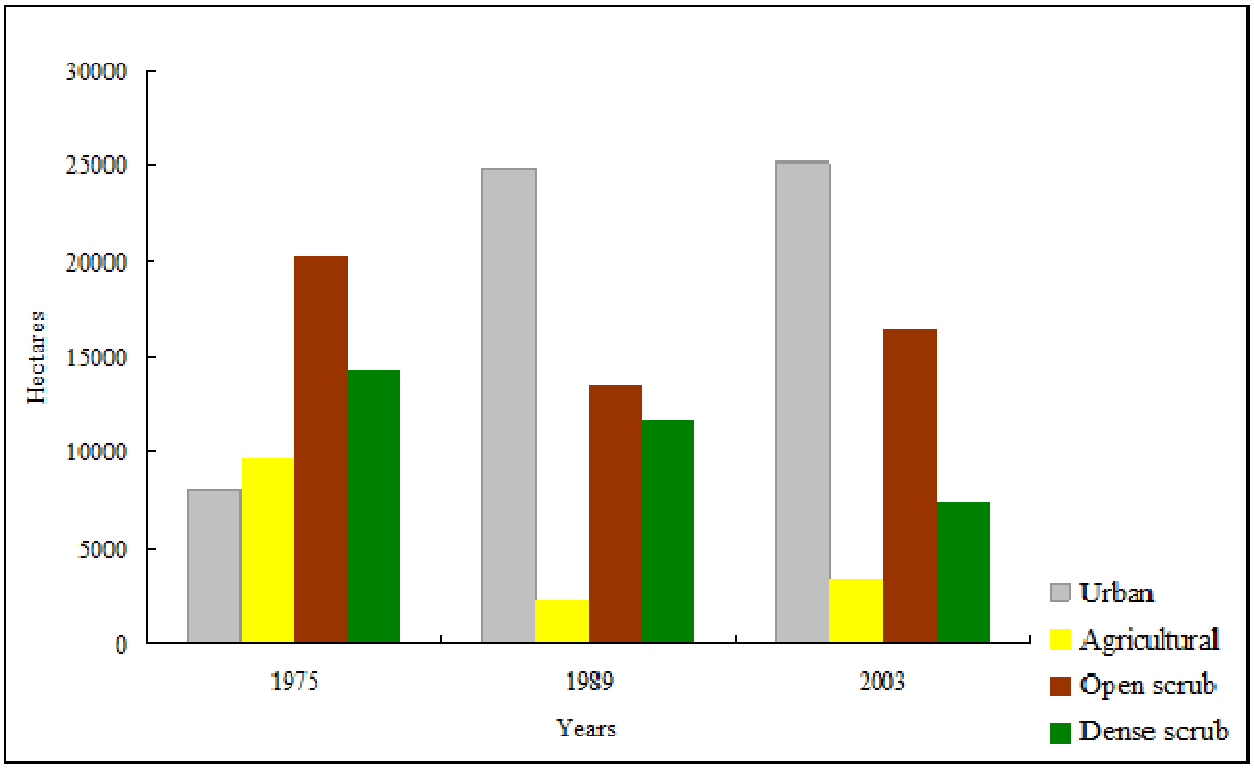


*Fig. 2:* Land use changes in the Santiago piedmont between 1975 and 2003. A = 1975, B = 1989, C = 2003.
Cambios en el uso de la tierra en la precordillera de Santiago entre 1975 y 2003. A = 1975, B = 1989, C = 2003.

Linnaeus, 1758 and the Norwegian Rat *Rattus norvegicus* Berkenhout, 1769 (Lobos et al. 2005). The decrease in presence of Degu during the trappings since 1978 on, and the low historic representation of the Chinchilla Rat (*Abrocoma bennetti* Waterhouse, 1837), are conspicuous facts, given that these species have the largest body size in the area. Over time, the Leaf-eared Mouse (*Phyllotis darwini* Waterhouse, 1837) and the Long-tailed Mouse have shown a trend to increase their abundances.

