BIOLOGICAL CONSERVATION 127 (2006) 272–281

available at www.sciencedirect.com

SCIENCE DIRECT®

journal homepage: www.elsevier.com/locate/biocon

Multiple effects of urbanization on the biodiversity of developing countries: The case of a fast-growing metropolitan area (Concepción, Chile)

Aníbal Pauchard[a,], Mauricio Aguayo[b], Eduardo Peña[a], Roberto Urrutia[b]*

[a]*Facultad de Ciencias Forestales, Universidad de Concepción, Casilla 160-C, Victoria 631, Concepción, Chile*
[b]*Centro de Ciencias Ambientales EULA-Chile, Universidad de Concepción, Concepción, Chile*

ARTICLE INFO

Article history:
Received 10 February 2005
Received in revised form 2 May 2005
Accepted 13 May 2005
Available online 20 October 2005

Keywords:
Homogenization
Urban ecology
South America
Chile

ABSTRACT

Urbanization is increasingly homogenizing the biota of less developed countries. Even though urban sprawl is a worldwide problem, most studies on the effects of urbanization, and the conceptual models have focused on developed countries. South America has not escaped urbanization, and here we discuss the potential impacts of urban sprawl with respect to three ecosystems in the metropolitan area of Concepción, Chile. We consider this area a good model and fairly representative of other cities in developing countries which are also experiencing rapid and uncontrolled growth. We found that the impacts of urban sprawl on biodiversity in the metropolitan area of Concepción differ little from cities in other parts of the world: native ecosystems are replaced by pavements and buildings and what is left of the natural soil is covered with green areas dominated by non-native ornamental species. Wetlands and other peri-urban ecosystems are rapidly being destroyed, fragmented or invaded by non-native species. We found that from a study area of 32,000 ha, there was a net loss to urbanization of 1734 ha of wetlands (23% of the original) and 1417 ha (9%) of agricultural, forest and shrub land cover types between 1975 and 2000. From the total area urbanized (3151 ha), 55% corresponded to wetlands and 45% to agricultural, forest and shrub lands cover types. We see the lack of environmental awareness as a major cause of the increasing deterioration of biodiversity in urban areas of developing countries. More research is needed to fully understand the effects of urban sprawl on the biodiversity of developing countries to include these ecosystems in global conservation strategies.

Urbanization is now considered a major driving force of biodiversity loss and biological homogenization not only in developed countries, but increasingly in less developed countries (Savard et al., 2000; Gupta, 2002; McKinney, 2002, this issue). However, urbanization appears to be having different effects on the biota of developed and developing countries (Lambin et al., 2001). In developed countries, urbanization is primarily fragmenting large areas, extending its influence over the entire landscape. In contrast, in developing countries, growth is still concentrated around urban cores, replacing adjacent land uses such as agricultural and more natural vegetation but at a slower rate than developed countries (McGranahan and Satterthwaite, 2003).

Even though the effects of urban sprawl on biota have received considerable attention from the scientific community, nearly all studies, and the derived conceptual frameworks,

* *Corresponding author*: Tel.: +56 41 204934; fax: +56 41255164.
E-mail address: pauchard@udec.cl (A. Pauchard).
0006-3207/$ - see front matter
doi:10.1016/j.biocon.2005.05.015

have focused on developed countries. The effects of urbanization on native and introduced biota in developing countries are poorly known and the scarce evidence that exists tends to focus on the effects with regards to specific taxa in particular situations (e.g., Estades, 1995; Fontes and Milano, 2002; Whitmore et al., 2002).

South America has not escaped the urbanization trend and is following current models of urban development, where urban areas are expanding and replacing rural and natural areas (Pimentel et al., 1998; Ryder and Brown, 2000). Whilst the level of development in South America is far less pronounced than in the United States or Europe, urban sprawl is still a major cause of impacts in peri-urban ecosystems. This process has major implications due to the high population densities of the cities of South America. The economic development boom of some countries is bringing new pressure for cities to expand and for the development of suburban neighborhoods (Henderson, 2002; Qadeer, 2004; Leao et al., 2004).

In recent decades, Chile has become a predominantly urban country with more than 87% of its 15 million inhabitants living in cities (INE, 2002). The concentration of people around urban centers is impacting on the biodiversity of urban and peri-urban areas, not only in the capital Santiago (Romero and Ordenes, 2004) but also in other medium-sized cities (Azócar et al., 2003). Most urban centers are located around the mediterranean zone, which is recognized as a biodiversity hotspot both for its endemism and the threat to its conservation (Myers et al., 2000), but is hardly represented in the public protected areas system (Pauchard and Villarroel, 2002). The metropolitan area of Concepción with almost a million inhabitants is located in what used to be a highly diverse area of transition between the mediterranean and the temperate biomes of Chile.

Here we discuss the potential impacts of urban sprawl regarding three ecosystem types in the metropolitan area of Concepción, Chile. We consider this area a good model and fairly representative of other cities in developing countries, which are also experiencing rapid and uncontrolled growth. We describe evidence of the effects of urbanization on flora, fauna, habitat loss and fragmentation, and the homogenization process . This example highlights the need for more research on the impacts of urban sprawl on biodiversity in the developing world to be able to recognize the differences with the better-studied systems of developed countries.

1. The metropolitan area of concepción

The metropolitan area of Concepción, Chile (36°49′S, 73°01′W) is a conjunction of two major cities, Concepción (pop. 221,000) and Talcahuano (pop. 300,000). The overall area of 381 km^2, containes 76 km^2 considered as urban (INE, 2002). There are also an additional number of neighborhoods associated with the area, which account for another 386,000 inhabitants. The population density in the urban areas is around 7000 persons/km^2. Major commercial activities in the area include industrial forest plantations, oil refineries, steel industry and large-scale fisheries (Sánchez, 1989).

Before European settlement, the native vegetation of Concepción was dominated by temperate forests with mediterranean elements and extensive areas of wetlands and riparian vegetation (Abad, 2000; Smith-Ramírez, 2004; Torrejon et al., 2004). Since the establishment of the city in the 1600s by the Spaniards, inhabitants have preferred to build in the low-elevation floodplains and wetlands. Less development has occurred in the higher elevation areas of the Coastal Range because of their steep slopes and high landslide risk. The urbanization process increased the use of the native forest for fuelwood and construction, reducing the forest cover around the city (Azócar and Sanhueza, 1999).

