Conservation Index for lentic ecosystems for an urban coastal wetland in south-central Chile - Rocuant Andalien

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Abstract

Wetlands are ecosystems of great importance worldwide. Global change puts pressure on these ecosystems, contributing to their degradation. Population growth and urban development are among the main problems affecting wetlands located in these areas. Therefore, this manuscript focuses on measuring the conservation status of the Rocuant-Andalíen wetland, located in the coastal region of Biobío, in the country's second largest urban center. This multifactorial approach offers a systematic and holistic evaluation to identify environmental impacts. The study area is one of the largest coastal wetlands in south-central Chile and has undergone various anthropogenic interventions over time. The Index of Conservation Status of Shallow Lentic Ecosystems was applied to establish the conservation status/priorities of the wetlands within the study area. The Index of Conservation Status of Shallow Lentic Ecosystems (ECELS), proposed by the Catalan Water Agency (2004) has been applied in Chile in previous studies. This is an environmental characterization based on hydrological, ecological, environmental, tourist, and landscape documents and reports that were analyzed to determine legal gaps. A total of 12,987 km^2, the largest areas are classified as low quality (3,705 km^2) or very poor quality (4,611 km^2) wetlands. This result can be explained by successive human interventions over the years, as well as surface reduction. In futures perspectives environmental recovery, this index can be used as an indicator of priority macro areas.

1. Introduction

1.1 Urban Changes and Wetlands

Cities are currently growing in both size and number. Large urban centers tend to offer better opportunities than smaller cities (Vignoli, 2019). This is one of the reasons why migration has accelerated, causing people to occupy inappropriate areas without infrastructure (Inalou, & Goki, 2022) and putting pressure on the real estate sector (Rodríguez-Pose, & Storper, 2020). According to Cabrera-Jara (Cabrera-Jara, 2019), the real estate operation has triggered a series of urban transformations in the morphological, functional, economic and cultural spheres.
In general, the territories chosen by the real estate demand have high environmental and landscape value, one of them being wetlands (Hernández, et al. 2019). Thus, urban wetlands are one of the ecosystems most affected by urban development and are disappearing at an accelerated rate (Rojas et al, 2019). Wetlands are very important ecosystems worldwide (Ramsar, 2018). They are defined as a surface saturated with water, seasonally or permanently, and are classified as inland; marine/coastal; and human-made (Vivanco, 2017). In particular, inland wetlands include lakes and rivers, subway aquifers, swamps and marshes, wet grasslands, peatlands, floodplains and oases. Coastal wetlands include estuaries, deltas and intertidal flats, mangroves and coastal marine areas, as well as coral reefs. In the case of artificial wetlands, these are rice fields, saline flooded depressions and cultivated ponds (Ramsar, 2018).

1.2 Wetlands Type

The permissiveness of the real estate sector allows wetlands to be filled for new construction, causing degradation or even extinction of the ecosystem (Jara, 2022). On a global scale, wetlands cover more than 12.1 million km², an area larger than Canada, with 54% permanently flooded and 46% seasonally flooded, and play a global regulating role (Ramsar, 2018). The ecosystem services provided by wetlands exceed the value of terrestrial services (Ramsar, 2018). The Peatlands and vegetated coastal wetlands are major carbon sinks (Bridgham, et al 2006). Salt marshes sequester millions of tons of carbon per year. Despite occupying only 3% of the earth's land surface, peatlands store twice as much carbon as the world's forests (Kauffman, & Donato, 2012). Freshwater wetlands are also the largest natural source of methane, a greenhouse gas, especially when not properly managed (Yang et al 2022). Tropical reservoirs also release methane (Shenoy et al, 2021).