The abundance of small- and medium-sized mammals did not show large variations during the study period. However, those species of larger sizes either reduced or maintained their low representation over the sampling efforts (Fig. 4), or even got extinct in historical time. This result coincides with the increase in number of patches and their associated reduction of mean patch size, which highlights a strong fragmentation of the sclerophylllous scrub of the Santiago piedemont.

*Raptors*

Three publications account for the diet of the Chilean Eagle in San Carlos de Apoquindo between 1973 and 1989. Schlatter et al. (1980) documented in 1973 and 1974 that the diet of the Chilean Eagle was composed by 57.6 % native Degu and 18.8 % European rabbit (n = 170). In 1984 and 1985, Jiménez & Jaksic (1989) reported 32.3 % Degu and 14.7 % Rabbit (n = 65), while Pavez et al. (1992) calculated 18.9 % Degu and 43.9 % Rabbit (n=624) in the diet. Finally, in 2006 we obtained 23.1 % Degu and 48.7 % Rabbit (n = 39). Thus the diet of the Chilean Eagle reveals a clear trend toward reduction of Degu (native prey) and increase of Rabbit (alien prey), highlighting the change first observed during 1985 and 1988 (Fig. 5).

Three publications provide information on the diet

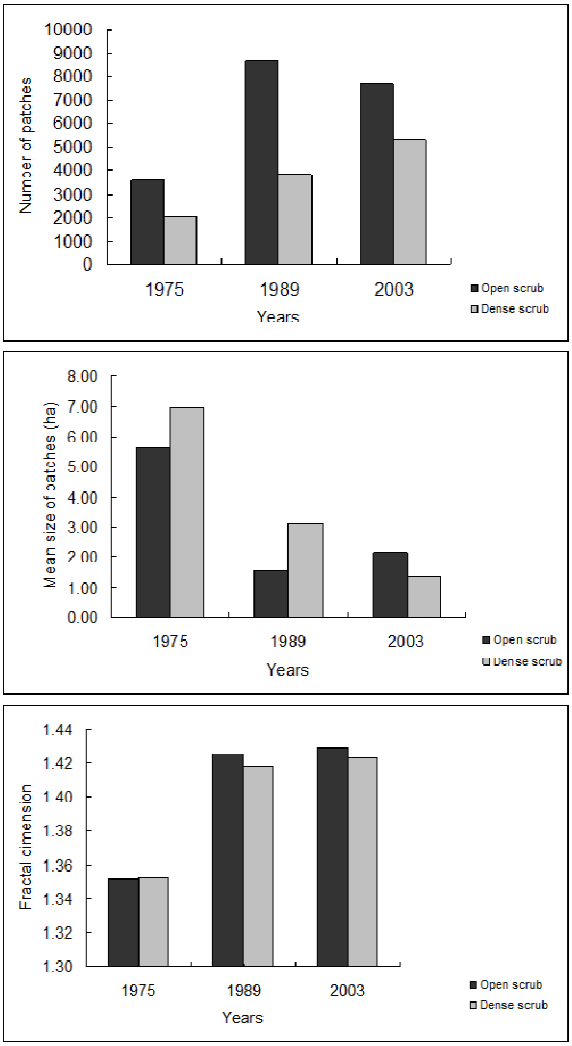


*Fig. 3:* Number of patches, mean size of patches (ha), and their fractal dimension for sparse and dense scrub in the Santiago piedmont between 1975 and 2003. A = 1975, B = 1989, C = 2003.

