Diversity of diurnal raptors in a suburban area of a city in southern Chile

Andrés Muñoz-Pedreros1 · Varia Dellacasa2

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Abstract
Raptor conservation programs should be based on knowledge of the birds’ ecology in both natural and urban habitats, justifying the inclusion of ecological studies in suburban zones into regional planning initiatives. The objective of this study was to determine the use of diurnal raptors within the habitats of a suburban area of a city in southern Chile. We characterize the different zones into five types of environment, and assess their raptor diversity for consideration in territorial planning. Acoustic surveys were conducted in auditory stations in addition to observations from fixed transects and trails. From a total of 161.39 h of survey, we obtained 664 sightings corresponding to ten species of diurnal raptors. The richest environment was dense forest (eight species), followed by grassland (six species), native forest regeneration (five species), shrubs (four species) and exotic tree plantations (three species). We discuss the relationship between the richness of diurnal raptors, the types of environment in the study area, and the spatial location of the sites, as well as the implications for territorial planning to support the conservation of birds of prey in the suburban zone studied.

Keywords Raptor diversity · Suburban environments · Southern Chile

Introduction
The magnitude and speed of anthropogenic alterations to the environment in the last century are unprecedented in the history of humanity. Land use intensification creates regions that may include a continuum of environmental conditions (Marzluff et al. 2001) from “wildlands” to rural, suburban and urban environments (Chapman & Reiche 2007), in which native vegetation is displaced and the species richness of wildlife is reduced (Cam et al. 2000; Fraterrigo and Wiens 2005). Urbanization affects species diversity and the composition of avian communities in natural areas surrounding urbanized zones (Chace and Walsh 2006; Ortega-Alvarez and MacGregor-Fors 2011; Mbiba et al. 2021). Biodiversity is changing rapidly, especially due to the conversion of natural to artificial systems (Pimm et al. 1995; Goldewijk 2001). The expansion and multiplication of urban areas reduces and fragments natural habitat, resulting in patchy remnants that are increasingly degraded (Armenteras et al. 2003).

These processes affect different faunal assemblages in different ways (Di Giulio et al. 2009); in some cases they may be beneficial, some species increase their populations in human-modified habitats due to increases in prey species, such as introduced mice and naturalized birds, that serve as new prey, less loss of eggs and nestlings by natural predators (e.g. Jaksic et al. 2001, Buij et al. 2013); but in others abundance and richness decrease (Cornelius et al. 2000) as the progressive isolation of areas of habitat lead to population decline and changing population dynamics in some species (Debinski and Holt 2000).

There have been significant transformations to the landscapes in rural areas of central and southern Chile (Paucharand et al. 2006), such as the increase in forest plantations with exotic species, intensive agricultural crops and urban expansion (Echeverría et al. 2012; Zamorano-Elgueta et al. 2015). They constitute the principal threat to birds of prey (Dale et al. 2000; Zalles and Bildstein 2000), which may be
threatened by decreasing availability of food and nest sites, except for a minority of them (Zalles and Bildstein 2000; Muñoz-Pedreros et al. 2010; Grande et al. 2018, Kettel et al. 2018, Mak et al. 2021).

The level of knowledge of the diversity and abundance of birds of prey in suburban areas is still low, and should be increased to conserve these birds, which are also important environmental sentinels (Espín et al. 2021). Reconciliation ecology (sensu Rosenzweig 2003) discovers how to modify and diversify anthropogenic habitats so that they harbor a wide variety of wild species. Therefore can be redesigned habitats in suburban spaces to allow recolonization of birds of prey. Given the inadequacy of natural reserve systems, the urban ecology can be in tune with the reconciliation ecology, considering, for example, the search for habitats analogous and ecological engineering (Lundholm and Richardson 2010). It is therefore important to carry out ecological studies in suburban zones (Dale et al. 2000), since the results can be included them in territorial planning initiatives and contribute to the design of a target vision to be achieved in the long term. Planning allows conservation actions to be defined and implemented. The objective of this study was to determine the use by diurnal raptors of the habitat in a suburban area of a city in southern Chile. We characterized the different zones into five types of environment, and we assessed their raptor diversity for consideration in territorial planning.

