Diversity of Diurnal Raptors in a Suburban Area of a City in Southern Chile

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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 objectives of this study were (a) to determine the use by diurnal raptors of the habitat in a suburban area of a city in southern Chile, and (b) to 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 hours of census, 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.

Introduction

The magnitude and speed of anthropogenic alterations to the environment in the last century are unprecedented in the history of humanity. Urbanization has been recognized as a cause of important effects on both species diversity and the composition of ecological 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 (Pimm et al. 1995), especially due to the conversion of natural to artificial systems (Goldewijk 2001). The expansion and multiplication of urban areas cause the reduction and fragmentation of original habitat, producing a mosaic of landscapes in which patches of natural environment are increasingly isolated and the remnants of natural vegetation are progressively 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, 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).

In rural areas of central and southern Chile, transformations in land use have been massive (Pauchard et al. 2006). They constitute the principal threat to birds of prey (Dale et al. 2000; Zalles and Bildstein 2000), affecting the availability of land, food and nesting sites (Hockin et al. 1992; Zalles and Bildstein 2000; Muñoz-Pedreros et al. 2010).

Landscape ecology studies these changes and allows us to analyse modifications to landscape structures and functions (Forman 1995). The discipline strengthens the ecological basis for planning and introduces a dynamic dimension into landscape studies, as well as providing a useful theoretical framework for urban planning (Botequilha et al. 2006). Raptor conservation programs must be based on knowledge of the birds' ecology in natural and urban habitats (Meynard et al. 2019).

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 native birds is reduced (Blair 1996; Clergeau et al. 1998; Cam et al. 2000; Fraterrigo and Wiens 2005). 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).

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 objectives of this study were (a) to determine the use by diurnal raptors of the habitat in a suburban area of a city in southern Chile, and (b) to characterize the different zones into five types of environment, and assess 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 Araucanía Region, 619.5 km south of Santiago de Chile. Temuco was founded in 1881; it had 10,000 inhabitants by 1893, 72,000 in 1960, 189,000 in 1982, 304,000 in 2002 and 410,520 in 2017, making it one of the fastest-growing cities in Chile in recent years.

The connected suburban areas included in the study were: (a) Chivilcan meadows (38º41'-38º43' S, 72º35'-72º36'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 (38º43'S-72º35'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. Suburban areas are defined as peripheral areas of a city (urban area), with housing density of 2.5–10 houses/ha. The climate is transitional between mediterranean climate and temperate rainforest (Di Castri and Hajek 1976), with a short, marked dry season (Inzunza 2003). The average annual temperature is 12ºC, relative humidity 80%, and the average annual rainfall is 1324.8 mm, with a dry summer period of two months. Five environments were identified from a land chart generated in GIS: (a) Meadows with winter flood regimes and mostly allochthonous vegetation (57.9%), predominantly hemicryptophytes (54%) and remains of the original swamp forest vegetation cleared for pasture (González and Cerda 1989); (b) dense scrub of *Ulex europeus* (an introduced species considered a weed) with fragments of *Chusquea quila* and *Aristotelia chilensis* surrounding a few native trees, mainly mature *Nothofagus obliqua*; (c) exotic tree plantations of *Pinus radiata* and *Eucalyptus globulus*, the area of which has been increasing over the years (Locher

2002), with contemporary monostratified plant coverage about 15 m high, without undergrowth; (d) regeneration, areas of young forest dominated by *N. obliqua, Peumus boldus* and *Cryptocarya alba* about 10 m high; and (e) dense forest containing clerophyllous species from the mediterranean area combined with Valdivian forest from the temperate rainy zone, formed by *Nothofagus-Perseetumboldetosum* (Oberdofer 1960); *Boldo-Cryptocaryetum* (Oberdofer 1960) and *Lapagerio-Aetoxiconetum* (Oberdofer 1960), 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).