Número de parches, tamaño medio de los parches (ha) y su dimensión fractal para matorral abierto y denso en la precordillera de Santiago entre 1975 y 2003.

of the Harris' Hawk in San Carlos de Apoquindo and La Dehesa between 1976 and 1985. Yáñez & Jaksic (1978) in 1976-78, found 75.2 % of native Degu in the diet, with complete lack of European Rabbit (n = 105). By 1979 Jaksic et al. (1980) reported 64.5 % Degu and 1.2 % Rabbit (n = 172). During the period of 1984-85, Jiménez & Jaksic (1993) documented 13.9 % Degu and 18.2 % Rabbit (n = 165). Finally, during 2006 in La Dehesa we observed a complete lack of Degu in the diet and 84.0 % Rabbit (n = 25). These data suggest that since the 80s Harris' Hawk reduced abruptly its consumption on native Degu, while increasing the proportion of European Rabbits (Fig. 5)

Of the 24 raptors species described for the Metropolitan region by Jaksic et al. (2001), 14 (58 %) use or have been using regularly the foothills of Santiago during the study period. However, we observed a tendency to reduce their richness and abundance, probably associated with the increased urbanization from the valley upwards the foothills. Correspondingly, we observed an increased richness and abundance of raptors along the gradient from urbanized areas towards scrubland, showing an intermediate level in agricultural areas, and a maximum richness and abundance in open scrub.

It is remarkable the case observed at the end of the 80s in the north-eastern end of the study area (San Carlos de Apoquindo and surroundings). Here, established and previously common couples of White-Tailed Kites (*Elanus leucurus* Vieillot, 1818) and of Short-Eared Owls (*Asio flammeus* Pontoppidan, 1763) disappeared (EF Pavez, unpublished data). Jaksic et al. (2001) reported both species as occasional visitors in San Carlos de Apoquindo. The Burrowing Owl (*Athene cunicularia* Molina, 1782) presented a similar trend: Jaksic et al. (2001) reported it as a scarcely present resident of San Carlos de Apoquindo. The American Kestrel (*Falco sparverius* Linnaeus, 1758) and the Chimango Caracara (*Milvago chimango* Vieillot, 1816) were identified as common and abundant by Jaksic et al. (2001); nevertheless, they were seen in smaller numbers than during the 60s and 70s (EF Pavez, unpublished data).

The raptor species associated to ravines and slopes, with reduced exposure to urbanization activities, have maintained more stable populations, specifically the Chilean Eagle and the Harris' Hawk. During 1987 and 1989, Pavez (2001) identified three resident couples of Chilean Eagles. During the summer of 2006, only two territories were occupied, and the western edge of the study site was unoccupied, coincidentally with the deterioration and loss of natural vegetation in this area due to increased urbanization. A similar trend was observed for Harris' Hawk, a species associated to lower parts of the foothills, which consequently has lost a larger section of its original habitat in the study site.