1.3 Chile

In Chile, there are 934 wetlands that sustain the biodiversity of the area where they are located, being vital for the flora, fauna, and microorganisms that inhabit them (Delgado, 2023). They are found in a wide geographical distribution, and the benefits and services they provide are diverse, such as, for example, food and resources, high biodiversity, groundwater recharge, fresh water, protection against tsunamis, among many others. They are characterized by providing habitats for endemic species (Pizarro-Araya et al 2022); they play a role in regulating the water balance, helping to maintain flows in drier seasons (Lagos et al, 2019); and carbon storage (Chavez et al 2019).
Among the various factors that threaten wetlands in Chilean territory are the extraction of water from aquifers that feed meadows and wetlands. The extraction of peat from peatland wetlands and the extraction of aggregates from the shores of lakes and rivers, and finally, real estate pressure on the margins of coastal systems, rivers and lakes (Vicepresidencia del Senado, 2019). Because of this, it is relevant and necessary to develop tools for their conservation in the face of anthropogenic threats,

as explained by the Vice-Presidency of the Senate (Vicepresidencia del Senado, 2019).

The Wetlands Law (Ley 21202 - https://www.bcn.cl/leychile/navegar?idNorma=114146). was enacted in Chile in January 2020 and came into force in May of the same year. This law aims to protect and conserve the country's wetlands, promoting their sustainable use and ensuring their long-term conservation. Measuring the conservation status of a wetland is essential because these ecosystems perform critical ecological functions and provide numerous benefits to both the environment and human communities. First, wetlands host a high level of biological diversity, including endemic and endangered species. Assessing their condition helps identify threats to biodiversity and guides protection and restoration efforts. In addition, wetlands act as natural water regulators: they filter pollutants, store water during rainy seasons, and release it during dry periods, which helps prevent flooding and mitigate droughts. These ecosystems also play a significant role in combating climate change, as they store large amounts of carbon in their soils; their degradation can release this carbon into the atmosphere and contribute to global warming (IPBES, 2019).

It establishes the creation of a National Wetlands Registry to be administered by the Ministry of the Environment, which will include information on the location, extent and conservation status of the country's wetlands. It also establishes the obligation to carry out environmental impact assessments for projects that may affect wetlands and establishes sanctions for those who violate the provisions of the Law (Ley 21202 - https://www.bcn.cl/leychile/navegar?idNorma=114146).

In addition, the law institutes a special protection regime for urban and peri-urban wetlands, which are those located in or near urban areas. These wetlands are exposed to a series of threats, such as urbanization, pollution and climate change, so the law establishes special measures for their protection (Ley 21202 - https://www.bcn.cl/leychile/navegar?idNorma=114146).

Wetlands are one of the most threatened ecosystems worldwide, and urban wetlands are even more exposed to ecosystem changes. The systematic lack of information needed to carry out protection studies is a major barrier to reducing environmental impacts. Thus, the objective of this study is to analyze the state of conservation based on quality index. This index evaluates five aspects related to wetland morphology: construction, infrastructure, and human uses; water appearance; helophyte vegetation; and submerged and floating vegetation. Figueroa et al. 2009, who applied the index for the first time in Chile to evaluate the wetlands quality in different geographic location and climates in Chile. This study applied the same method to understand ecosystem changes in urban wetland. The results obtained allow the identification of priority macro-areas for future environmental management and for urban planning addressing.

2. Methodology

2.1 Study Area

Fig. 1a represents Chile in South America, and Biobio location. The Rocuant-Andalién wetland was chosen as the study area, with a surface area of approximately 12.66 km^2 located in the coastal zone of one of Chile's largest urban centers, Concepción (Fig. 1b). This ecosystem is a recognized urban wetland located in the municipalities of Talcahuano and Penco (Fig. 1a). Due to the highly urbanized environment, new infrastructure works are expected, which makes it recognized as an ecosystem with complex probabilities of being affected. It is currently affected by dumps, landfills, infrastructure works and agricultural activity, which alters its hydrological and ecological connectivity and, at the same time, affects its biodiversity and the provision of ecosystem services. All this together has an impact on its degradation and loss of surface area. It is therefore necessary to invest in a process of protection and restoration, which is covered by the Urban Wetlands Act (GEF Humedales costeros centro-sur de Chile, 2023; *MMA-ONU Medio Ambiente 2025*).