Methodology

The sampling stations were selected in the field and then geographically referenced to prepare a chart with the census design (Fig. 1). Information on the richness and abundance of diurnal raptors was obtained using three complementary methodologies: (a) Acoustic census 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 agricultural ecosystems in six locations in southern Chile (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 10.00h, 12.00 to14.00h and 18.00 to 20.00h; (b) Fixed observation points on vantage points, with good visibility to the naked eye and using 10 x 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 11.00h and 15.00 to 18.00h); (c) 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 10.00h, at noon (12.00-14.00h), and from 18.00 to 20.00h 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 on days with favourable weather conditions (persistent rainy days were discarded), and using a template for sightings (Márquez et al. 2004).

We determined the following parameters: (a) Richness of species (S), defined as the number of species in a sample; (b) Relative abundance (AB%), defined as the percentage fraction of all birds of prey (sensu Krebs 1985) 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:

$H' = -\Sigma (pi \times \log2\ pi)$, (1) 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 log2 S. In addition, we calculated the Pielou equity index (J) according to the equation: J = H'/ H'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). To test the null hypothesis that the diversity H’ of diurnal raptors of the different environments are the same we followed the procedure of Hutcheson (1970) described in Zar (1996), consisting of a *t* test calculating the weighted diversity index: Hp = (*N*log*N*) - (α*fi* log *fi*) / *N*), including the calculation of variance for each environment according to: $S_{H'}^2 = [\Sigma fi \log2 fi - (\alpha fi \log fi)^2 / N] / N^2$ (d) β diversity (between environments) was represented by the species turnover or through a cluster similarity/dissimilarity dendrogram (between sectors) based on the Bray-Curtis Index (1957), using the BioDiversity Professional program (McAleece 1998); (e) g diversity, represented by all the species of diurnal raptors recorded in the Araucanía region (31,842 km^2) in a sample taken from five national parks covering 137,138 ha (4.3%), supplemented by published (Pavez, 2000; Silva-Rodríguez et al., 2008) and unpublished information (CONAF, T. Rivas-Fuenzalida, C. Gonzalez-Bulo, V. Raimilla, R. Reyes-Carrasco, P. Caceres, A. Jaramillo pers. comm.). For the ranges of abundance we followed Jaksic et al. (2001): abundant = > 5 individuals detected (seen or heard) per day; common = 1-5 individuals detected daily; frequent = 1 individual detected weekly; low = 1 individual detected monthly; rare = <5 individuals detected annually.

Data analysis

Spatial information was constructed and analysed with a land use chart prepared from aerial photographs and previous studies (Hauenstein et al. 1988b) and processed in a Geographic Information System (GIS) in the software ArcGIS 9.3. The vegetation structure of each land use was verified in the field, characterizing the diversity of vegetation strata to build up a chart of the environments by grouping disaggregated uses into more homogeneous structural environments. The 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 km^2), 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 conducted an analysis of the spatial patterns present, using the following landscape metrics (sensu Botequilha et al. 2006): shape (based on the morphometric characteristics of the fragments), metric area (calculated based on the area corresponding to each of the fragments), edge metrics (calculated to estimate the amplitude of the edge habitat in relation to the interior habitat), proximity analysis (to calculate distance to the nearest fragment of the same class within a given search radius), and analysis of core areas (which calculates the interior habitat area of each fragment). The metrics were applied at patch level (discrete basic spatial unit, polygons), by class (typological category, classifiable feature) and to the entire landscape according to importance (Forman and Godron 1986). The landscape metrics were analysed in vector format, consisting of a representation of spatial forms in points, lines and polygons based on vectors (nodes and lines).

ArcGIS 9.3 extensions, Fragstat v3.3, v3.0 and Patch Analyst vLATE, were used for spatial analysis. 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 hrs in all environments, 664 individuals of 10 species were recorded (Table 1). The following categories of abundance were established: rare: *Accipiter chilensis, Caracara plancus, Falco femoralis* and *Falco peregrinus*; frequent: *P. unicinctus, F. sparverius* and *Elanus leucurus*; common: *Buteo ventralis* and *Geranoaetus polyosoma*, and abundant: *Milvago chimango*. The frequency of records per species diversity and equity indexes for each temperature are shown in Table 1. The environment with the highest diversity was dense forest with eight species and a low equity, and 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. Records of all other species were < 2%.