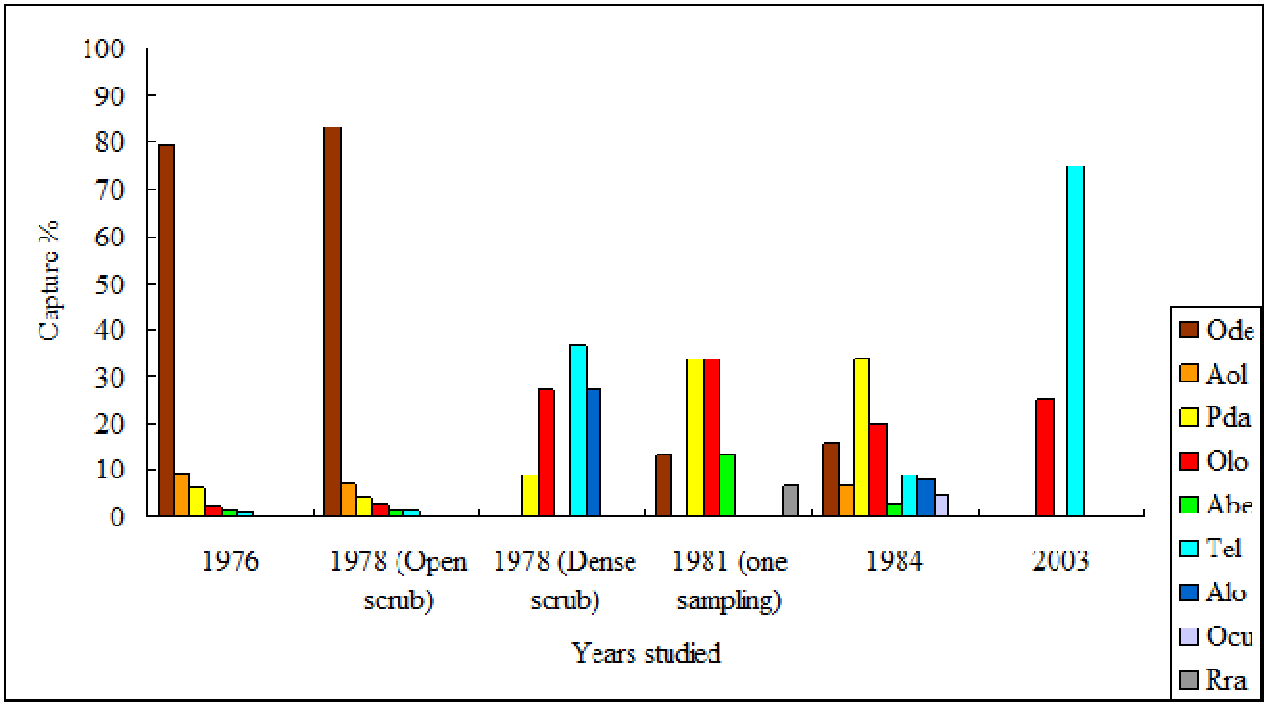


*Fig. 4:* Percent captures of small mammals in the Santiago piedmont between 1976 and 2003. Sources: for 1976, Jaksic & Yañez (1978); for 1978, Jaksic et al. (1981); for 1981, Simonetti (1983a, 1983b); for 1984, Iriarte et al. (1989a); for 2003, authors' own data. Key to species same as above. Ode = *Octodon degus*, Aol = *Abrothrix olivaceus*, Pda = *Pyllotis darwini*, Olo = *Oligoryzomys longicaudatus*, Abe = *Abrocoma bennetti*, Tel = *Thylamys elegans*, Alo = *Abrothrix longipilis*, Ocu = *Oryctolagus cuniculus*, Rra = *Rattus rattus*.

Porcentaje de captura de micromamíferos en la precordillera de Santiago entre 1976 y 2003. Fuentes: para 1976, Jaksic & Yáñez (1978); para 1978, Jaksic et al. (1981); para 1981, Simonetti (1983a, 1983b); para 1984, Iriarte et al. (1989a); para 2003, datos propios.

## DISCUSSION

Human occupation in the mediterranean region of Chile has been associated with severe modifications in the configuration of the original landscape, with deep consequences for the natural biota (Arroyo 1999, Myers et al. 2000). Those areas with lower accessibility have been able to preserve an important extent of their natural flora and fauna (Alados et al. 2004); however, the increasing demand for new territories (for urbanization, agriculture and recreational use) threatens the integrity of these natural environments (Pauchard et al. 2006).

The dynamics of change of the foothills of central Chile shows that between 1975 and 2003 an important land use shift occurred, with a loss of 23.3 % for the scrub as a whole, and 12 % for the agricultural landscape. Only urban land use showed an increase (31.5 %) between these dates, demonstrating the accelerated growth of the city. Nevertheless, these data only partly represent the historical urbanization process. Romero et al. (1999) indicated that the largest change in land use occurred between 1962 and 1974, when 7,544 ha were modified from agricultural use to urban use. Several authors (Paul & Meyer 2001, Riley et al. 2005, Mc Kiuney 2006, Pauchard et al. 2006) agree that urbanization is one of the main threats to biodiversity. The preservation of buffer zones, such as traditional agricultural lands, is considered as an important tool to improve the conservation of biodiversity in Mediterranean ecosystems of Spain (De Miguel 1999) and in other continents (Mc Neely & Schroth 2006).

