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Inventory

Inventory of birds in two urban wetlands in Temuco (Chile): a basis for monitoring species

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Abstract: In the city of Temuco, Chile, the importance of urban wetlands has been recognized with the legal declaration of two key ecosystems: Humedal Vegas de Chivilcán and Humedales de Antumalén. This paper presents an inventory of birds in these wetlands, following the Darwin Core standard, and compares the results with other selected inventories in Chile. Observations were made using point counts and 21-hour transects. A total of 50 species from 26 families and 15 orders were identified, with a predominance of native species. Fourteen species were found in both wetlands, 20 exclusively in Chivilcán and 15 in Antumalén. Comparison with other studies revealed significant differences in bird composition between urban and peri-urban habitats, illustrating that urban habitats maintain a unique diversity distinct from that of peri-urban areas. The diversity of habitats and the 'least concern' status of most species highlight the importance of these wetlands as refuges for avian biodiversity. The structure of the Darwin Core database facilitates their integration with other biodiversity systems, highlighting the need for continued conservation and study of these urban ecosystems.
Keywords: *Avifauna; Darwin Core; urban ecology; aquatic habitats; biological monitoring.*

Inventario de aves en dos humedales urbanos de Temuco (Chile): una base para el monitoreo de especies

Resumen: En la ciudad de Temuco, Chile, se ha reconocido la importancia de los humedales urbanos con la declaración de dos ecosistemas clave: Humedal Vegas de Chivilcán y Humedales de Antumalén. Este trabajo presenta un inventario de aves en estos humedales, siguiendo la norma Darwin Core, y compara los hallazgos con otros inventarios seleccionados en Chile. Las observaciones se realizaron mediante conteos puntuales y transectos durante 21 horas. Se identificaron un total de 50 especies de 26 familias y 15 órdenes, predominando las especies nativas. Catorce especies se encontraron en ambos humedales, 20 eran exclusivas de Chivilcán y 15 de Antumalén. La comparación con otros estudios reveló diferencias significativas en la composición de aves entre hábitats urbanos y periurbanos, mostrando que los hábitats asociados a ciudades mantienen una diversidad singular que difiere de los hábitats periurbanos. La diversidad de hábitats y el estatus de "preocupación menor" de la mayoría de las especies resaltan la importancia de estos humedales como refugios para la biodiversidad aviar. La estructura de la base de datos Darwin Core facilita su integración con otros sistemas de biodiversidad, subrayando la necesidad de continuar con la conservación y el estudio de estos ecosistemas urbanos.
Palabras clave*: Avifauna; Darwin core; ecología urbana; hábitat acuático; monitoreo de especies.*

Introduction

The conservation of bird habitats, especially in urban areas, has become a critical aspect of biodiversity efforts. Birds play important ecological roles as pollinators, seed dispersers and pest controllers, and their well-being is intrinsically linked to the health of urban socio-ecosystems (Marzluff, 2001; Shanahan et al., 2014). The presence of birds in urban environments enhances the human experience by providing access to biodiversity that is typically restricted to areas far from the city. This proximity encourages both environmental education and a deeper commitment to biological conservation (Ratcliffe et al., 2013; Cox 2016).

Wetlands serve as crucial refuges offering vital resources and protection for a wide variety of birds (Kushlan, 1993; Dehorter & Guillemain 2008). In Chile, around 30% of bird species, or roughly 125 species, rely on wetland habitats (Estades et al., 2017). Among these species are, for example, the Black-faced Ibis (*Theristicus melanopis*) and the Yellow-billed Teal (*Anas flavirostris*). Urban wetlands provide ecosystem services such as climate regulation, water purification, and recreational opportunities, in addition to their ecological importance (Mitsch & Gosselink, 2000; Barbier et al., 2011). The proximity of these ecosystems to urban centers not only enhances the quality of life for local populations but also promotes greater awareness and appreciation of nature (Tzoulas et al., 2007).