In the prairie 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).

There were significant differences in the equity index of diversity (H') only between the dense forest and scrub environments (t 0.05 (2) 207 = 1.64), dense forest and exotic tree plantations (t 0.05 (2) 45 = 1.67), and dense forest and native forest regeneration (t 0.05 (2) 20 = 1.72). No significant differences were found between the other environments.

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 b diversity is relatively high, since both clusters have low similarity (43.7%).

The g 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, in descending order: pasture-crop rotation; exotic species plantations; fens; medium density mature native forest; medium density scrub; medium density native forest to plantation; harvested exotic plantations; perennial grasslands; dense mature native forest; open scrub with prairie; medium density regeneration and open scrub. The areas and proportions are shown in 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 prairie and the lowest richness in exotic tree plantations.

Fig. 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. Fig. 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 (functionally connected to three cores). The fragment in the municipal district is larger and has more connectivity.

Discussion

Diversity by environments

The richness of diurnal raptors varied according on the environment. The highest diversity was found in dense forest, headed by 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 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 Rodríguez-Estrella (1996), since many species of raptors need wooded areas with low anthropogenic disturbance for nesting.

Prairie was the second most diverse environment, 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 Rodríguez-Estrella (1996), as birds of prey make opportunistic use of fragments of agricultural areas for hunting. Species associated with open and semi-open areas have probably benefited from changes in land use (Jaksic and Jimenez 1986; Thiollay 2007).

Native forest regeneration presented a richness of species very similar to that of prairie, with the exception of *F. femoralis*, which was not recorded. This similarity may be because the species occupy these environments (meadow and seedlings of forest species) to hunt but not in their reproductive activities since they nest in mature trees (Brown and Amadon 1968; Dunk 1995). This environment has a very low territorial representation in the study area (2.5%) and a sparse structure, which may explain the low diversity recorded.

In scrub, four species were recorded (*F. sparverius, M. chimango, P. unicinctus* and *G. polyosoma*). Rodríguez-Estrella et al. (1998) in a study conducted in scrub in Mexico, found that populations of most species of diurnal raptors did not diminish with a small to moderate loss of original vegetation cover. The scrub in the study area is particularly dense and severely limits the habitat requirements of most species of diurnal birds (e.g. foraging area, shelter).

Finally, exotic tree plantation was the least rich environment, agreeing with Thiollay (1996) who reported that plantations had low a 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 exhibit rapid adaptation to habitat modifications and some of them are even favoured by these changes, foraging in modified matrices (Rodríguez-Estrella et al. 1998). 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).

Habitat preferences

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* (Donázar et al. 1993; Travaini et al. 1995), which shows great adaptability to human disturbance (Morrison and Phillips 2000; Jaksic et al. 2001).

Landscape ecology

Temuco district (466 km^2 = 46,600 ha) is set in an agroforestry matrix and continues to experience a process of extensive anthropogenic disturbance. Mature native forest fragments decreased by 50% between 1994 and 2001 (Locher 2002) and currently are poorly represented (706 ha, 8.6%). Only two core areas of native forest remain, of 493 and 89.5 ha, both located in the northern part of the district. Both have protected status. For the effects of the large home ranges of raptors, functional connectivity probably exists between these two cores, especially considering that the surrounding agricultural matrix is used by many of the species recorded as hunting grounds. This underlines the importance of preserving and increasing the number and size of native forest fragments in these agricultural and forestry plantation systems (Cardenas et al. 2003; Harvey et al. 2006).