The natural landscape of the foothills of central Chile (scrub and sclerophyllous forests) have been strongly impacted in attributes such as patch number, mean size of patches, and degree of complexity, revealing an important degree of fragmentation and loss of habitat (Peña-Cortés et al. 2006). Given this context, size reduction of patches may have strong impacts on habitat specialists (Franklin & Forman 1987), including Bridge's Degu (possibly extinct in the foothills of Santiago; Saavedra & Simonetti 2003) and the Degu, *Octodon degus*.

In addition, landscape modification may favor alien

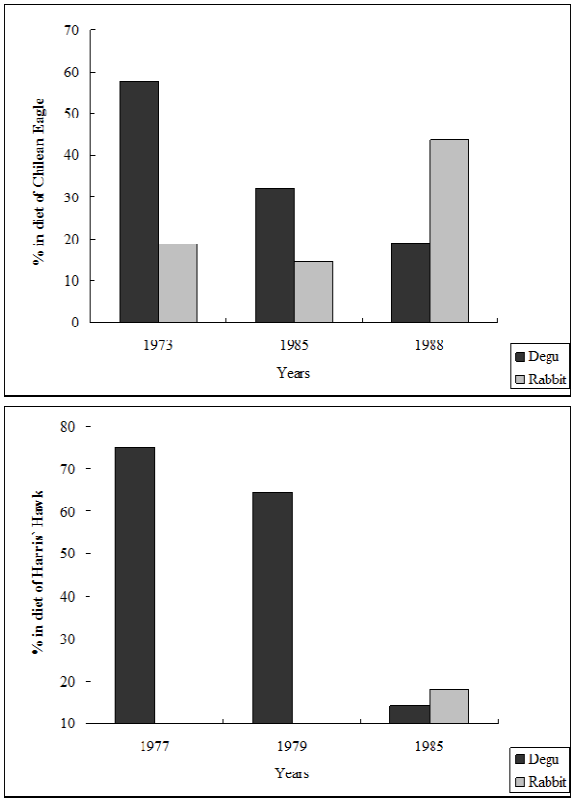


*Fig. 5:* Percent occurrence of native degu (*Octodon degus*) and exotic rabbit (*Oryctolagus cuniculus*) in the diet of native eagles and hawks in the Santiago piedmont between 1977 and 2006. Sources: for 1973, Schlatter et al. (1980); for 1977, Yañez & Jaksic (1978); for 1979, Jaksic et al. (1980); for 1985, Jiménez & Jaksic (1989, 1990, 1993); for 1988, Pavez et al. (1992); for 2006, our own data.

Variación porcentual de degú nativo (*Octodon degus*) y conejo exótico (*Oryctolagus cuniculus*) en la dieta de águilas y peucos en la precordillera de Santiago entre 1977 y 2006. Fuentes: para 1973, Schlatter et al. (1980); para 1977, Yáñez & Jaksic (1978); para 1979, Jaksic et al. (1980); para 1985, Jiménez & Jaksic (1989, 1990, 1993); para 1988, Pavez et al. (1992); para 2006, datos propios.

invasive species, which in turn alter ecosystem attributes and in many cases facilitate new invasions (Dukes & Mooney 2004). The European rabbit has successfully invaded the piedmont of Santiago, fact that has been attributed to low predation pressure (Jaksic & Soriguer 1981, Jaksic & Ostfeld 1983). Notwithstanding, landscape transformation could also be associated to this successful invasion. This becomes evident with the successful colonization of the mediterranean region of Chile by alien Murids (Lobos et al. 2005). Similarly, productive activities such as livestock raising, have been associated to habitat modification and facilitation to invasive species such as Rabbit (Simonetti 1983b). A dense canopy cover of scrub is important for native mammals to escape from predators (Iriarte et al. 1989a, 1989b), while Rabbit uses open areas, apparently more interested in foraging opportunities than in escaping predators (Jaksic & Soriguer 1981, Simonetti 1983b). Consequently, habitat modification is favoring alien Rabbit over native mammals.