**Methods**

**Study area**

The study was conducted in suburban areas of the city of Temuco in southern Chile, located in the central depression of the Araucania Region, 619.5 km south of Santiago de Chile. Temuco was founded in 1881 and had 410,520 inhabitants in 2017, making it one of the fastest-growing cities in Chile in recent years. In this study we considered zones with housing densities 2.5–10 houses/ha as suburban, and >10 houses/ha as urban (see Mason et al. 2007). Suburban areas were defined as peripheral areas of a city (urban area), with housing density of 2.5–10 houses/ha.

The connected suburban areas included in the study were: (a) Chivilcan grassland (38°41’–38°43’ S, 72°35’–72°36’ W) covering 1,700 ha, altitude 112 m a.s.l., on the slopes of Huimpil Ñielol mountain (González and Cerda 1989); and (b) the Ñielol Hill protected area, adjacent to Chivilcan (38°43’S–72°35’W), 89.5 ha, altitude between 115 and 322 m a.s.l, with steep topography (Fig. 1). This second area is considered urban for administrative purposes, but contains no urban infrastructure, so for the purposes of this study it was considered part of the suburban area of the city.

The climate of the study area is wet-temperate, with a short, marked dry season (Di Castri and Hajek 1976;
Inzunza 2003). The average annual temperature is 12°C, relative humidity 80%, and the average annual rainfall is 1324.8 mm, with a dry summer period of two months.

Habitat types in our study area were classified into 5 categories identified from a land chart generated in GIS: (a) Grassland with winter flood regimes comprising, mostly allochthonous vegetation (57.9%), of the total predominate the hemicryptophytes (54%) and remains of the original swamp forest vegetation cleared for grassland (González and Cerda 1989); (b) dense scrub of Ulex europeus (an introduced species considered a biological invader) with fragments of scrub an a few native trees; (c) exotic tree forestry plantations of Pinus radiata and Eucalyptus globulus, with monostatified plant coverage about 15 m high; (d) regeneration of native forest about 10 m high; and (e) dense native forest with multi-layered, multi-aged plant cover containing trees between 20 and 45 m high, in open and closed canopies respectively (Hauenstein et al. 1988a).

Fieldwork

The sampling stations were selected in the field covering the existing environments in the study area, and then geographically referenced to prepare a chart with the survey design (Fig. 1). Information on the richness and abundance of diurnal raptors was obtained using three complementary methodologies: The first approach was the acoustic survey with three hearing stations from which acoustic decoys were emitted to record the responses of raptors (Fuller and Mosher 1987). We used a digital portable player connected to a megaphone, which emitted the calls of diurnal raptors obtained from a study performed with acoustic lures in six locations in southern Chile (e.g., Harris’ hawk Parabuteo unicinctus, Cinereous Harrier Circus cinereus and American kestrel Falco sparverius) (Contreras and Gonzalez, 2007). The calls were emitted alternately for one minute with five-minute waiting periods for each species, to provoke a territorial defence response or contact (Ralph et al. 1996). The acoustic recordings were played from 08.00 to 10.00 h, 12.00 to 14.00 h and 18.00 to 20.00 h. The second approach used fixed observation points on vantage points, with good visibility to the naked eye and using 10×50 binoculars and a 20-60X telescope, together with photographic records when possible. These points were manned for two 3-hour periods per day (08.00 to 11.00 h and 15.00 to 18.00 h). The third approach was vehicle-borne runs to record sightings along two transects on roads (gravel, with a medium level of traffic). The vehicle passed through the environments of the study area at a speed of 20–40 km per hour with two observers. Observation stops were made on both sides of the transect, recording the time, type of habitat, and activity (e.g. resting, in flight) for each bird, in the mornings from one hour after sunrise to 10.00 h, at noon (12.00-14.00 h), and from 18.00 to 20.00 h to detect twilight species. Each transect was sampled only once to avoid double counting and pseudo-replication.