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). Landscape ecology can act as a framework to allow us to move from traditional conservation strategies, characterized by action in natural environments, to strategies including suburban spaces and even urban green areas, allowing greater territorial connectivity (Flores et al. 1998).

Green corridors in suburban areas are an effective measure to mitigate the negative effects of urbanization on biodiversity (Mason et al. 2007). Among other benefits, these corridors preserve the habitat of many local species of native flora and fauna, provide recreation and leisure areas for neighbouring communities, contribute to urban beautification, 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.

Conclusion

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). We propose that the different environments (i.e. dense forest, grassland and scrubland) should be considered as a single territory 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 dense 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.

Declarations

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Conflicts of interest/Competing interests

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Availability of data and material (data transparency)

All data and materials support published claims and meet field standards.

Code availability (software application or custom code)

Not applicable.

Additional declarations for articles in life science journals that report the results of studies involving humans and/or animals

Not applicable

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)

Not applicable.

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Tables

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Figures

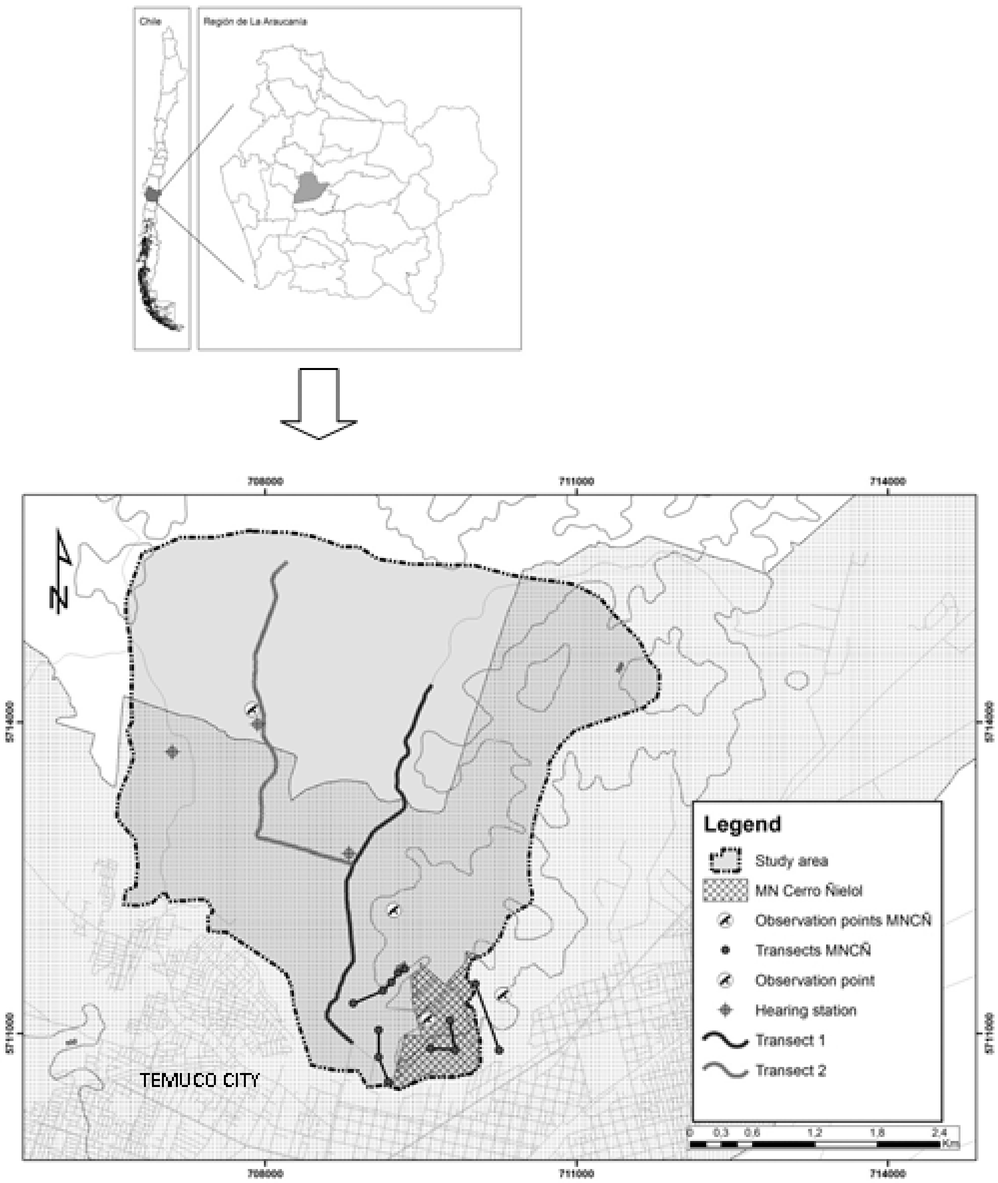

Figure 1

Location of study area in a suburban area of Temuco, southern Chile. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

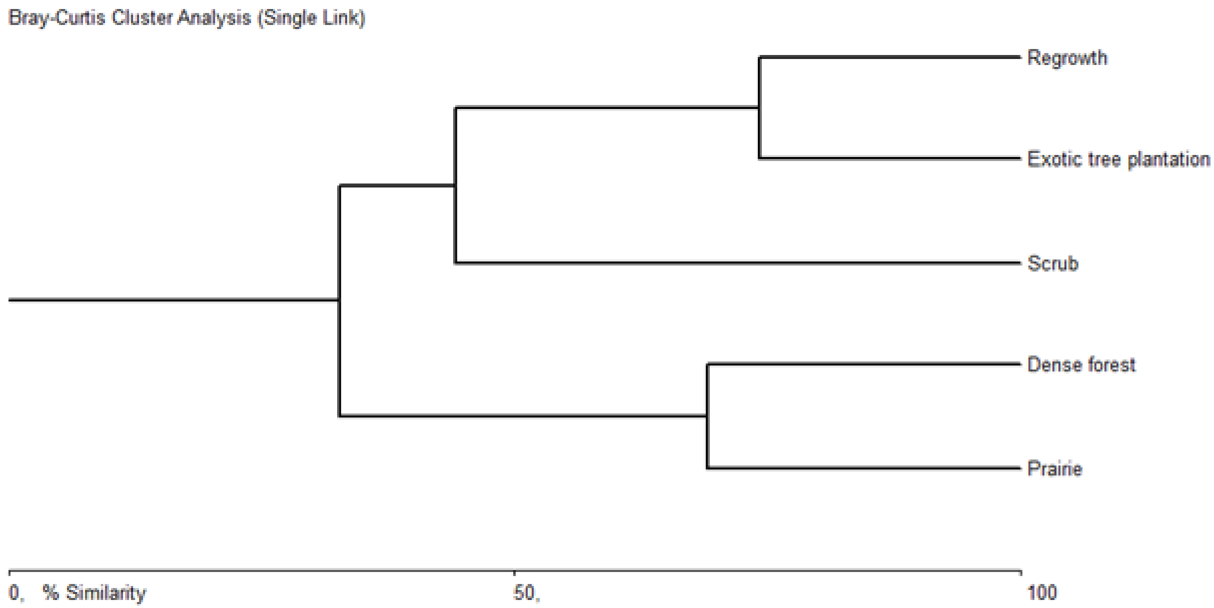

Figure 2

Dendrogram showing the similarity between five environments in a suburban area of Temuco, southern Chile, based on the richness of diurnal raptors.