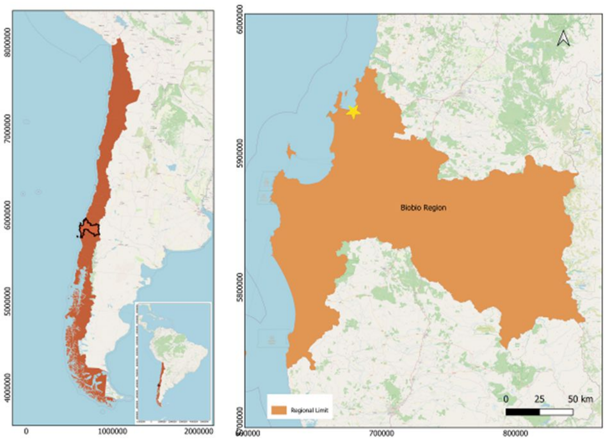

Figure 1. a) Represents Chile location at South America. b) The yellow star represents the Rocuant-Andalien wetland - Study Area. Own Elaboration based on official Chilean data.

2.2 State of Conservation

To determine the conservation status, a comprehensive analysis was made of all the information obtained during the execution of this study, as well as the information collected from both primary and complementary sources. Hydrological, ecological, human environment, tourism and landscape documents and reports that have been reviewed to determine the legal gaps.

Based on the information obtained, the environmental characterization of the present technical bases will be generated, and the Index of Conservation Status of Shallow Lentic Ecosystems (ECELS) was applied to establish the conservation status/priorities of the wetlands within the study area. The ECELS, proposed by the Catalan Water Agency (2004), has been applied in Chile by (Figueroa et al. 2009) and is structured in 5 blocks, where aspects related to wetland morphology, using expert criteria; constructions, infrastructures and human uses; water appearance; helophyte vegetation and submerged and floating vegetation are valued according to:

BLOCK 1, values the slope of the littoral strip and is modulated (corrected) by the presence of landings or fills that alter said strip. The highest value for this block (20 points) is obtained when the slope is < 25%.

BLOCK 2, values the alterations caused by constructions, infrastructures such as roads, water abstractions or human uses of the territory that significantly affect the wetland. The maximum value for this block is 20 points.

BLOCK 3, refers to the appearance of the water, qualitatively, assessing the odor and color. The maximum value for this block is 10 points.

BLOCK 4, analyzes the helophyte vegetation of the coastal strip, scoring positively the occupation of the plant community of the entire strip and the diversity of species. On the other hand, the dominance of some plants over others is penalized. The seasonality of the water is also valued. Maximum score 30 points.

Finally, BLOCK 5 analyzes the submerged and floating vegetation, the amount and coverage of each of them in the wetland. It is modulated and corrected for the dominance of any

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of the formations. The maximum is 20 points. The results should be integrated by the relationship: The final value, will be obtained from the sum of the blocks and its quality will be valued in 5 classes:
- Very Good: between 80-100
- Good Quality: between 60-80
- Medium Quality: between 40-60
- Poor Quality: between 20-40
- Very Poor Quality: between 0-20

2.3 Fieldwork

Field work was based on visits to fifteen sites distributed throughout the study area. At each point, a ECELS questionnaire was applied, where the aspects represented by each block (detailed above) were quantified. The points were distributed based on the fragmentation of the wetland and the environmental pressure generated by its surroundings, as well as the ecosystemic difference.
Once evaluated and quantified, the results were transferred to the geographic information system (QGIS v. 3.22.5, 2025). The zone statistics method was applied to estimate subareas, based on the value attributed per point. The figure 2 represents evaluating points overview.

Figure 2. Rocuant Andalién Wetland. Own Elaboration.

The 14 areas were defined based on accessibility and degree of fragmentation. The extension located in the marshland area was connected to the southern area, within the urban perimeter. The field team assessed morphology (slope of the coastal strip, presence of fill), constructions, infrastructure, and human uses (hydraulic infrastructure, roads, buildings, agricultural and livestock use), human frequency, state of conservation (presence of waste, information about space or incentives for environmental protection), appearance of the water (transparency, odor), helophyte vegetation (dominant community, tree cover, and permanence in the water), and finally, submerged and floating vegetation.
The categories mentioned above are divided into subcategories, each of which receives a score based on presence, absence, or condition. Once the total score was calculated, it was attributed to the geographical location obtained by GPS. Then, the Voronoi polygon spatial statistics method was applied. This method consists of dividing a space into regions (polygons) according to their proximity to a set of initial points. In this way, it assigns a unique area of influence to each reference point, allowing for the analysis of proximity patterns on a map or in a data set. During fieldwork, representative points were sought based on the characteristics of each space, so that the macro areas would be representative (within the limits of the scale used and accessibility to the sites) The entire process was carried out using expert criteria. For this Spanish index to be representative in Chile (high endemism index), the presence of more than three native species receives a higher score.