Chile stands out as the sole country in Latin America to have implemented a dedicated law, to protect urban wetlands (PNUMA 2022): Law 21.202. This legislation amends various legal instruments with the aim of preserving these ecosystems and ensuring their inclusion in urban regulatory plans. The declaration of an urban wetland is initiated directly by the Ministry of the Environment through an official notice or upon request by the municipalities. This process enhances the local connection by enabling community groups to actively participate through requests made via their local municipalities, thereby enabling their involvement in the conservation efforts. Furthermore, Chile has established the National Strategy for Bird Conservation (2021-2030), which includes promoting research and monitoring of birds as one of its key objectives (MMA 2022). The country also supports iNaturalist Chile (https://inaturalist.mma.gob.cl/), a platform that encourages the observation of nature and the dissemination of biodiversity.

Maintaining up-to-date biodiversity inventories is crucial for the effective management of these areas. Inventories provide a snapshot of biodiversity at a specific point in time and are necessary for monitoring changes, identifying threats, and guiding conservation efforts (Magurran et al., 2010). In the context of urban wetlands, where anthropogenic pressures can be intense, up-to-date inventories are essential tools for informed decision-making and the implementation of adaptive management strategies (Turner et al., 2015). Such pressures include land-use changes, wetland infilling (Rojas et al., 2022), urbanization (Rojas et al., 2015), and agricultural (Peña-Cortés et al., 2006) and forestry expansions (Peña-Cortés et al., 2011), which significantly impact the wetland ecosystems.

In the city of Temuco, capital of the Araucanía region, the importance of urban wetlands has recently been recognised with the declaration of two important ecosystems: Humedal Vegas de Chivilcán and Humedal Antumalén. These declarations highlight the importance of these natural spaces in the urban context and reflect the commitment of the local community to their conservation. In this context, the aim of this paper is to present an inventory of birds in these wetlands, structured according to the international Darwin Core standard (https://dwc.tdwg.org/). This standard ensures that the data are comparable, interoperable and easily accessible to other researchers, managers and conservation decision-makers. It is expected that this inventory will serve as a basis for monitoring these species and as a tool for effective wetland management, allowing the identification of changes, threats and conservation opportunities, in line with the objectives of Law 21.202 and conservation targets at local and national levels.

Material and Methods

1. Study area

Vegas de Chivilcán Wetland: The Vegas de Chivilcán wetland, declared an urban wetland by Resolution 813 Exenta of 4 August 2021, is a permanent swamp ecosystem covering 450 hectares (Figure 1). Its formation is due to a combination of geomorphological and geological factors, such as the presence of impermeable soils and the topography of the area, which facilitate the accumulation of water on the surface. In addition, the influence of groundwater and the proximity of the Pichi-Temuco stream contribute to the maintenance of humid conditions in the area. Although it has been heavily disturbed by agricultural and livestock activities, its south-eastern edge retains a lesser degree of alteration, with the presence of hydrophilic herbaceous vegetation. The proximity of the Ñielol cordon (a protected area) acts as a biological corridor between the rural and urban areas. The flora includes introduced species such as *Populus nigra* L., *Salix* spp. and *Rumex* spp. as well as native grasses such as *Cyperus eragrostis* Lam and *Juncus procerus* E. Mey.

Antumalén wetland: Recognised as an Urban Wetland by Resolution 814 Exenta of 19 August 2021, the Antumalén Wetland is a riparian wetland of 194 hectares (Figure 1). It is located on the fluvial terraces of the River Cautín, which gives it a characteristic geomorphology with an irregular surface that facilitates the deposition of water in different sectors. Flanked by residential areas to the north and the River Cautín to the south, its vegetation is mainly concentrated along the river banks, with a predominance of introduced tree species such as *Racosperma dealbatum* (Link) Pedley and *Salix* spp. There are also native herbaceous species such as *Juncus* spp. and *Hydrocotyle* spp.

2. Sampling design

Sampling was conducted on three separate days during the summer: February 1, 2022, February 1, 2023, and February 16, 2023. All sampling sessions were carried out between 8 AM and 12 PM. Further details are provided in the Supplementary material 1.

Vegas de Chivilcán wetland: Four different habitats were identified in this wetland (aquatic, shrub, low and high herbaceous grassland). Six counting stations were chosen. The stations were strategically placed to cover the different habitats observed. Sampling was carried out for 10 minutes at each station (see Bibby et al., 2000, Mendoza et al., 2007 and Muñoz-Pedreros et al., 2019).

Antumalén wetland: Four habitat types were identified for this wetland (aquatic, shrub, forest and eroded grassland). We worked with

Figure 1. Map of study area featuring Chivilcán and Antumalén wetlands, Temuco, Chile.