Concepción became an important industrial city during the 1900s due to its close proximity to the port of Talcahuano (Sánchez, 1989). The major industrial and urban boom started in 1950 with the strengthening of the metropolitan area and the development of exotic tree plantations (Sánchez, 1989; Sanhueza and Azócar, 2000). Since the 1970s, there has been a major shift towards urban sprawl. People began settling in areas far from the city by building satellite neighborhoods. The remaining wetlands and other flat areas are now being filled in and used for both residential development and industrial complexes (Azócar and Sanhueza, 1999; Riffo and Villarroel, 2000). The Bío-Bío river that crosses the metropolitan area, is now confined by development on both sides (Fig. 1).

We have chosen for discussion two examples of which urban sprawl is affecting biodiversity: the coastal wetlands and associated riparian systems (the Bio-Bio River) and the peri-urban mosaic of rural land use, which includes exotic tree plantations and native forest fragments.

2. Wetlands and riparian ecosystems

In Chile, as in the rest of the world, foundations of cities have been primarily associated with water bodies and areas of high biodiversity, especially coastal areas (Duncan et al., 2004). Water is usually related to geomorphic elements highly suitable for human settlement such as floodplains and depositional valleys, making these hydrological systems highly prone to urbanization (Malmqvist and Rundle, 2002; Charlesworth et al., 2003). In addition, these areas are usually environments rich in biodiversity due to a combination of climatic and historical factors, increasing the threat of urbanization over the local biota (Kuhn et al., 2004).

The metropolitan area of Concepción is embedded in a diversity of aquatic ecosystems associated with the watersheds of the Bio-Bio and Andalién rivers and their interface with the Pacific Ocean, specifically with the bays of Concepción and San Vicente (Parra, 1989). The Bio-Bio and Andalien rivers, the lake systems of San Pedro and Concepción and the wetlands of Rocuant, Lenga and Los Batros are major elements of this complex aquatic system and maintain interesting samples of native plants and animals (EULA, 1999, 2000; Ilabaca, 1992).

The urban expansion of the metropolitan area of Concepción has been complex, erratic and poorly planned, as in most cities of Chile (EULA, 1999, 2000). Most of this urban development has occurred around and over the aquatic

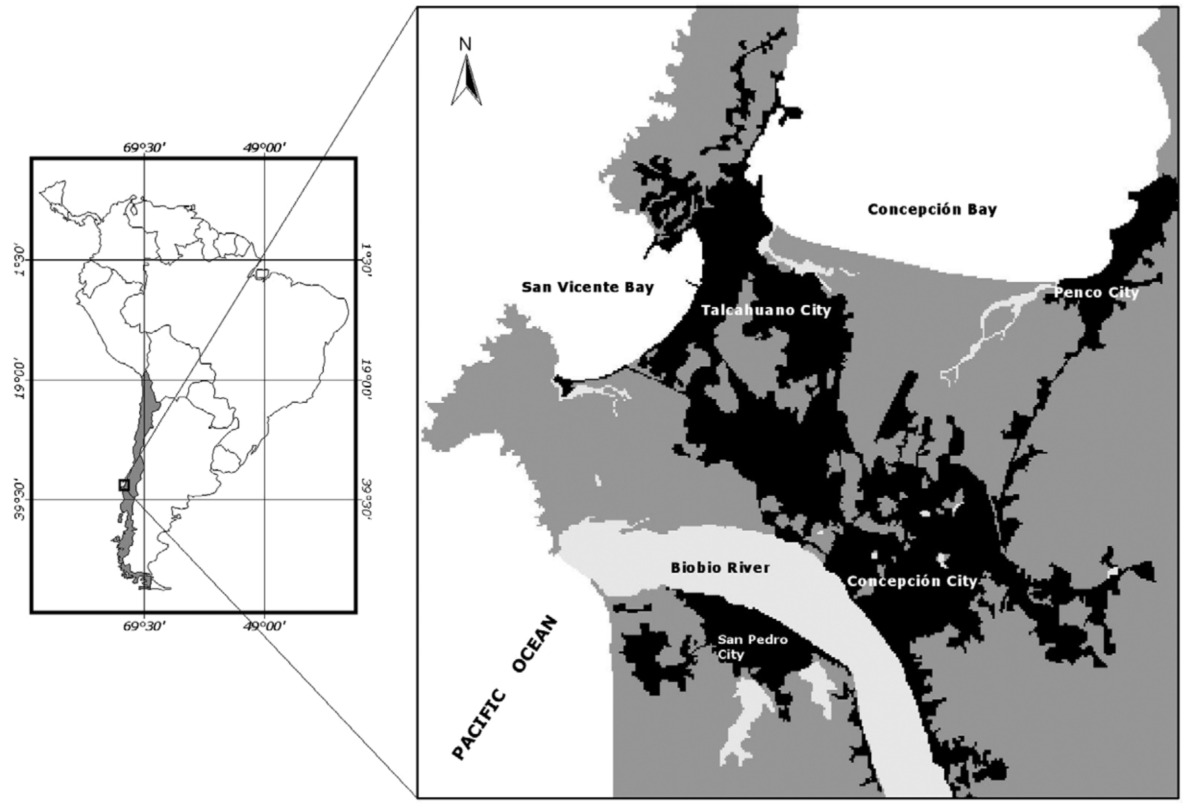

Fig. 1 – Location of the metropolitan area of Concepción.

systems, affecting their biological and physical qualities (Parra, 1989). Large sections of the two main rivers have been disrupted through channelling, filling and flow detour, which have affected the floodplain and subsequent recharge of the river greatly. Wetlands have also suffered from over-development. City growth of has led to the draining and filling of wetlands for both home and industrial development (EULA, 2000).