3. Results and Discussion

This method offers a systematic and holistic evaluation of wetland conservation status by integrating multiple dimensions: hydrological, ecological, human impact, and landscape features. It ensures that the condition of a wetland is not assessed based on isolated parameters, but through a multifactorial approach that reflects the ecosystem's complexity. There were 14 zones classified and represented in a thematic map with classifications from Very Poor Quality (0) to Very good Classification conservation state index.

3.1 Quality Index

The application of the ECELS (Index of Conservation Status of Shallow Lentic Ecosystems) provided a valuable framework for evaluating the conservation status of the wetland within the study area. The results revealed a heterogeneous pattern in wetland quality, with the largest extent classified as Very Poor (4,611 km²), and the smallest area falling under the Very Good category (1,226 km²). Notably, no zones were rated as Good Quality, highlighting a concerning gap in mid-level ecological integrity and suggesting a polarization in wetland conditions. Human impacts are represented by exposed litter located in Very Poor-Quality area, and human pressure from urbanization, including small organic waste dumps, represented by Figure 3. In the past, the coastline was connected to the marshland strip of the wetland, and for many years it was used as a garbage dump. Due to environmental concerns, this activity was suspended, but the garbage dump remains in place.

Figure 3. Urban Waste in coastal wetland (Very Poor-Quality Area). Own Elaboration.

The spatial distribution of conservation status, presented by Figure 4, reflects both ecological processes and historical anthropogenic pressures. For instance, the western sector demonstrated low ECELS scores due to the legacy of industrial development and population growth in Talcahuano during the mid-20th century (Beltrán, 2012; Fundación Terram, 2022). These pressures have led to severe habitat degradation and pollution, especially in zones like Rocuant Island and the El Morro Canal. Similarly, the southern sector, affected by urban fragmentation and infrastructure development such as the Carriel Sur Airport, also scored poorly due to disrupted vegetation patterns and altered hydrology (Ministerio del Medio Ambiente, 2020).

In contrast, the eastern sector, which scored in the Very Good range, benefits from being located on privately owned land where conservation efforts are in place and native biodiversity is preserved (Fundación Kennedy, 2022). This contrast underlines the importance of land tenure, land use, and governance in influencing wetland conservation outcomes.

The ECELS methodology proved particularly useful in objectively identifying conservation gradients and prioritizing areas for intervention. Its modular structure—evaluating elements such as littoral slope, human impacts, water quality, helophyte cover, and submerged vegetation—allowed for a nuanced understanding of how different pressures manifest across the landscape. For example, the low scores in Block 2 (infrastructure and human use) and Block 4 (helophyte vegetation) in urbanized sectors highlight the significant role of anthropogenic disturbance in shaping ecological condition.

Moreover, by incorporating both biophysical indicators and human influence, ECELS supports a systems-based approach to wetland assessment. This aligns with recent conservation policy trends in Chile, including the implementation of the Urban Wetlands Law (Law 21.202) and the National Landscape Restoration Plan (Ministerio del Medio Ambiente, 2021, 2024). The method's ability to reveal legal and management gaps, through the review of SEIA documents, enhances its utility not only as a scientific instrument but also as a regulatory and planning tool.

Classification	Area (km^2)
Very Good Quality	1,226
Good Quality:	0
Medium Quality	3,336
Poor Quality	3,705
Very Poor Quality	4,611

Table 1. Extensions of Conservation Index. Own Elaboration.