12 count points and a linear transect of 1.8 km, following the northern bank of the Cautín River. The selection of count points was based on the four habitat types identified, and the linear transect was designed to capture variability along the riverbank. Sampling was carried out for 10 min at each point and for 3 h along the transect (Bibby et al., 2000, Mendoza et al., 2007 and Muñoz-Pedreros et al., 2019).

In the case of Vegas de Chivilcán, two peripheral sampling points were included due to the continuity of the habitat with the surrounding rural landscape and the ecological importance of these areas for birds. One was located 200 m outside the wetland boundary, at the foot of the mountain range to the south of the study area (a site called "Canto de Rana" or song of the frogs), and the other 70 m from the main road, also in the southern area (a site near a rural school). In contrast, sampling in Antumalén focused strictly on the wetland, as it is largely bounded by the city of Temuco to the northeast and the Panamericana Sur highway to the southwest, reducing ecological interaction with surrounding areas. This inclusion recognises the natural mobility of birds and the ecological interaction between the wetland and its surroundings, providing a more complete picture of biodiversity in the region.

Species identification was based on the guidelines of Jaramillo, A. (2005) and Muñoz-Pedreros et al., (2019). Conservation status was determined according to the IUCN Red List (2022) and the Chilean Ministry of the Environment's species classification (https://clasificacionespecies.mma.gob.cl/). The nomenclature followed the World Bird List of the International Ornithological Committee (IOC).

3. Database organisation

The database was constructed using 23 fields, including scientific name, order, family and number of individuals observed for each species (Table 1). In addition, geographic data such as latitude, longitude and geodetic datum (WGS84) with an estimated uncertainty of 30 metres were recorded to represent the geographic location of the observations. Additional details such as habitat preference ('terrestrial birds' or 'aquatic birds') have been added to enrich the content (see dynamicProperties in Database). The table was structured according to the Darwin Core standard (https://dwc.tdwg.org/), a globally recognized framework designed to facilitate the consistent formatting and sharing of biological data. Darwin Core is composed of a set of standardized terms that describe the fundamental aspects of biodiversity data, primarily focused on the occurrence, taxonomy, and location of species observations. This standard ensures that data is organized in a technically coherent manner, enhancing the ease of data integration and interoperability with other biodiversity databases and information systems (Wieczorek et al., 2012). This structuring is consistent with more widely accepted data management practices in ecology and contributes to the efficiency and accessibility of information (Michener & Jones, 2012).

4. Comparison with selected articles

The data collected were compared with five inventories carried out in the south-central region of Chile, an area characterised by a

Table 1. Description of urban wetland database fields according to the Darwin Core Standard.

Field Name	Darwin Core Description
occurrenceID	An identifier for the Occurrence (as opposed to a particular digital record of the occurrence).
scientificName	The full scientific name of the organism.
order	The full scientific name of the order in which the taxon is classified.
family	The full scientific name of the family in which the taxon is classified.
individualCount	The number of individuals represented present at the time of the Occurrence.
establishmentMeans	The process by which the biological individual(s) became established at the location.
degreeOfEstablishment	A statement about whether an Occurrence record represents an organism or organisms which were wild or cultivated at the time the Occurrence was recorded.
dynamicProperties	A list (concatenated and separated) of additional measurements, facts, characteristics, or assertions about the record.
habitat	A category or description of the habitat in which the Event occurred.
locationRemarks	Comments or notes about the Location.
country	The name of the country or major administrative unit in which the location occurs.
municipality	The full, unabbreviated name of the next smaller administrative region than county (city, municipality, etc.) in which the location occurs.
stateProvince	The name of the next smaller administrative region than country (state, province, canton, department, region, etc.) in which the location occurs.
location	A list (concatenated and separated) of names of geographic locations.
locality	The specific description of the place.
samplingProtocol	The name of, reference to, or description of the method or protocol used during a sampling event.
samplingEffort	The amount of effort expended during a sampling event.
decimalLatitude	The geographic latitude (in decimal degrees, using the spatial reference system given in geodeticDatum) of the geographic center of a Location.
decimalLongitude	The geographic longitude (in decimal degrees, using the spatial reference system given in geodeticDatum) of the geographic center of a Location.
geodeticDatum	The ellipsoid, geodetic datum, or spatial reference system (SRS) upon which the geographic coordinates given in decimalLatitude and decimalLongitude as based.
coordinate Uncertainty InMeters	The horizontal distance (in meters) from the given decimalLatitude and decimalLongitude describing the smallest circle containing the whole of the Location.
eventDate	The date-time or interval during which an Event occurred.
recordedBy	A list (concatenated and separated) of names of people, groups, or organizations responsible for recording the original Occurrence.