The surveys were conducted from September 2010 to May 2011 (which corresponds to the spring to autumn seasons) on days with favourable weather conditions (persistent rainy days were discarded) and using a template for sightings (Márquez et al. 2004).

Ecological parameters

We determined the following parameters:

(a) Species richness (S), defined as the number of species in a sample;

(b) Relative abundance (AB%), defined as the percentage fraction of all birds of prey (Krebs 1985; Magurran 1998) from which we could identify the species with low representation (low abundance); (c) α diversity (intra-environment), considering the specific richness and structure. The latter was determined by the Shannon and Wiener diversity Index, according to the function:

\[ H' = -\sum (pix \log_2 pi), \]  

where pi is the proportion of the total number of individuals of the species in the sample, with values which vary between zero when there is only one species and the maximum (H’max) corresponding to \( \log_2 S \). In addition, we calculated the Pielou equity index (J) according to the equation:

\[ J = H'/H'_{\text{max}}, \]  

to measure the contribution of equity to the total diversity observed. The values varied between 0 (low heterogeneity) and 1 (maximum heterogeneity, when the species are equally abundant) (Magurran 1998).

(c) β diversity (between environments) was represented by the species turnover or through a cluster similarity/dis-similarity dendrogram (between sectors) based on the Bray-Curtis Index (1957), using the BioDiversity Professional program (McAleece 1998);

(d) γ diversity, represented by all the species of diurnal raptors recorded in the Araucanía region (31,842 km²) in a sample taken from five national parks covering 137,138 ha (4.3%), supplemented by published (Pavez 2000; Silva-Rodriguez et al. 2008) and unpublished
Data analysis

We created a landcover map using data from aerial photographs and previous studies with ArcGIS 9.3 (Hauenstein et al. 1988b). We then validated data in the field the vegetation structure of each land, characterizing the diversity of vegetation strata. Raptor occupancy attributes of each environment were assigned from records and these attributes were incorporated into a final chart of richness of raptors. To contrast the environments, the plant species associated with native forest were analysed for Temuco municipal district (466 km²), homologating the territory to the environments of the study area; ecological and visual techniques with GIS tools were used for this analysis. We identified the spatial structure of the landscape mosaic, recognizing the elements present and reclassifying vegetation coverage in order to obtain a minimum of classes of fragments. The categories were used as classes to represent landscape heterogeneity, regrouped in the environments described above. We then carried out general dissolution of the polygons adjacent to mature forest in order to analyse the polygons with core areas. We also analysis of the spatial patterns, using landscape metrics (sensu Botzquilha et al. 2006): shape (morphometric characteristics of the fragments), metric area (area of each of the fragments), edge metrics (amplitude of the edge habitat in relation to the interior habitat), proximity analysis (distance to the nearest fragment of the same class), and analysis of core areas (interior habitat area of each fragment). The metrics were applied at patch level, by class (typological category) and to the entire landscape according to importance (Forman and Godron 1986).

We were used for spatial analysis ArcGIS 9.3 extensions, Fragstat v3.3, v3.0 and Patch Analyst vLATE. Finally, for mature native forest species the structural and functional connectivity of the landscape was analysed. Structural analysis was applied to adjacent, physically connected native forest polygons (McGarigal and Marks 1995), whereas the functional study analysed dependencies by distance based on connection with ecological phenomena. Thus distance matrices were first analysed and then evaluated on the basis of distance thresholds, to reflect the probability of connection of the different fragments at a certain distance (McGarigal and Marks 1995).