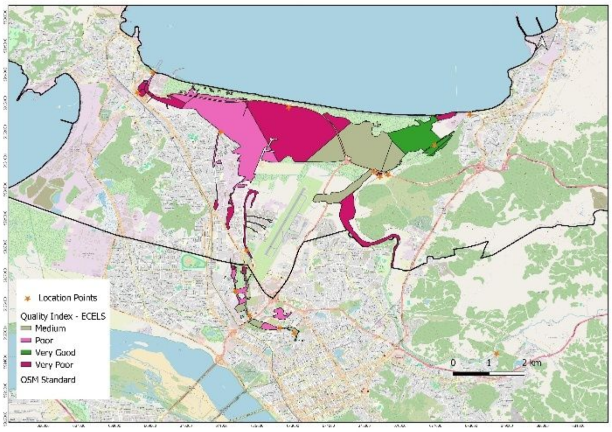

Figure 4. Conservation Index Map. Own Elaboration.

4. Conclusion

This work is a macro characterization that allowed us to identify the degree of conservation of the Rocuant-Andalién urban wetland by evaluating relevant aspects of the wetland's morphology, type and distribution, and diversity of vegetation that determine available habitats; constructions, infrastructure, human uses, and water appearance that determine pressures. This tool that provides an overview of current environmental problems, allowing for the targeting of ecosystem management and restoration measures.

The Rocuant-Andalien wetland has experienced various socio-environmental changes, including loss of surface area and fragmentation due to urban expansion, pollution, and agricultural activities. These changes are represented on a macro scale by the results of the quality index, where very poor quality is predominant. This also reflects how much progress needs to be made in Chile in terms of wetland conservation policy (primarily). These legal loopholes allow these areas to be subjected to anthropogenic disturbances.

Wetlands in poor condition lose much of their ecological functionality, limiting the services available to society and increasing vulnerability to environmental and climate risks. Therefore, monitoring wetland quality not only reflects their ecological health but also their capacity to sustain human well-being in the long term.

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References

Beltrán, M. B. (2012). Transformaciones espaciales y valoración social del humedal Rocuant - Andalién (Concepción, Chile): periodo de 1950 a 2011. Universidad de Chile. Tesis de Pregrado.

Bridgham, S. D., Megonigal, J. P., Keller, J. K., Bliss, N. B., & Trettin, C. (2006). The carbon balance of North American wetlands. Wetlands, 26(4), 889–916.

Cabrera-Jara, N. (2019). Mercado inmobiliario y metamorfosis urbana en ciudades intermedias. Gringolandia en Cuenca: la tierra prometida. Bitácora Urbano Territorial, 29(1), 93–100.

Chávez, R. O., Christie, D. A., Olea, M., & Anderson, T. G. (2019). A multiscale productivity assessment of high Andean Peatlands across the Chilean Altiplano using 31 years of Landsat imagery. Remote Sensing, 11(24), 2955.

Delgado, J. (2023). Humedales en Chile: un ecosistema de biodiversidad. https://www.chile.travel/blog/humedales-en-chile-un-ecosistema-de-biodiversidad/

Figueroa, R., Suarez, M. L., Andreu, A., Ruiz, V. H., & Vidal-Abarca, M. R. (2009). Caracterización ecológica de humedales de la zona semiárida en Chile Central. Gayana (Concepción), 73(1), 76–94.

Fundación Kennedy. (2022). Humedales urbanos: Protección y conservación en terrenos privados. https://fundacionkennedy.cl

Fundación Terram. (2022). Isla Rocuant: una de las zonas más contaminadas del mundo. https://www.terram.cl

Hernández, C. V., Lemus, Y. M., Vieyra, A., & Ortiz, D. A. A. (2019). Urbanización neoliberal y destrucción territorial creativa del ejido periurbano: el caso de La Aldea, Morelia, Michoacán.

Inalou, R. B., Sharafi, H., & Goki, S. K. (2022). The Analysis of Sustainable Small City Development: A Sustainable Method for Reducing Rural–Urban Population Migration from Rural Settlement to Big Cities Considering Golbaf, Iran. Journal of Urban Planning and Development, 148(4), 04022041.