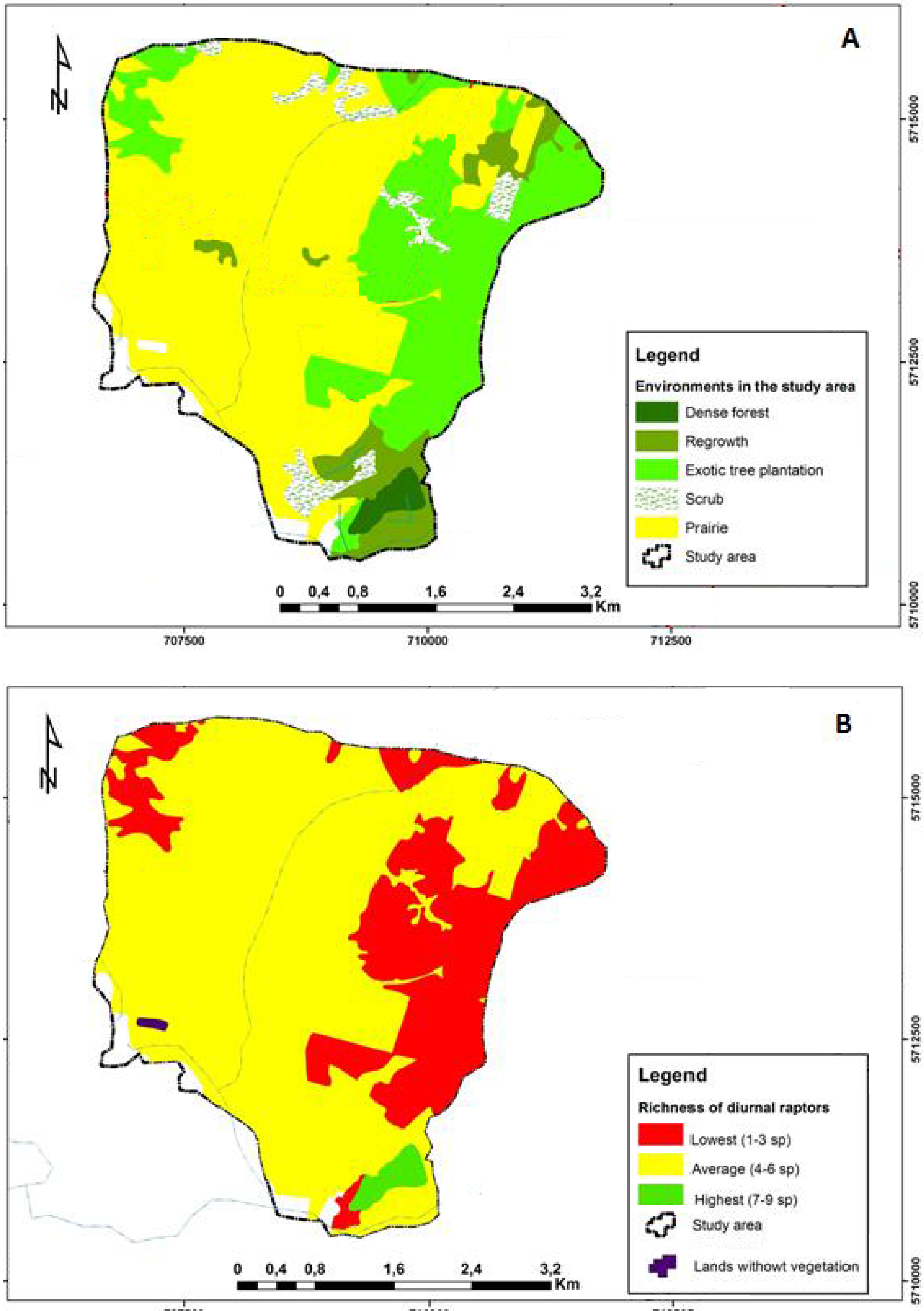

Figure 3

A= Chart of environments present in the study area, located in a suburban area of Temuco. B= Chart of environments and richness of diurnal raptors in the study area, southern Chile 2010-2011. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