In relation to the temporal trajectory of the assemblage of native mammals of the area, those species that most reduced their abundance in captures are those of larger size. Saavedra & Simonetti (2003) indicate that during the late Holocene, Bridge's Degu (a specialist of dense scrub) and the Chilean Rock-Rat (*Aconaemys fuscus*) occupied the foothills of central Chile, concluding that both species were affected by habitat modifications effected by humans. The Chinchilla Rat, also a specialist of dense scrub, has a low representation over the study site (GA Lobos, unpublished data). A peculiar case is the Degu, considered abundant and on occasions a pest (Mann 1987), in relation to its high historical abundance. Nonetheless, our time series reveals an important reduction in its abundance, which we attribute to two principal factors. Firstly, the loss of surface cover of scrub and the deterioration of its habitat quality for native species. Secondly, livestocking load, potential food competition, and soil erosion (by large ungulates and goats) could be an additional impact factor.

The trend toward reduction of the Degu population is also correlated with its lower representation in diets of Chilean Eagle and Harris Hawk, with a concomitant increase of Rabbit in the diets of both local predators. Studies consucted on the diet of Culpeo foxes (*Pseudalopex culpaeus* Molina, 1782) in San Carlos de Apoquindo show a similar trend, with 19.7 % of Rabbit identified in 1976 (Jaksic et al. 1980), 37 % in 1983 (Simonetti 1986) and 48 % in 1984 (Iriarte et al. 1989b). The increased consumption of Rabbit by Chilean Eagle through time has been identified as a functional response to a relatively more abundant prey (Pavez et al. 1992). We postulate that this response results from the important reduction of populations of its native prey, the Degu, historically an important element of the Eagle and Hawk diets up to the mid 80s. It should be noted the coincidence of this process with the strong habitat deterioration of the scrub observed during 1975-1989 in the study area. Also, Pavez et al. (1992) stated that Rabbit is present in San Carlos de Apoquindo since 1940 and that its numbers do not seem to have increased notoriously in the years previous to their study, which would support the idea that the increase of this prey in Eagles and Hawks is not a response to an increase of its abundance, but to the decrease of Degu.

Landscape modification of the foothills not only have had impacts on the diets of opportunistic raptor species, with the ability to switch to food resources of the size of Rabbit (the case of Chilean agle and Harris' Hawk), but also have apparently reduced the abundances of other raptors, such as White-Tailed Kites, Short-Eared Owls, and Burrowing Owls, which are associated to scrub and agricultural areas, specially at the lower and thus more disturbed parts. Other pressure factors, such as the illegal hunting of raptors, are not evaluated in this study, but this activity has been operating at the study site since historical times.

Rio Clarillo, a national reserve located immediately south of our study site, is another example of large impacts on the assemblage of small mammals and their predators in the last 30 years, due to loss of natural environments at the foothills of Santiago. In this area, a large number of species can be found below the 1,600 m elevation, which corresponds to sclerophyllous scrub and largest human usage load (Díaz et al. 2002). The situations of San Carlos de Apoquindo and Rio Clarillo respond to continuing modifications in the regulatory plans of the Metropolitan Region, which have favored real estate development and industry, at the expense of the natural ecosystems and traditional agriculture. Additionally, the mediterranean ecosystems of central Chile are scarcely represented in the National System of Protected Wildlife Areas (Muñoz et al. 1996, Simonetti 1999, Pauchard & Villarroel 2002).

From a political-environmental perspective, land use planning is a legal tool which should be implemented with high urgency in Chile. This tool should account for environmental requirements for the conservation of viable populations and the high value of natural ecosystems in the mediterranean region, one of the five on the planet, among the 34 hotspots of biodiversity. Another aspect needing highlighting is the lack of long-term research sites for biodiversity, which precludes analyses at larger spatio-temporal scales. Finally, we suggest to complement our study with more research focused on other factors that could be affecting the assemblages of small mammals and their predators, such as fire, interference with alien species, livestock and hunting activities.

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Hermosilla, an outstanding naturalist of Chile, who passed away in January 2010.

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