IPBES. (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (E. S. Brondizio, J. Settele, S. Díaz, & H. T. Ngo, Eds.). IPBES secretariat. https://doi.org/10.5281/zenodo.3831673

Jara, J. C. (2022). Rellenos amenazan humedal Vasco de Gama de Hualpén: Comunidad exige declararlo urbano. https://resumen.cl/articulos/rellenos-amenazan-humedal-vasco-de-gama-de-hualpen-comunidad-exige-declaratoria-de-humedal-urbano

Kauffman, J. B., & Donato, D. C. (2012). Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Center for International Forestry Research.

Lagos, N. A., Labra, F. A., Jaramillo, E., Marín, A., Fariña, J. M., & Camaño, A. (2019). Ecosystem processes, management and human dimension of tectonically-influenced wetlands along the coast of central and southern Chile. Gayana, 83, 57–62. https://doi.org/10.4067/S0717-65382019000100057

Ley 21.202 de los humedales urbanos. (2020). Santiago de Chile. https://www.bcn.cl/leychile/navegar?idNorma=1141461

MMA-ONU Medio Ambiente. (2025). Guía metodológica para el desarrollo de iniciativas de restauración de humedales con énfasis en la recuperación de sus servicios ecosistémicos (Ibarra-Cariola, J. & Flores-Toro, L.). Proyecto GEF/SEC ID: 9766.

Ministerio del Medio Ambiente (MMA). (2020). Guía metodológica para la identificación y delimitación de humedales urbanos. https://humedaleschile.mma.gob.cl

Ministerio del Medio Ambiente (MMA). (2021). Plan Nacional de Restauración de Paisajes 2021–2030. https://restauracionpaisajes.mma.gob.cl

Ministerio del Medio Ambiente (MMA). (2024). Informe de seguimiento de la Ley de Humedales Urbanos N°21.202. https://humedales.mma.gob.cl/ley21202

Municipalidad de Talcahuano. (2020). Informe ambiental comunal: Humedal Rocuant-Andalién. https://www.talcahuano.cl

Observatorio Urbano Chile. (2023). Expansión urbana y uso de suelo en Concepción y Talcahuano (1960–1980). https://observatoriourbano.minvu.cl

Pizarro-Araya, J., Alfaro, F. M., Gómez, F. A., & Villablanca, R. (2022). Arthropod fauna of the urban coastal wetland of Aguada La Chimba (Antofagasta Region, Chile): A wetland in an arid matrix. Anthropocene Coasts, 5(1), 11.

Rodríguez-Pose, A., & Storper, M. (2020). Housing, urban growth and inequalities: The limits to deregulation and upzoning in reducing economic and spatial inequality. Urban Studies, 57(2), 223–248.

Rojas, C., Sepúlveda, E., Jorquera, F., Munizaga, J., & Pino, J. (2022). Accessibility disturbances to the biodiversity of urban wetlands due to build environment. City and Environment Interactions, 13, 100076.

Shenoy, D. M., Kurian, S., Shirodkar, G., Uskaikar, H., Gauns, M., & Naqvi, S. W. A. (2021). Impact of physical processes on oxygen loss and production of hydrogen sulphide and methane in a tropical freshwater reservoir. Environmental Science and Pollution Research, 28, 39655–39667.

Sobre los Humedales, C. D. R. (2018). Perspectiva mundial sobre los humedales: Estado de los humedales del mundo y sus servicios a las personas. Secretaría de la Convención de Ramsar. https://static1.squarespace.com/static/5b256c78e17ba335ea89fe1f

Vignoli, J. R. (2019). Migración de las grandes ciudades de América Latina: el efecto rejuvenecedor, 1975–2010. Revista Latinoamericana de Población, 14(26), 150–178. https://doi.org/10.31406/relap2020.v14.i1.n26.7

Vicepresidencia del Senado. (2019). Los humedales urbanos. Pontificia Universidad Católica de Valparaíso. https://bibliotecadigital.ciren.cl/handle/20.500.13082/29473

Vivanco, E. (2017). Humedales: definiciones, funciones y amenazas. Biblioteca del Congreso Nacional de Chile (BCN).

Yang, T., He, Q., Jiang, J., Sheng, L., Jiang, H., & He, C. (2022). Impact of water table on methane emission dynamics in terrestrial wetlands and implications on strategies for wetland management and restoration. Wetlands, 42(8), 120.