This urban sprawl has been caused by population and income growth and little environmental awareness, coupled with relaxed legal regulations. Here, the population has traditionally seen wetlands as wastelands that could provide a much greater service if they were drained and filled. Many of these wetlands are used for water and solid waste disposal and are considered by the population as a source of mosquitoes (Angulo, 2000). Additionally, the sprawl has been concentrated in the floodplains and wetlands because of technical difficulties and greater costs of urban expansion into other areas such as the coastal range, (Riffo and Villarroel, 2000).

A good example of urban sprawl over a wetland is the case of the freshwater-salt wetland of Chepe-Carriel Sur, which has experienced a drastic reduction in area from 1257 ha, in 1955, to 553 ha in 2000 (Tobar, 2003). This wetland has been greatly fragmented due to the construction of the city airport, avenues and highways, and it now contains more than 10 different land uses, with agricultural and residential use being the greatest. The potential for conservation, recreation and education on these urban wetlands has thus been lost (Riffo and Villarroel, 2000).

To make an objective estimate of land-cover change in the Metropolitan area of Concepción, we contrasted two Landsat images taken in 1975 and 2000. For the year 1975, the image had a 79-m resolution (MSS, Multispetral scanner), and for the year 2000, the image had a 30-m resolution (ETM, Enhanced Tematic Mapper). Images were geo-referenced and land-cover data were derived from maximum-likelihood classifications (Wear and Bolstad, 1998) (Fig. 2). A transition matrix was built to compare both land covers (López et al., 2001). In the period from 1975 to 2000, we found that in an area of 32,000 ha, there was a net loss to urbanization of 1734 ha (23% of the original) of wetlands and 1417 ha (9%) of agriculture, forest and shrub land cover types. From the total area that has been urbanized (3151 ha), 55% corresponded to wetlands and 45% to agriculture, forest and shrub land cover types (Fig. 2). This confirms the notion that urban developers tends to occur in the flat terrains provided by wetlands rather than the steeper terrain of the coastal range, a trend that is found elsewhere (Gupta and Ahmad, 1999; Brannstrom and Oliveira, 2000; Duncan et al., 2004).

Even though the effects of urbanization on natural environments are evident, environmental concerns by planners have, in at best, resulted in the creation of city parks. These parks have incorporated little or no consideration of the natural ecological function of riparian and wetland systems. Instead, mimicking European or American models, park planners have focused their efforts on aesthetic values, both of which homogenize and reduce biodiversity (Breuste, 2004).

Briefly, the combined effects of the multiple elements of urbanization have led to the reduction, alteration and frag-

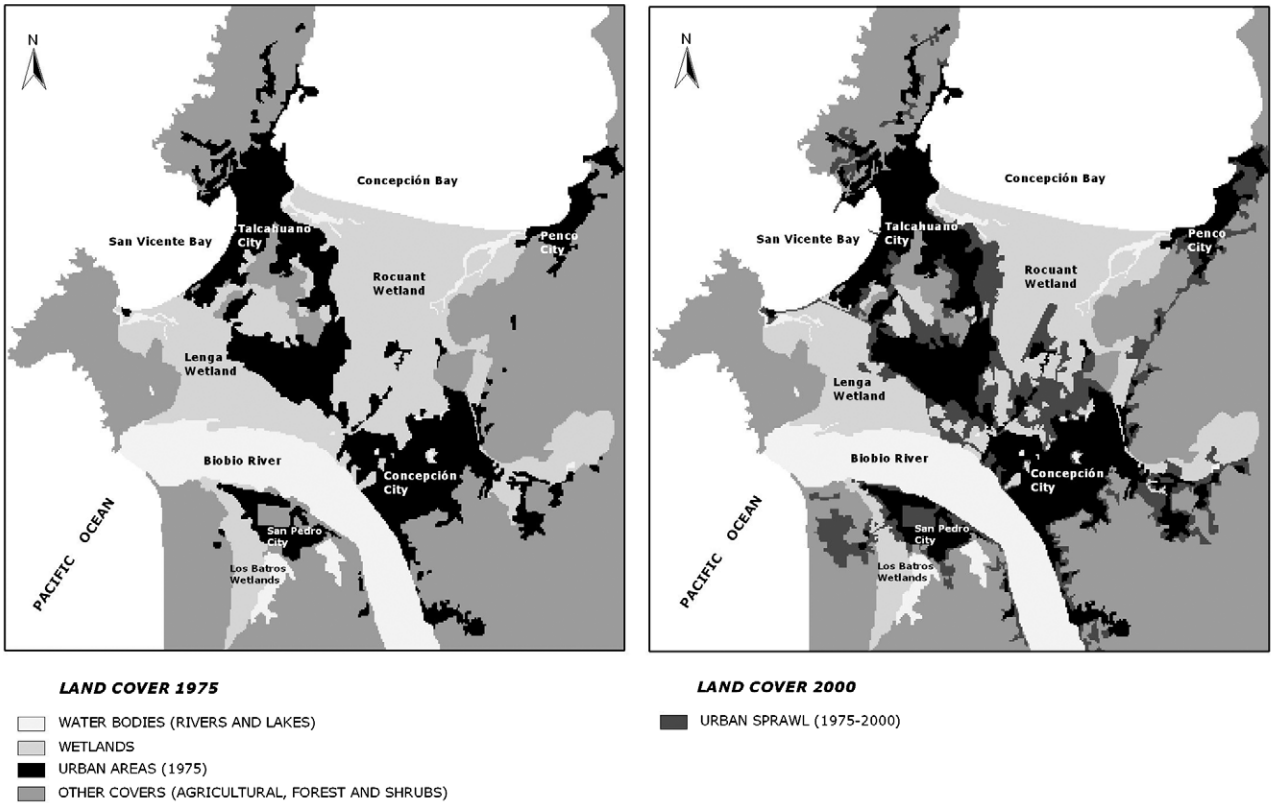

Fig. 2 – Land cover use for the metropolitan area of Concepción in 1975 and 2000. Maps were developed based on Landsat images. Notice the reduction on wetlands and other covers caused by urbanization.

mentation of the terrestrial and aquatic systems associated with riparian and wetland environments. Furthermore, the use of these predominantly aquatic systems for urban development has increased the risk of natural disasters such as flooding and landslides (e.g., Santiago in Romero and Ordenes, 2004).