Results

Abundance and diversity α, β and γ

In 120 surveys conducted over 161.39 h in all environments, 664 individuals of 10 species were recorded (Table 1). The following categories of abundance were established: rare: Bicolored Hawk Accipiter bicolor, Southern Caracara Caracara plancus, Aplomado Falcon Falco femoralis and Peregrine Falcon Falco peregrinus; frequent: Bicolored Hawk P. unicinctus, American Kestrel F. sparverius and White-tailed Kite Elanus leucurus; common: Rufous-tailed Hawk Buteo ventralis and Variable Hawk Geranoaetus polyosoma, and abundant: Chimango Caracara Milvago chimango. The frequency of records per species diversity and equity indexes for each environment are shown in Table 1. The environments with the greatest diversity of species were, in decreasing order, Dense forest, Grassland, Regeneration, Scrub and Exotic tree plantations. Dense forest had the highest diversity with eight species and a low equity, within this habitat the most abundant species was M. chimango (> 80% frequency of observation) followed by B. ventralis and G. polyosoma (> 9% and > 6.1% respectively). These three species were recorded nesting in this environment. All other species account for less than 2% each.

In the grassland environment, six species were recorded with low equity: the most common species was M. chimango (> 90%); all other recorded species present fewer records (> 3.5%). In regeneration the richness was five species with medium equity, G. polyosoma being the most abundant (> 55%), followed by M. chimango, E. leucurus and P. unicinctus (> 12%). In dense scrub the richness was four species with medium equity; the most abundant species was M. chimango, with half of the sightings, followed by G. polyosoma (< 35%). Exotic tree plantations presented the lowest diversity, with three species, high equity and G. polyosoma the most abundant species (< 50% of sightings).

The analysis of similarity/dissimilarity (see Fig. 2) shows that there are two clusters, one grouping the native forest regeneration and exotic tree plantations (74.28% similarity), and another consisting of dense forest and grassland (69.09% similarity). Scrub is dissimilar to both clusters (< 43.6% similarity). Thus β diversity is relatively high, since both clusters have low similarity (43.7%).

The γ diversity (national parks in the region of Araucanía) is represented by 15 species of diurnal raptors: (A) chilensis, Geranoaetus melanoleucus, Buteo albigula, G. polyosoma, (B) ventralis, Circus cinereus, E. leucurus, M. chimango, Phalcoboenus megalopterus, Phalcoboenus albogularis, (C) plancus, F. peregrinus, F. femoralis, F. sparverius, 10 of which were recorded in the study area (66.7%).
Characterization, diversity and connectivity of environments

The different land uses in the 1,794 ha of the study area are dominated pasture-crop rotation (51%) and exotic species plantations (24%), the rest of each category of land use amounting to less than 4% each (Table 2). The five environments configured are shown in Fig. 3-A, and the richness of diurnal raptors associated with them in Fig. 3-B. The highest richness in the administrative urban environment was recorded in dense forest (1.3% of the total). Average richness was recorded in three environments: regeneration (young forest), scrub and grassland and the lowest richness in exotic tree plantations.

Figure 4-A shows the landscape mosaic of Temuco district (466 km²). There is a very extensive agricultural matrix, followed by the large area of exotic forest matrix in which are embedded persisting fragments of native forest. Figure 4-B shows the chart components with structural and functional connectivity of mature native forest, and core areas. Only two fragments of native forest larger than 80 ha are structurally connected, one of them within the urban radius (and functionally connected to two cores) and the other nearby

Table 1  Species of diurnal raptor recorded in five environments in a suburban area of Temuco, southern Chile, 2010–2011. F = Frequency; S = Species richness; H = Shannon-Wiener Index; H’ max = Expected maximum diversity; and J = Pielou Index