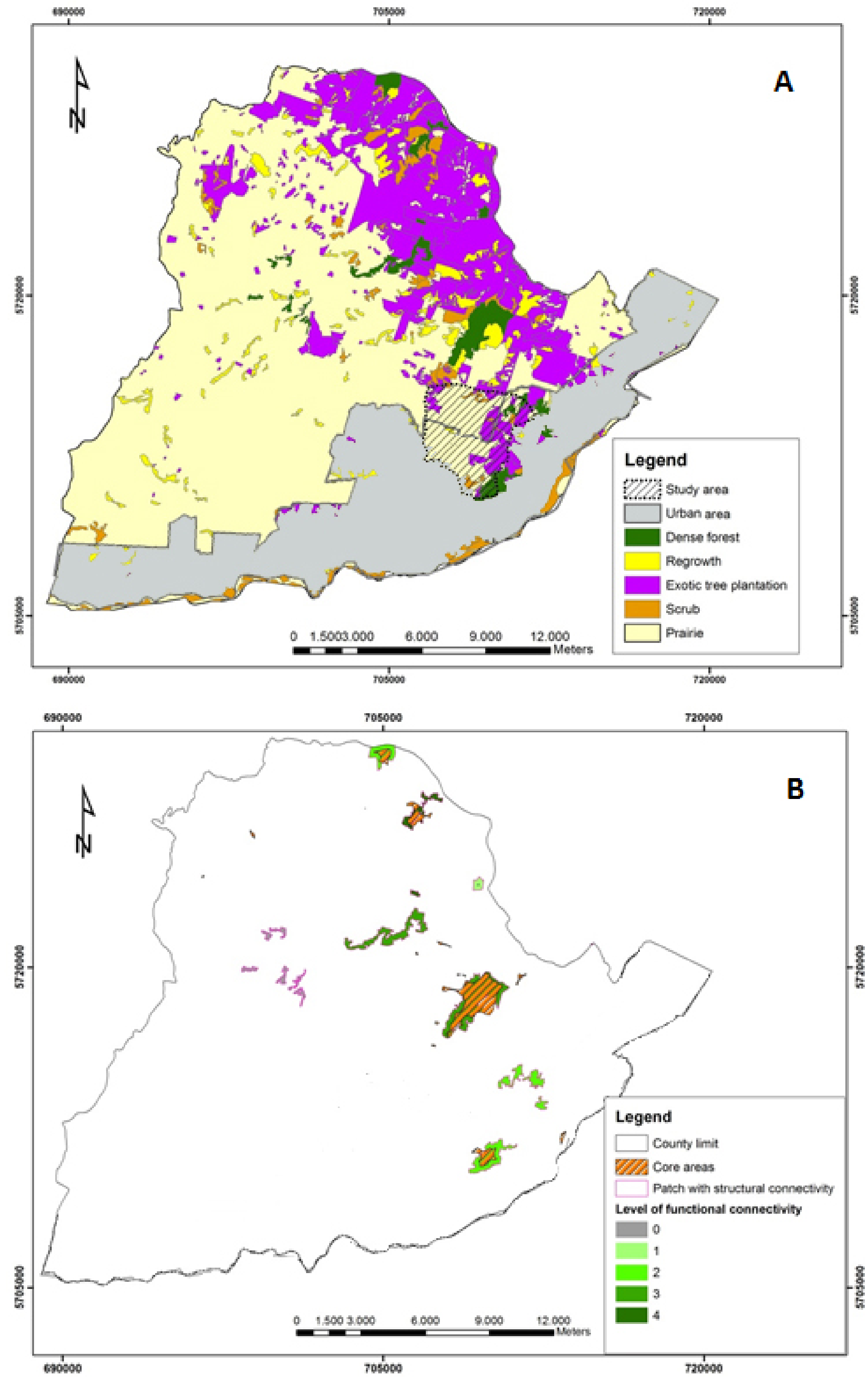

Figure 4

A= Chart with landscape mosaic of Temuco municipal district. B= Chart units of structural and functional connectivity components, with cores, in Temuco municipal district. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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