phytoclimatic transition from a Mediterranean to a temperate climate. Five inventories were selected from north to south. The first is a study conducted in the city of Santiago (33°28'58.26"S; 70°38'20.63"W), located in a predominantly Mediterranean climate with a low presence of wetlands in a highly anthropised urban space (Benito et al., 2019). The second study was conducted near the Carriel Sur airport in Talcahuano (36°46'21.61 "S; 73°3'40.24 "W), inserted in the metropolitan area of Concepción, in a mixed landscape of wetlands and forest plantations, under a coastal climate with Mediterranean-temperate climate interaction (Barrientos et al., 2016). The third inventory was conducted in the city of Valdivia (39°49'53.77"S; 73°13'36.12"W), notable for its diversity of riverine wetlands (e.g., Rio Calle Calle) and the least intervened environment of all the studies, under a temperate rainy climate (Silva et al., 2015). The last two inventories were carried out in Osorno (40°34'30.46"S; 73°8'40.91"W), in a livestock and agricultural environment with a temperate rainy climate (Cursach and Rau, 2008). Here, Parque IV Centenario, in the city centre, and Parque Chuyaca, on the banks of the River Damas, with a mix of introduced and native tree species, were studied.

Hierarchical cluster analysis was used to assess the structure of bird communities between sites. Jaccard's dissimilarity measure was used to calculate distances between sites, and the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm was used to cluster data in PRIMER v7 software (Clarke and Gorley 2015).

A permutation test with 10,000 iterations was used to assess the statistical significance of the clusters identified (SIMPROF), with a significance level of 5%.

Results

1. Database

The Chivilcán and Antumalén wetlands are habitats for a total of 50 bird species, which belong to 26 families and 15 taxonomic orders. Fourteen species are shared between the two wetlands (see Supplementary material 1, Table 1, Figure 2). Most species are native (Figure 3, Supplementary material 2), except for *Callipepla californica*, an introduced species. During the observation period, several species were frequently observed, including *Theristicus melanopis*, *Tachycineta leucopyga*, *Anas flavirostris*, *Vanellus chilensis* and *Cistothorus platensis*. The observed densities ranged from 36 to 72 individuals per hour. *Hymenops perspicillatus* was the only breeding species observed. Most species are classified as 'Least Concern' by the IUCN, with only *Speculanas specularis*, *Elanus leucurus* and *Parabuteo unicinctus* are near threatened (Supplementary material 1).

The Chivilcán wetland, 35 species belonging to 22 families and 12 orders have been recorded, 20 of which are exclusive, such as *Agelasticus thilius*, *Anas sibilatrix* and *Diuca diuca*. These birds occupy a variety of habitats, including wet meadows with herbaceous vegetation, seasonally saturated soils and a lagoon with hydrophilic vegetation, where species such as *Pygarrhichas albogularis* and *Vanellus chilensis* have been observed.

The Antumalén wetland, contains 29 species from 21 families and 13 orders were identified, including 15 exclusive species, such as *Anairetes parulus* and *Anas sibilatrix*. Habitats vary from riparian areas and eroded soils to areas of shrub and tree vegetation, where species such as *Anas georgica* and *Ardea alba* have been observed.

2. Comparison with selected articles

In this section, we explore the diversity of bird species across a latitudinal gradient in Chile, examining how this diversity varies in urban, semi-urban, and transitional rural habitats. Among the sites studied, the Carriel Sur airport in Talcahuano had the highest species richness, with a total of 69 species recorded. In contrast, the Centenario site, located in the heart of the city of Osorno, had the lowest species richness, with 23 species. Taking all the sites together, the average was 36 species.