| Species      | Grassland | Scrub | Exotic tree plantations | Regeneration | Dense forest |
|--------------|-----------|-------|-------------------------|--------------|--------------|
| F. sparverius| 11 2.7%   | 1 1.5%| 0 0%                    | 1 6.3%       | 2 0.7%       |
| F. femoralis | 1 0.2%    | 0 0%  | 0 0%                    | 0 0%         | 0 0%         |
| E. peregrinus| 0 0%      | 0 0%  | 0 0%                    | 0 0%         | 1 0.4%       |
| M. chimango  | 373 91.0% | 34 50%| 5 26.3%                 | 2 12.5%      | 224 81%      |
| E. leucurus  | 6 1.5%    | 0 0%  | 0 0%                    | 2 12.5%      | 0 0%         |
| P. unicinctus| 13 3.2%   | 8 11.7%| 4 21.1%                 | 2 12.5%      | 5 1.8%       |
| G. polyosoma | 6 1.4%    | 25 36.8%| 10 52.6%               | 9 56.2%      | 17 6.2%      |
| B. ventralis | 0 0%      | 0 0%  | 0 0%                    | 0 0%         | 25 9.1%      |
| A. chilensis | 0 0%      | 0 0%  | 0 0%                    | 0 0%         | 1 0.4%       |
| C. plancus   | 0 0%      | 0 0%  | 0 0%                    | 0 0%         | 1 0.4%       |
| Total        | 410 100%  | 68 100%| 19 100%                 | 16 100%      | 276 100%     |
| S            | 6 4%      | 4 3%  | 4 3%                    | 5 2%         | 5 4%         |
| H’           | 0.187     | 0.447 | 0.442                   | 0.554        | 0.699        |
| H’ max       | 0.778     | 0.602 | 0.477                   | 0.699        | 0.793        |
| J            | 0.24      | 0.742 | 0.926                   | 0.793        | 0.811        |
The richness of diurnal raptors varied with the environment. The highest diversity was found in dense forest (eight species), with two forest specialist species (B. ventralis and A. chilensis). We consider the sighting of (A) chilensis to be accidental, as it was detected only once, whereas (B) ventralis was the second most frequent species in the study. Pavez et al. (2019) and Trejo et al. (2006) document that populations of B. ventralis and A. chilensis are negatively affected by the loss of mature native forest, which may explain their absence from the other environments without dense native forest. F. sparverius and M. chimango use a wide variety of environments (Donázar et al. 1993) and have a high capacity to adapt to changes in their habitat caused by human activities (Morrison and Phillips 2000; Jaksic et al. 2001). This explains the high abundance of M. chimango over other species and the presence of both these species in all the environments, with the exception of F. sparverius in exotic tree plantations. P. unicinctus, G. polyosoma and (C) plancus are widespread in Chile and also use a wide variety of environments, G. polyosoma being the third most common species in the study area. The species nesting in this environment coincide with Rodriguez-Estrella (1996), since many species of raptors need wooded areas with low anthropogenic disturbance for nesting. It is important the dense forest because it is the most diverse environment, offers nesting sites for many species, and yet comprises only a small proportion of land in the study area. The urban forests, especially suburban, provide important refuge for sensitive raptors (Fröhlich and Ciach 2018).

Grassland was the second most diverse environment (six species), despite suffering major changes in the composition and configuration of the original vegetation, mainly due to the change in land use to cattle-farming. All the species recorded are associated with open areas covered by the herbaceous vegetation necessary for foraging and hunting (Smallwood 1987; Thiollay 1996; Young and Thompson 2004), coinciding with Rodriguez-Estrella (1996), as birds of prey make opportunistic use of fragments of agricultural areas for hunting. Thus, species associated with open and semi-open may benefit from land use transformations when these introduce feeding opportunities (Jaksic and Jimenez 1986; Thiollay 2007). Survey records of the foraging environment may have been underestimated, as raptors may spend a disproportionately greater amount of time roosting (at the nest site) rather than hunting (Dobler 1993).

Native forest regeneration had similar species richness as prairie, with only one species absent. This may be because the raptors are still capable of exploiting foraging opportunities within these environments (grassland and seedlings of forest species) despite the lack of mature nest stands there for breeding (Brown and Amadon 1968; Dunk 1995). However, this environment comprised only a small portion of the study area (2.5%), and sparsely distributed, which may explain the low diversity recorded. But, if it is protected and allowed to evolve into mature forest, it would be an ideal situation, with grassland serving the needs of hunting areas and native forest those of reproduction.