2.1. *Direct effects on biodiversity*

The biodiversity of wetlands have undergone irreversible changes caused by urban sprawl. The increasing number of home development projects on the infilled wetlands has reduced the area, and the natural variability in seasonal fluctuations of the hydrological regime. This has reduced the environmental heterogeneity and with it the complex native wetland plant communities and associated effects on native birds (Riffo and Villarroel, 2000).

The wetlands of Lenga and Los Batros harbor ca. 115 animal species, 18 of which have identified conservation problems (Quintana, 1993; Riffo and Villarroel, 2000). Among the endangered species are the endemic fish Carmelita de Concepción (*Percillia irwinii*), the Chilean frog (*Caudiverbera caudiverbera*), the black neck swan (*Cygnus melancoryphus*) and the common snipe (*Gallinago gallinago*). Of 95 bird species recorded in both wetlands, 15 are considered regular migratory species and 8 are from the northern hemisphere: *Hymenops perspicillata*, *Numenius phaeopus*, *Larus pipixcan*, *Pluviales dominica*, *Arenaria interpres*, *Limosa haemastica*, *Calidris alba* and *Sterna paradisaea* (Quintana, 1993; Riffo and Villarroel, 2000).

River channeling, which includes changes in its morphology, impervious cover of its shores, and alteration of the sediment structure, have produced important changes in the ecosystem of the Bío-Bío and Andalién rivers causing habitat fragmentation, habitat loss, and homogenization (Habit and Parra, 2001). This homogenization or loss of environmental heterogeneity triggers changes in the structure of species assemblages, opening new niches for the invasion of alien species (Habit and Parra, 2001).

Campos et al. (1993) established for the Bío-Bío River that of the 17 fish species found, four were alien and are considered among the eight most aggressive fish invaders (Worlds Worst Invasive Alien Species, cited in Cambray, 2003): *Oncorhynchus mykiss* (rainbow trout), *Salmo trutta* (brown trout), *Gambusia affinii* (gambusia) y *Cyprinus carpio* (common carp). The same species are also found in the adjacent Andalién River (Habit et al., 2003). These voracious invaders share their habitat with three endangered native species: *P. irwinii*, *Bullockia maldonadoi* y *Nematogenys inermes* (Campos et al., 1993; Habit et al., 2003).

Even though the four alien fish occupy the river around the metropolitan area, their presence is probably related to larger scale processes such as introduction programs rahter than urbanization (Soto et al., 2001). Nonetheless, the heavy impacts of this urban center on rivers is probably increasing the richness and abundance of more generalist non-native species, which are adapted to disturbed environments and that outcompete and predate native fishes (Boet et al., 1999; Cambray, 2003).

Lake systems in the metropolitan area of Concepción have also suffered pressure from urban development. One of the major effects is eutrophication caused mainly by the nutrient discharge and bacteriological pollution contained in water runoff and sewer systems draining from surrounding urban areas (Parra, 1989; Urrutia et al., 2000). Eutrofication promotes the overdevelopment of invasive aquatic species such as *Egeria densa* (Common waterweed) and the blooming of algae (*Microcystis aeruginosa*) (Urrutia et al., 2000). *E. densa* is one widely dispersed non-native species, which is considered an invasive weed in other areas of the world (deWinton and Clayton, 1996; Wells et al., 1997).

3. Peri-urban forests

Besides the wetlands, the metropolitan area of Concepción is surrounded by a highly disturbed matrix containing exotic forestry plantations (*Pinus radiata* and *Eucalyptus globulus*), small scale agriculture and dispersed fragments of secondary native forest (Clapp, 2001; Smith-Ramírez, 2004). A long history of agriculture has been replaced by intensive forestry plantations and urban sprawl, creating a fine-grained mosaic where native and exotic species intermix (Sánchez, 1989).

The type of development in the peri-urban interface is, as in most countries, clearly related with the socio-economics of the inhabitants. Lower income groups tend to build small houses in crowded environments with limited infrastructure (electricity, gravel streets, etc.). Of course, in these areas there is almost no space for natural or even exotic vegetation. Furthermore, human-caused fires have devastating effects on native vegetation, and are a greater risk in the urban–rural interface, especially in populated neighborhoods. Conversely, suburban developments of higher income groups have lower household densities and therefore, more space, more vegetation and a lower intensity of human disturbances.

However, as is true of developed countries, people in suburban neighborhoods tend to choose traditional landscaping (extensive lawns and exotic trees) over more natural vegetation, reducing the potential for native biota (Breuste, 2004; Table 1). Recently, there has been a growing trend to take advantage of natural elements of the landscape, such as remnant native vegetation, topographical features and riparian areas. In some cases, developers are including natural areas as private parks inside their developments. Some of these new neighborhoods may serve as refuge for native species due to the lack of hunting and extractive use (pers. observation). There is an obvious paradox here, larger lots in suburban neighborhoods are friendlier to native biota (McKinney, this issue), but at the same time this is the type of development that is having the more extensive effects and important indirect effects such as massive land use change increasing car use, and overall over-consumption (e.g., construction

Table 1 – Frequent non-native species in urban, peri-urban forests, wetlands, and aquatic systems of the metropolitan area of Concepción

Land use	Trees	Shrubs	Mammals	Birds
Urban	*Liquidambar styraciflua* *Robinia pseudoacacia* *Tilia cordata* *Platanus orientalis* *Prumnus ceracifera* *Ulmus* sp. *Populus* spp. Fruit trees (*Persia*, *Prumnus*, *Citrus*)	*Crataegus* sp. *Ligustrum* *Pittosporum* *Cotoneaster*	*Ratus norvergicus* *Ratus ratus* *Canis familiaris* *Felis domesticus*	*Columba* *Passer domesticus*
Forests	*Pinus radiata* *Eucalyptus globulus* *Acacia dealbata* *Acacia melanoxylon* *Populus spp* *Cupressus macrocarpa*	*Cytisus monspesulana* *Rubus* spp. *Rosa moschaeta*	*Lepus europaeus* *Oryctolagus cuniculus* *Ratus norvergicus*	*Callipepla californica*
Wetlands	*Acacia melanoxylon* *Eucalyptus globulus* *Salix babylonica* L. *Pinus radiata* *Populus nigra* *Cupressus* sp.	*Rubus ulmifolius* *Teline monspessulana*	*Mus musculus* *Ratus ratus* *Lepus europaeus* *Oryctolagus cuniculus*	*Columba livia* *Passer domesticus* *Callipepla californica*
	Aquatic plants		Fish	
River and water bodies	*Egeria densa* *Eicchornia crassipes* *Limnobium laevigatum* *Nymphaea alba*		*Oncorhynchus mykiss* *Salmo trutta* *Gambusia affinii* *Cyprinus carpio* *Gambusia holbrooki*	

materials, electricity, irrigation water) (McGranahan and Satterthwaite, 2003).