The highest similarity in terms of composition, was observed between Chuyaca and Centenario with 62.5%, while the lowest similarity was found between Santiago and Antumalén in Temuco, with only 12.3%. Exclusive species were found in all the sites studied. For instance, in the city of Santiago, the presence of *Myiopsitta monachus*

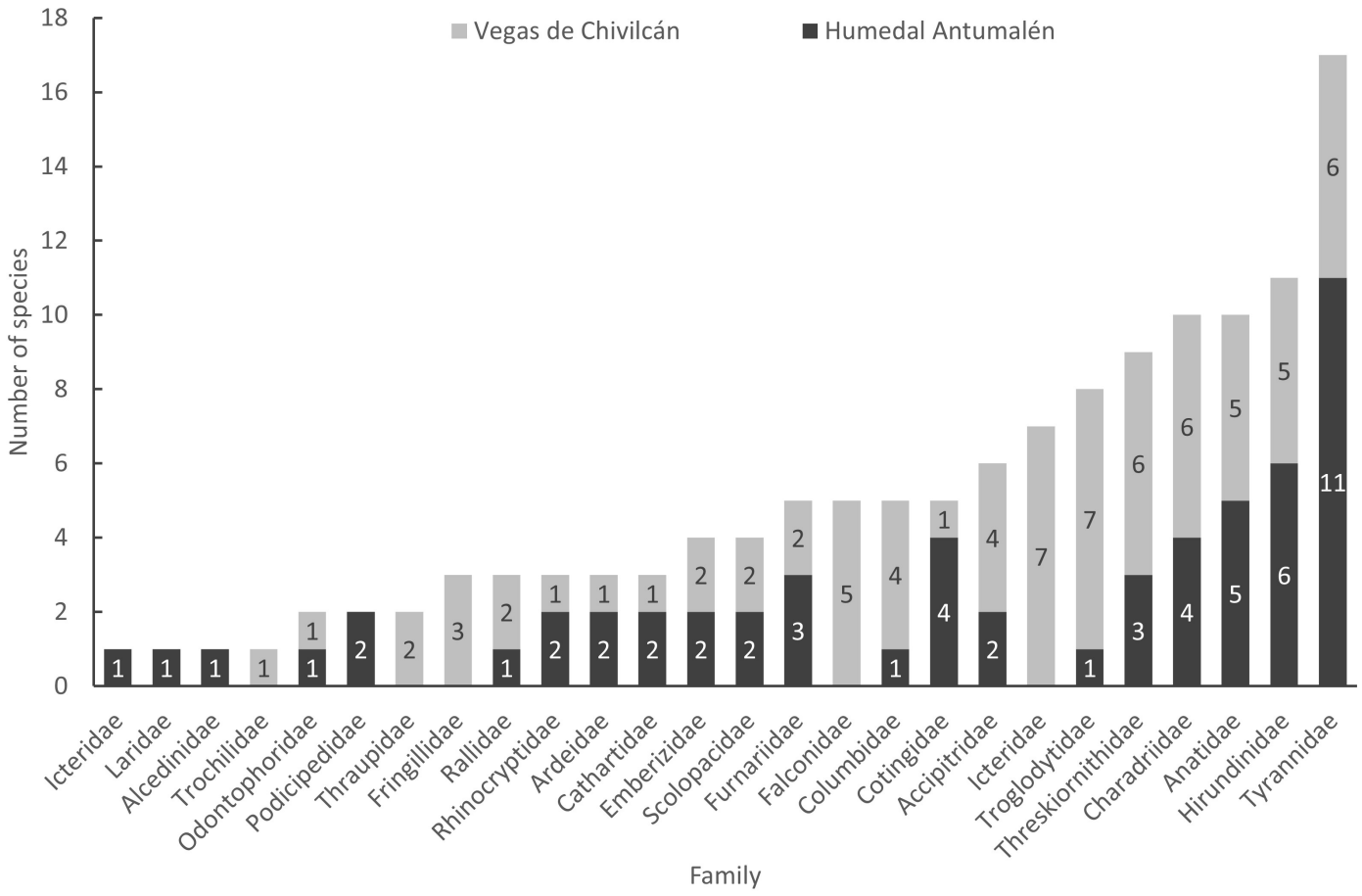

Figure 2. Species richness by family in the Antumalén and Chivilcán wetlands (Temuco).