In scrub, four species were recorded (F. sparverius, M. chimango, P. unicinctus and G. polyosoma). Rodriguez-Estrella et al. (1998) in a study conducted in scrub in Mexico, found that populations of most species of diurnal raptors can tolerate small to moderate loss of original vegetation cover. The scrub in the study area is particularly dense which reduces foraging/breeding opportunities and suitability for most species of diurnal birds.

Table 2 Land use of the study area, suburban area of Temuco, southern Chile

| Land use                                | Area (ha) | Percentage (%) |
|-----------------------------------------|-----------|----------------|
| Urban zone                              | 1794      | 100            |
| Harvested exotic species                | 167       | 0.91           |
| Medium density mature native forest     | 922       | 51.4           |
| Medium density mature native forest     | 35        | 0.2            |
| Pasture-crop rotation                   | 11        | 0.6            |
| Perennial grasslands                    | 26        | 1.4            |
| Medium density scrub                    | 57        | 3.2            |
| Open scrub                              | 3.5       | 0.2            |
| Other lands without vegetation          | 3.1       | 0.2            |
| Open scrub with grassland               | 131       | 7.3            |
| Medium density regeneration             | 11        | 0.6            |
| Plantations of exotic species           | 430       | 24.0           |
| Medium density scrub of exotic species  | 35        | 2.0            |
| Medium density to plantation            | 38        | 2.1            |
| Medium density mature to plantation     | 71        | 4.0            |
| Medium density to plantation            | 24        | 1.3            |
| Total                                   | 772       | 43.0           |

Discussion

The richness of diurnal raptors varied with the environment. The highest diversity was found in dense forest (eight species), with two forest specialist species (B. ventralis and A. chilensis). We consider the sighting of (A) chilensis to be accidental, as it was detected only once, whereas (B) ventralis was the second most frequent species in the study. Pavez et al. (2019) and Trejo et al. (2006) document that populations of B. ventralis and A. chilensis are negatively affected by the loss of mature native forest, which may explain their absence from the other environments without dense native forest. F. sparverius and M. chimango use a wide variety of environments (Donázar et al. 1993) and have a high capacity to adapt to changes in their habitat caused by human activities (Morrison and Phillips 2000; Jaksic et al. 2001). This explains the high abundance of M. chimango over other species and the presence of both these species in all the environments, with the exception of F. sparverius in exotic tree plantations. P. unicinctus, G. polyosoma and (C) plancus are widespread in Chile and also use a wide variety of environments, G. polyosoma being the third most common species in the study area. The species nesting in this environment coincide with Rodriguez-Estrella (1996), since many species of raptors need wooded areas with low anthropogenic disturbance for nesting. It is important the dense forest because it is the most diverse environment, offers nesting sites for many species, and yet comprises only a small proportion of land in the study area. The urban forests, especially suburban, provide important refuge for sensitive raptors (Fröhlich and Ciach 2018).

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Finally, exotic tree plantation was the least rich environment (three species), agreeing with Thiolay (1996) who reported that plantations had low diversity of raptor species in the northern Andes.

The study area, although small, contains many of the diurnal raptor species recorded at regional level; protection is therefore important.
The effects of human disturbance on the habitat of raptors may differ in degree and magnitude, causing their diversity and abundance to vary. Many species can adapt to, or thrive with, habitat modifications due to increased hunting and breeding opportunities (Rodríguez-Estrella et al. 1998; Rutz 2008; Seress and Liker 2015). Thus urbanization does not necessarily diminish the diversity of biological communities; indeed, suburban areas, which generally offer a mixture of environmental conditions and habitats, may have a richer biodiversity than natural areas (Glennon and Porter 2005). Fischer et al. (2015) propose new definitions for the native fauna present in urban and suburban areas, the former are urban dwellers independent of natural areas, and the seconds are urban utilizers occur as nonbreeders or as breeders that are present only because of dispersal from adjacent natural areas, but species, depending on changes in habitat, can move from one definition to another, changes that can be favorable and in this case, urbanized landscapes may become increasingly important to conservation efforts as populations of more species become urban utilizers and urban dwellers (Walk et al. 2010).