3.1. *Direct effects on biodiversity*

The campus of the University of Concepción, which is adjacent to the city center area of Concepción, is part of a larger estate that contains interesting examples of forest plantations and small fragments of native vegetation. We have chosen this area to study the effects of the urban–rural gradient on biodiversity patterns, specifically on birds and vascular plants. Birds were recorded using a point sampling method (Reynolds et al., 1990; González, 2003). Sampling points were located along trails and tracks, and all species seen or heard were recorded during a 5-min period (Estades and Temple, 1999). For plants, we used transects and circular plots to record species composition of trees, shrubs and herbs in multiple patches of the vegetation mosaic (Pauchard et al., 2000; Figueroa, 2004).

We found that the rural mosaic although altered greatly, remains as an important reservoir of local biodiversity. In approximately 80 ha of mixed plantations and native vegetation fragments, we identified 150 vascular plant species, 50 (33%) of them were alien (Figueroa, 2004). This ratio is much higher than those found in protected areas of Chile (ca. 12% in Arroyo et al., 2000; Pauchard and Alaback, 2004). Many of the non-native species are concentrated along roadsides and disturbed ground, but a significant number have entered native forest fragments and dominate the understorey of forest plantations (e.g., *Citysus monspesulana*, *Rubus ulmifolia*, *Acacia delbata*). Prescribed burns, after forest harvests, worsen the situation favoring the establishment of these aggressive species.

The large number of non-native species in the peri-urban environment is influenced greatly by the previous agricultural land use. However, due to its proximity to the city center and the intense recreational use of the area, some of the non-native species may have been brought from the city of Concepción. Primary dispersal agents may be the machinery used in silvicultural practices, the large number of recreational visitors or natural vectors (e.g., birds, wind). At a much larger scale, Arroyo et al. (2000) found a similar positive correlation between road density and the number of alien species for administrative regions of Chile.

The Herbarium of the University of Concepción has recorded 113 alien plant species from the streets and abandoned lots of Concepción city center (Table 2), whereas only a few native species survive. These aliens represent more than 15% the total number of the 723 alien species recorded for Chile (Pauchard and Alaback, 2004). Many of these aliens are generalists and considered as global weeds, adapted to highly disturbed environments, and imported to Chile through agriculture and ornamental introductions (Figueroa et al., 2004).

Birds also showed a clear response to the urban–rural gradient. In the city interior, the abundance and richness of birds was lower than in peri-urban environments. *Passer domesticus* (house sparrow) and *Columba livia* (common pigeon), two exotic species distributed worldwide (Fernandez-Juricic, 2001), dominated in highly urbanized areas whereas native species are absent (Table 1). *Larus dominicanus* (kelp gull), a transcontinental exploiter of urban environments, also takes advantage of urban structures located within a short distance from the coast. In parks and green areas *Turdus falcklandii* (zorzal) is common, this is a native species and is one of the few native exploiters of the urban setting (sensu McKinney, 2002; Díaz and Armesto, 2003). Other native bird species have a more sporadic presence, usually associated with peri-urban environments: e.g., *Elaenia albiceps* (fio fio), *Carduelis barbatus* (jilguero), *Milvago chimango* (tiuque) and *Sephanoides sephanoides* (colibrí), a tiny firecrown.

The low abundance and richness of native species in urbanized environments may be related to the high density of urban dwellings, the low proportion of green areas and open spaces, and the dominance of alien tree species (Díaz and Armesto, 2003; Table 1). Thus, the absence of native species appears to be more related to local habitat than to overall landscape context (Clergeau et al., 2001; Jokimaki and Kaisanlahti-Jokimaki, 2003). The habitat requirements for native birds are provided by vegetation, either native or exotic, which is extremely scarce in urban areas. This would explain why most native bird species of south-central Chile adapt better to rural than to urban environments (MunozPedreros et al., 1996).

In our field surveys, we observed that across the environmental gradient from the urban areas to the forest mosaic, the number of species increased from 3 to 12 species per sampling point (González, 2003). The peak in diversity occurs more than 500 m from the urban area and where native vegetation remains in riparian corridors. An associated factor that confounds the urban effect is the presence of fast growing plantations of *E. globulus*, which appears to favor diversity in the earlier stages of crop development due to their open structure.

We found that more than 70% of the species recorded have adapted to some degree to urban and peri-urban environments and agricultural or forestry crops. The native urban avoiders are those that require dense native forest or any dense vegetation (e.g., family Rhinocryptidae, *Scelorchilus rubecula* (Chucao); Reid et al., 2004; Willson, 2004). In most cases this cover is provided by native species, but it may also be provided by dense stands of *C. monspesulana* and *Rubus ulmifolius*, two invasive European species.

Alien mammals such as *Lepus europaeus* (European hare) and *Oryctolagus cuniculus* (European rabbit) are widely distributed and abundant in the peri-urban areas of Central Chile (Jaksic, 1998). Some alien mammals have become agricultural pests, and appear to be affecting native species by predation and competition (see Jaksic, 1998 and Jaksic et al., 2002, for review). No published data was found to describe native and alien mammal distribution along the peri-urban gradient of Concepción.