Figure 3. A sample of the species observed.

and *Veniliornis lignarius* was observed, whereas species such as *Anas bahamensis* and *Anas cyanoptera* were recorded near Talcahuano airport. The Antumalén and Chivilcán wetlands in Temuco had fewer exclusive species observed, with only *Callipepla californica* in the former and *Anas sibilatrix* and *Circus cinereus* in the latter. In Valdivia, *Megaceryle torquata* and *Porphyriops melanops* were recorded, while in Osorno some of the species exclusive to the Chuyaca site were *Enicognathus leptorhynchus*, and in Centenario *Carduelis barbata* and *Ceryle torquata*.

However, several species had a wider distribution and were observed in six or seven of the studied sites. For instance, *Vanellus chilensis*, *Zonotrichia capensis* and *Elaenia albiceps* were observed at all sites. Moreover, species such as *Milvago chimango*, *Falco sparverius* and *Troglodytes aedon* were widespread in the region and were recorded in at least six of the seven sites. These common species across sites suggest a certain uniformity in avifaunal composition across this south-central region, possibly influenced by the continuity of certain habitat elements.

The SIMPROF analysis allowed the identification of three distinct groups, with a significant cluster ($p \leq 0.05$) between Chivilcán and Antumalén, showing a similarity of 33%. On the other hand, Santiago and Talcahuano Airport were grouped in one cluster with a similarity of 33%, while Valdivia was grouped in another cluster with a similarity of 40%. Finally, Chuyaca and Centenario, located in Osorno, formed a third cluster with a similarity of 62% (Figure 4).

Discussion

Regular updating of biodiversity inventories is crucial for effective ecosystem management. Inventories offer baseline information on biodiversity at a specific point in time and are critical for monitoring changes, identifying threats and directing conservation efforts (Magurran et al., 2010). In the context of urban wetlands, up-to-date inventories are essential tools for informed decision-making and implementation of adaptive management strategies, particularly where anthropogenic pressures can be severe (Turner et al., 2015).

The structure of avifaunal communities in south-central Chile, appears to be more influenced by habitat type than by latitudinal gradient, as revealed by cluster analysis. The bird composition similarity between Chivilcán and Antumalén, both located in urban-rural transition zones, shows how the continuity of natural habitats – promoted by the Ñielol cordon and the Cautín River, respectively – could favour a comparable avifaunal composition (see Muñoz-Sáez et al., 2017, Lisón et al., 2022). In contrast, the urban environments of Santiago (Benito et al., 2019), Talcahuano airport (Barrientos et al., 2016) and Valdivia (Silva et al., 2015) showed a distinctive clustering, possibly reflecting the altered ecological conditions typical of these areas (Chamberlain et al., 2009). The third cluster, formed by Chuyaca and Centenario in Osorno (Cursach and Rau, 2008), shows an intermediate bird composition, possibly due to the mixing of urban and rural habitats, with the Río Damas acting as a biological corridor.

The identification of exclusive species at specific sites, along with the distribution of common species across this habitat gradient, highlights the sensitivity of avifauna to habitat alteration or change. This is because some species appear to be more habitat specialists, relying on specific conditions for survival and reproduction, while others are more generalist, capable of adapting to a variety of environments (Blair et al., 1996; Tryjanowski et al., 2015). For instance, vegetation cover and the presence of rocks are crucial for nest survival and reducing vulnerability to predators in coastal birds (Schüttler et al., 2009). Likewise, shallow zones and suitable vegetation are essential for the survival of key species in wetlands (Jaramillo et al., 2007). Moreover, proximity to native vegetation is vital for maintaining greater avian diversity (Muñoz-Sáez, Pérez-Quezada, & Estades, 2017). Landscape structural heterogeneity clearly favors the presence of more species (Gonzalez-Gajardo et al., 2009), although the retention of patches of native forest is essential for effective protection of avian biodiversity