Some species of diurnal raptors have specific habitat preferences, while others are generalists and occupy diverse habitats as available. Among the specialists, (A) chilensis and (B) ventralis depend on the presence of mature native forest for nesting and hunting, occupying dense forests of Nothofagus in rough terrain and lowland steppe scrub (Bierregard 1995). However, B. ventralis also occupies open habitats associated with native forest fragments, and it is not known whether it is favoured by fragmentation (Figueroa et al. 2000; Jaksic and Jiménez 1986) proposed that this species has benefited from human activities over much of its geographical distribution. Another species that inhabits forest edges and grassland is G. polyosoma, which hunts on both flat terrain and rocky or steep areas (Jiménez 1995); it may nest in a variety of environments, not only in forests (Trejo et al. 2006) but also in low scrub, on telephone poles or on rocky outcrops (Jiménez 1995).

C. plancus and F. peregrinus use a wide variety of environments, showing a preference for open areas and thickets (Pavez 2019). E. leucurus and F. sparverius prefer open habitats, typically agroecosystems, using low-lying areas, grasslands and wetlands (Brown and Amadon 1968; Donázar et al. 1993; Dunk 1995). E. leucurus nests in trees, usually with dense plant cover, however single trees or isolated trees in large forests are sometimes selected (Dunk 1995). F. sparverius nests in cavities in various open and semi-open habitats covered by low vegetation, including grasslands, agroecosystems, fens, and sometimes urban or suburban zones (Smallwood and Bird 2002). Other species that hunt in open areas are F. femoralis (Brown and Amadon 1968) and M. chimango (Donázár et al. 1993; Travaini et al. 1995), which shows great adaptability to human disturbance (Morrison and Phillips 2000; Jaksic et al. 2001).
Conclusion and recommendations

In the suburban area to the north of Temuco the habitat use of diurnal raptors differs according to the environment. Despite its small size, the study area contains most of the species of diurnal raptors recorded at regional level (γ diversity); although it is in an agroforestry matrix Mature native forest fragments are poorly represented (8.6%) and only remain two core areas of 493 and 89.5 ha, both have protected status. For the large home ranges of raptors, functional connectivity probably exists between these two cores, and the surrounding agricultural matrix is used by many of the species as hunting grounds. Quantification of the distance between the larger fragments in a territory, and their connectivity, provide important information for estimating the ecological viability of raptor populations. In species associated with native forests, this connectivity facilitates the exchange of individuals between remaining fragments, enabling them to cross uninhabitable or partially uninhabitable matrices (Bélisle and Desrochers 2002). This underlines the importance of preserving and increasing the number and size of native forest fragments (Cardenas et al. 2003; Harvey et al. 2006).

Landscape ecology (sensu Forman 1995, Botequilha et al. 2006) consider including green corridors in suburban spaces and even urban green areas, allowing greater territorial connectivity (Flores et al. 1998; Mason et al. 2007), they would restore the habitat of many local species of native flora and fauna, and act as a buffer zone for many wildlife species living in nearby natural areas (Ahern 1995). There is a theoretical optimum configuration of land uses which can enhance their ecological integrity and environmental sustainability (Wu 2004); however, the important thing is to establish the proper definition of these land uses in suburban areas in order to combine urban needs with habitats for wildlife, and to incorporate urban-rural connectivity into suburban planning.

We propose that the different environments (i.e. forest, grassland and scrubland) should be considered in an integrated way in local land use plans, seeking to improve connectivity, structure and functionality, thus promoting the conservation and diversity of diurnal raptors. At the same time, it is important to retain the native forest fragments and to expand the area being restored by regeneration; to restrict urban occupation in grasslands and to evaluate the implementation of regulations for the territory studied.

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Ethics approval  (include appropriate approvals or waivers)
The manuscript has not been submitted to more than one journal for simultaneous consideration. The work presented is original and has not been published elsewhere in any form or language (in whole or in part). This study follows the standards of the Committee on Publication Ethics (COPE).

Consent to participate  (include appropriate statements)
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