4. Future directions

Impacts of urban sprawl on biodiversity in the metropolitan area of Concepción, differ little from the world-wide situation: native ecosystems are replaced by pavement and buildings and what is left of the natural soil is covered with green

Table 2 – Alien species list for the urban area of Concepción

Achillea millefolium
Alisma plantago-aquatica
Alyssum alyssoides
Amaranthus hybridus
Anagallis arvensis
Anthemis cotula
Arctotheca calendula
Atriplex patula
Avena barbata
Avena fatua
Avena sativa
Bartsia trixago
Bidens aurea
Bidens laevis
Borago officinalis
Brassica rapa
Briza maxima
Briza minor
Bromus catharticus
Bromus diandrus
Bromus hordeaceus
Bromus scoparius
Capsella bursa-pastoris
Carduus pycnocephalus
Cestrum parqui
Chamaemelum mixtum
Chenopodium album
Chenopodium multifidum
Chenopodium murale
Cichorium intybus
Conium maculatum
Convolvulus arvensis
Coronopus didymus
Cymbalaria muralis
Cynodon dactylon
Cynosurus echinatus
Cyperus eragrostis
Dactylis glomerata
Datura stramonium
Digitaria sanguinalis
Echinochloa crusgalli
Echium plantagineum
Echium vulgare
Eichhornia crassipes
Epilobium tetragonum
Erodium cicutarium
Eschscholzia californica
Euphorbia peplus
Festuca arundinacea
Foeniculum vulgare
Fumaria capreolata
Galega officinalis
Gastridium phleoides
Hordeum vulgare
Hydrocotyle ranunculoides
Hypericum perforatum
Lagurus ovatus
Linum usitatissimum
Lolium multiflorum
Lolium perenne
Lotus uliginosus
Ludwigia peploides
Lupinus arboreus
Malva nicaeensis
Medicago polymorpha
Melilotus indicus
Modiola caroliniana
Muehlenbeckia hastulata
Nothoscordum gracile
Oenothera stricta
Oxalis corniculata
Oxalis rosea
Panicum urvilleanum
Papaver somniferum
Paspalum dasypleurum
Phalaris canariensis
Plantago lanceolata
Plantago major
Poa annua
Polygonum aviculare
Polygonum hydropiperoides
Polygonum orientale
Polygonum persicaria
Polypogon monspeliensis
Prunella vulgaris
Raphanus raphanistrum
Raphanus sativus
Rorippa sylvestris
Rumex acetosella
Rumex crispus
Senecio aquaticus
Senecio vulgaris
Setaria viridis
Silene armeria
Silene gallica
Sisymbrium officinale
Solanum furcatum
Spergularia rubra
Stellaria media
Taraxacum officinale
Teline monspessulana
Trifolium dubium
Trifolium incarnatum
Trifolium pratense
Verbascum virgatum
Verbena litoralis
Veronica anagallis-aquatica
Vicia hirsuta
Vicia sativa
Vicia villosa
Vinca major
Vulpia myuros
Xanthium spinosum

Data from the Herbarium of the University of Concepción.

areas, which are dominated by non-native ornamental species. Wetlands and other peri-urban ecosystems have been destroyed, fragmented or invaded by non-native species over the course of centuries.

We may hypothesize, from this short review, that there are two major differences between urbanization in developing and developed countries: (1) the amount of per capita resources is many times lower than in developed countries (McGranahan and Satterthwaite, 2003), (2) human population reach higher densities and urban sprawl is still concentrated around the urban core rather than suburban neighborhoods (Lambin et al., 2001). Theoretically, these two factors may have positive implications for the biodiversity of developing countries, since less resources are consumed, less pollution is produced and less land is converted to urban use. However, the push for economic growth and the low environmental standards may increase the risk of impacting on biodiversity. Furthermore, high population densities increase the intensity of urban impacts, displacing completely those native species not adapted to human disturbances.

We consider that the lack of awareness about the importance of maintaining natural elements in the urban environment and reducing the impacts over peri-urban ecosystems, is probably the major cause of the exponential deterioration of biodiversity in urban areas of developing countries. It may be that the already impoverished environment where most urban inhabitants grow have offer very little stimulus for them to protect natural elements (Turner et al., 2004).

More research is needed to reveal the biological effects of urbanization in South American urban and peri-urban ecosystems. In fact, after searching the ISI Web of Knowledge database, we found very few articles related to this topic for South American countries. Most articles analyzed the situation from a population, planning and economic points of view, and only a fraction discuss any ecological implications.

We hope that by exposing the impacts of urban sprawl in areas such as the metropolitan area of Concepción, there will be an increasing interest in considering biological variables when planning and executing urban development. The destiny of major biodiversity hotspots could be determined by how much society can reduce the impacts of uncontrolled urbanization. As Miller and Hobbs (2002) conclude, we cannot afford to limit our conservation efforts solely to pristine environments, much still needs to be done to include human disturbed areas such as urban landscapes into our conservation strategies.

Acknowledgements

We thank M.E. Figueroa and P. Gonzalez for their work and data. To A. Marticorena for providing the herbarium data. To M. McKinney and K. Dircksen and four anonymous reviewers for their comments in earlier versions of this MS. To MECESUP AUS0103, DINV-Universidad de Concepción and Fondecyt 1040528 for partially funding this work.

REFERENCES

Abad, C.E., 2000. Marco geológico de los humedales de Concepción. Gayana 64 (suplemento), 3–6.

Angulo, O., 2000. Las poblaciones de zancudos en los últimos 20 años en los humedales de Concepción. Gayana 42 (suplemento), 13–22.

Arroyo, M.T.K, Marticorena, C.M., Matthei, O., Cavieres, L., 2000. Plant invasions in Chile: present patterns and future predictions. In: Mooney, H.A., Hobbs, R. (Eds.), Impact of Global Change on Invasive Species. Island Press, New York, pp. 385–421.

Azócar, G., Sanhueza, R., Henriquez, C., 2003. Changes in growth patterns in an intermediate city: the case of Chillan in Central Chile. EURE-Revista Latinoamericana de Estudios Urbano Regionales 29 (87), 79–92.

Azócar, G., Sanhueza, R., 1999. Evolución del uso del suelo en las cuencas hidrográficas de las lagunas de la comuna de San Pedro de la Paz, región del Biobío: análisis histórico y tendencias. Revista Geográfica de Chile. Terra Australis 44, 63–78.