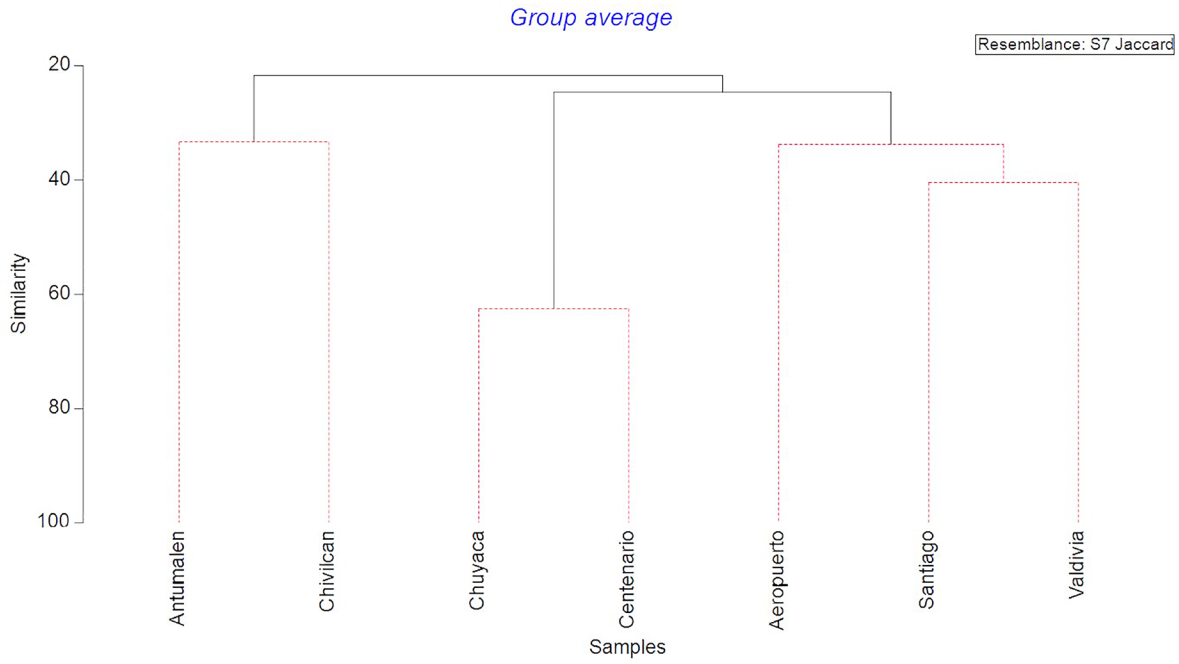

Figure 4. Similarity analysis of bird species composition between seven sites. Red lines show significant clusters using PRIMER's SIMPROF test.

(Vergara & Armesto, 2008). These cases suggest that the latitudinal gradient has secondary importance in the configuration of these avian communities in the region studied.

The findings of this study can contribute to Chile's Urban Wetlands Act by highlighting the critical importance of habitat heterogeneity in shaping bird communities. Given that urban wetlands are subject to intense anthropogenic pressures, identifying the importance of habitat type across latitudinal gradients provides a clear direction for management and conservation. The law could benefit from incorporating conservation strategies that focus on the preservation and restoration of specific habitat types, particularly in urban-rural transition zones. These areas, as the study has shown, often act as important ecological corridors that maintain the diversity and structure of bird communities. The identification of unique species in specific locations also highlights the need for locally adapted conservation measures. This would not only protect avian biodiversity, but also strengthen the ecological resilience of urban wetlands in general. Finally, the diversity of habitats and the conservation status of the species highlight the ecological importance of these wetlands as refuges for bird biodiversity.

Supplementary Material

The following online material is available for this article:
Supplementary material 1.
Supplementary material 2.

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Associate Editor

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Author Contributions

Rodolfo A. Tardone led the bird observation efforts, was responsible for recording and identifying species, and played a critical role in writing the manuscript. He also took the lead in developing the database in accordance with the Darwin Core standard.

Jimmy M. Pincheira-Ulbrich was involved in bird observation and carried out the statistical analysis. He also contributed to the manuscript writing and assisted in the database development, ensuring it met the Darwin Core standard.

Ximena X. Alarcón provided support in bird observation and database development, adhering to the Darwin Core standard. She was also involved in the discussion and planning of the article's structure.

Conflicts of Interest

The authors declare that they have no conflicts of interest related to the publication of this manuscript.

Ethics

All bird sampling and observation procedures were carried out in accordance with relevant ethical guidelines and regulations to ensure the welfare of the species studied. The necessary permits for fieldwork were obtained from the relevant authorities, including the Municipality of Temuco.

Data Availability

The data collected and analysed in this study has been archived in the public data repository Biota Neotropica Dataverse, that provides free access and guaranteed preservation. Access URL: https://doi.org/10.48331/scielodata.ETMPPZ.

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