Boet, P., Belliard, J., Berrebi-dit-Thomas, R., Tales, E., 1999. Multiple human impacts by the City of Paris on fish communities in the Seine river basin, France. Hydrobiologia 410, 59–68.

Brannstrom, C., Oliveira, A.M.S., 2000. Human modification of stream valleys in the western plateau of Sao Paulo, Brazil: implications for environmental narratives and management. Land Degradation and Development 11, 535–548.

Breuste, J.H., 2004. Decision making, planning and design for the conservation of indigenous vegetation within urban development. Landscape and Urban Planning 68, 439–452.

Cambray, J.A., 2003. Impact on indigenous species biodiversity caused by the globalisation of alien recreational freshwater fisheries. Hydrobiologia 500 (1–3), 217–230.

Campos, J., Gavilán, F., Alay, F., Ruiz, V., 1993. Comunidad íctica de la hoya hidrográfica del río Biobío. In: Faranda, F., Parra, O. (Eds.), Evaluación de la calidad de agua y ecología del sistema limnético y fluvial del rió Biobío, Serie Monografías científicas, 12. Editorial Universidad de Concepción, Concepción, Chile, pp. 249–278. 409 pp.

Charlesworth, S.M., Harker, E., Rickard, S., 2003. A review of sustainable drainage systems (SuDS): a soft option for hard drainage questions? Geography 88, 99–107.

Clapp, R.A., 2001. Tree farming and forest conservation in Chile: do replacement forests leave any originals behind? Society and Natural Resources 14, 341–356.

Clergeau, P., Jokimaki, J., Savard, J.P.L., 2001. Are urban bird communities influenced by the bird diversity of adjacent landscapes? Journal of Applied Ecology 38, 1122–1134.

deWinton, M.D., Clayton, J.S., 1996. The impact of invasive submerged weed species on seed banks in lake sediments. Aquatic Botany 53, 31–45.

Díaz, I.A., Armesto, J.J., 2003. La conservación de las aves silvestres en los ambientes urbanos de Santiago. Ambiente y Desarrollo 19 (2), 31–38.

Duncan, B.W., Larson, V.L., Schmalzer, P.A., 2004. Historic landcover and recent landscape change in the north Indian River Lagoon Watershed, Florida, USA. Natural Areas Journal 24, 198–215.

Estades, C.F., Temple, S.A., 1999. Deciduos-forest bird communities in a fragmented landscape dominated by exotic pine plantations. Ecological Aplications 9 (2), 573–585.

Estades, C.F., 1995. Aves y vegetación urbana, el caso de las plazas. Boletín chileno de Ornitología 2, 7–13.

EULA, 1999. Estudio de Impacto Ambiental del Plan Regulador Comunal de San Pedro de La Paz. Unidad de Planificación Territorial Centro EULA-Chile. Documento de Trabajo Sistema Natural.

EULA, 2000. Estudio de Impacto Ambiental del Plan Regulador Comunal de Talcahuano. Unidad de Planificación Territorial Centro EULA-Chile. Documento de Trabajo Sistema Natural.

Fernandez-Juricic, E., 2001. Avian spatial segregation at edges and interiors of urban parks in Madrid, Spain. Biodiversity and Conservation 10, 1303–1316.

Figueroa, J.A., Castro, S.A., Marquet, P.A., Jaksic, F.M., 2004. Exotic plant invasions to the mediterranean region of Chile: causes, history and impacts. Revista Chilena de Historia Natural 77, 465–483.

Figueroa, M.E., 2004. Flora y vegetación del fundo La Cantera y El Guindo. Memoria de Título, Ingeniería Forestal. Universidad de Concepción, Concepción, Chile.

Fontes, L.R., Milano, S., 2002. Termites as an urban problem in South America. Sociobiology 40, 103–151.
González, P.A., 2003. Identificación de aves del predio La Cantera y el Guindo, temporada invierno – primavera. Memoria de Título, Ingeniería Forestal. Universidad de Concepción, Concepción, Chile.
Gupta, A., 2002. Geoindicators for Tropical Urbanization Environmental Geology 42, 736–742.
Gupta, A., Ahmad, R., 1999. Geomorphology and the urban tropics: building an interface between research and usage. Geomorphology 31, 133–149.
Habit, E., Parra, O., 2001. Impactos ambientales de los canales de riego sobre la fauna de peces. Ambiente y Desarrollo 17, 50–56.
Habit, E., Victoriano, P., Rodríguez-Ruíz, A., 2003. Variaciones espacio-temporales del ensamble de peces de un sistema fluvial de bajo orden del Centro-Sur de Chile. Revista Chilena de Historia Natural 76, 3–14.
Henderson, V., 2002. Urbanization in developing countries. World Bank Research Observer 17, 89–112.
Ilabaca, P., 1992. Evolución de la costa de Concepción: caso de las Bahías de Concepción y San Vicente. Revista de Biología Pesquera 18, 29–35.
INE, 2002. Censo Nacional 2002. <http://www.ine.cl/redatam/i-redatam.htm> (downloaded march 30th, 2005).
Jaksic, F.M., 1998. Vertebrate invaders and their ecological impacts in Chile. Biodiversity and Conservation 7, 1427–1445.
Jaksic, F.M., Iriarte, J.A., Jiménez, J.E, Martínez, D.R., 2002. Invaders without frontiers: cross-border invasions of exotic mammals. Biological Invasions 4, 157–173.
Jokimaki, J., Kaisanlahti-Jokimaki, M.L., 2003. Spatial similarity of urban bird communities: a multiscale approach. Journal of Biogeography 30, 1183–1193.
Kuhn, I., Brandl, R., Klotz, S., 2004. The flora of German cities is naturally species rich. Evolutionary Ecology Research 6, 749–764.
Lambin, E.F., Turner II, B.L., Geist, H.J., Agbola, S., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., Xu, J., 2001. The causes of land-use and land-cover change - Moving beyond the myths Global. Environmental Change: Human and Policy Dimensions 11, 261–269.
Leao, S., Bishop, I., Evans, D., 2004. Simulating urban growth in a developing nation's region using a cellular automata-based model. Journal of Urban Planning and Development-Asce 130, 145–158.
López, E., Bocco, G., Mendoza, M., Duhau, E., 2001. Predicting land-cover and land-use change in the urban fringe. A case in Morelia city, Mexico. Landscape and Urban Planning 55, 271–285.
Malmqvist, B., Rundle, S., 2002. Threats to the running water ecosystems of the world. Environmental Conservation 29, 134–153.
McGranahan, G., Satterthwaite, D., 2003. Urban centres: an assessment of sustainability. Annual Review of Environmental Resources 28, 243–274.
McKinney, M.L., 2002. Urbanization, biodiversity and conservation. Bioscience 52, 883–890.
McKinney, M.L., this issue. Urbanization as a major cause of biotic homogenization. Biological Conservation.
Miller, J.R., Hobbs, R.J., 2002. Conservation where people live and work. Conservation Biology 16, 330–337.
MunozPedreros, A., Gantz, A., Saavedra, M., 1996. Nest boxes in *Pinus radiata* woodlands in southern Chile: A tool to mitigate negative environmental impacts. Revista Chilena de Historia Natural 69, 393–400.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kents, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.
Parra, O., 1989. La eutrofización de la Laguna Grande de San Pedro, Concepción, Chile: un caso de estudio. Ambiente y Desarrollo 1, 117–136.
Pauchard, A., Alaback, P.B., 2004. Influence of elevation, land use, and landscape context on patterns of alien plant invasions along roadsides in protected areas of south-central Chile. Conservation Biology 18, 238–248.
Pauchard, A., Ugarte, E., Millán, J., 2000. A multiscale method for assessing vegetation baseline of Environmental Impact Assessment (EIA) in protected areas of Chile. In: McCool, S.F., Cole, D.N., Borrie, W.T., O'Loughlin, J. comps (Eds.), Wilderness Science in a Time of Change Conference: Wilderness as a Place for Scientific Inquiry, Missoula, MT, May 23–27, 1999, Proceedings RMRS-P-15-VOL3, vol. 3. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT, pp. 111–116.
Pauchard, A., Villarroel, P., 2002. Protected areas in Chile: history, current status and challenges. Natural Areas Journal 22, 318–330.
Pimentel, D., Giampietro, M., Bukkens, S.G.F., 1998. An optimum population for North and Latin America. Population and Environment 20, 125–148.
Qadeer, M.A., 2004. Urbanization by implosion. Habitat International 28, 1–12.
Quintana, V., 1993. Caracterización florística y faunistica de un humedal costero de la VIII Region, el caso del estero Lenga. In: Faranda y, F., Parra, O. (Eds.), Planificación y gestión de la zona costera un analisis de caso: Lenga, Serie propuesta de ordenación, vol. 8. Editorial Universidad de Concepción, Concepción, Chile, pp. 41–58. 84 pp.
Reid, S., Diaz, I.A., Armesto, J.J., Willson, M.F., 2004. Importance of native bamboo for understory birds in Chilean temperate forests. The Auk 121, 515–525.
Reynolds, R., Scott, J., Nussbaum, R., 1990. A variable circular-plot method for estimating birds numbers. Condor 82, 309–313.
Riffo, R., Villarroel, C., 2000. Caracterización de la flora y fauna del humedal Los Batros, comuna de San Pedro de la Paz. Gayana 64, 23–37.
Romero, H., Ordenes, F., 2004. Emerging urbanization in the southern Andes – environmental impacts of urban sprawl in Santiago de Chile on the Andean Piedmont. Mountain Research and Development 24, 197–201.
Ryder, R., Brown, L.A., 2000. Urban-system evolution on the frontier of the Ecuadorian Amazon. Geographical Review 90, 511–535.
Sánchez, M.A., 1989. La presencia del recurso natural en el proceso de desarrollo regional de la región del. Bío-Bío 5 (1), 47–53.
Sanhueza, R., Azócar, G., 2000. Transformaciones ambientales provocadas por los cambios económicos de la segunda mitad del siglo XIX; provincia de Concepción. Revista Geográfica de Chile Terra Australis 45, 181–194.
Savard, J.L., Clergau, P., Mennechez, G., 2000. Biodiversity concepts and urban ecosystems. Landscape and Urban Planning 48, 131–142.
Smith-Ramírez, C., 2004. The Chilean coastal range: a vanishing center of biodiversity and endemism in South American temperate rainforests. Biodiversity and Conservation 13, 373–393.
Soto, D., Jara, F., Moreno, C., 2001. Escaped salmon in the inner seas, southern Chile: facing ecological and social conflicts. Ecological Applications 11, 1750–1762.
Tobar, D., 2003. Bases para la elaboración de un plan de manejo orientado a la conservación del humedal dulceacuícola Chepe-Carriel Sur. Región del Biobío, Concepción, Chile.

Memoria de Título, Biología. Universidad de Concepción, Concepción, Chile.
Torrejon, F., Cisternas, M., Araneda, A., 2004. Environmental effects of the Spanish colonization from de Maullin river to the Chiloe archipelo southern Chile Revista. Chilena de Historia Natural 77, 661–677.
Turner, W.R., Nakamura, T., Dinetti, M., 2004. Global urbanization and the separation of humans from nature. Bioscience 54, 585–590.
Urrutia, R., Sabbe, K., Cruces, F., Pozo, K., Becerra, J., Araneda, A., Vyverman, W., Parra, O., 2000. Paleolimnological studies of Laguna Chica of San Pedro (VIII region): diatoms, hydrocarbons and fatty acid records Revista. Chilena de Historia Natural 73, 717–728.
Wear, D.N., Bolstad, P., 1998. Land-use changes in southern Appalachian landscapes: spatial analysis and forecast evaluation. Ecosystems 1, 575–594.
Wells, R.D.S., De Winton, M.D., Clayton, J.S., 1997. Successive macrophyte invasions within the submerged flora of Lake Tarawera, Central North Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 31, 449–459.
Whitmore, C., Slotow, R., Crouch, T., 2002. Conservation of biodiversity in urban environments: invertebrates on structurally enhanced road islands. African Entomology 10, 113–126.
Willson, M.F., 2004. Loss of habitat connectivity hinders pair formation and juvenile dispersal of chucao tapaculos in Chilean rainforest. Condor 106, 166–170.