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Spatial interactions between perceived biophilic values and neighborhood typologies in urban wetlands

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Abstract

Wetlands provide a wide range of ecosystem services; however, little is known about their perception value or use for improving urban planning and wetland management. This study explores the perception values towards the Los Batros Wetland in Chile, by inhabitants from different neighborhood typologies. A sample of 457 responses evaluated the wetland by applying the Kellert framework of 9 biophilic values using a Public Participation Geographic Information Systems (PPGIS) approach. A spatial autocorrelation analysis with hotspot revealed that the spatial distribution of biophilic values varies by neighborhood typology. Subsequent ANOVA and T-test suggest that such distribution is affected by perceived accessibility and visitation purposes, and is influenced by socio-demographic aspects that vary among neighborhood typology. Inhabitants of the garden city typology located next to the wetland area, whose residents have higher education and income levels and who have easy and moderate access to the wetland, agreed with a diverse type of biophilic values. In the garden city, the ecologistic-scientific value has the higher spatial concentration. In the condominium typology, with similar education and income levels and accessibility, but situated far from the wetland, there was less agreement with biophilic values, and these were more dispersed, i.e. biophilic values are less representative. In this case, the aesthetic value prevails over others. At the north area of the neighborhood unit, where residents had lower education and income levels along with moderate to difficult physical access to the wetland, but they developed horticultural activities alongside the wetland, inhabitants agree with various biophilic values, highlighting its symbolic value. Conversely, biophilic values of people in the favela were not in agreement nor disagreement, regardless they have similar physical access and distance to the wetland as residents in the condominium typology, but have the lowest income and education level. Findings suggest that effective wetlands management requires appreciation of the clusters of values assigned to wetland environments, which in this case relate to neighborhood typologies. These clusters should be considered when planning to restore, protect, and improve urban wetlands.

Keywords: Urban wetland, Biophilic values, PPGIS, Neighborhood typologies, Spatial analysis, Perception

Introduction

The 2030 Agenda for Sustainable Development includes the sustainable use of wetlands as one of the 17 Sustainable Development Goals (SDGs). However, there is a lack of comprehensive guidelines for implementing this goal in practice. Aligning with SDG number 11, the new urban agenda (Habitat III) recommends enhancing the compact and sustainable city by integrating "blue spaces," public open spaces, and green areas to improve the overall quality of life (UN Habitat, 2017).

Achieving this goal poses a complex challenge in Latin America, where rapid urbanization has resulted in adverse health effects and a growing disconnect between residents and natural environments (Ezquiaga Arquitectura Sociedad y Territorio S.L., 2015). In Chile, recent research has highlighted the widespread loss of wetlands in highly urbanized areas, particularly in the Concepción Metropolitan area. Between 2004 and 2014, urban areas in the region expanded by 28%, while the wetland area decreased by 10% and is projected to further decrease by up to 32% (Rojas, Munizaga, Rojas, Martínez & Pino, 2019).

Despite being one of the most threatened landscapes in Chile (Rojas et al., 2019), urban wetlands have received limited attention in studies focusing on perception and valuation. Existing research indicates that wetlands are valued for their ecosystem services, such as flood regulation, habitat conservation, and cultural significance, as well as for recreational and survival purposes (Rojas et al., 2017b; Alikhani, Nummi & Ojala, 2021; Rojas, Soto, Rojas & López, 2022; Villagra & Alves, 2016; Villagra & Dobbie, 2014). However, there is a need for further investigations to understand how perceptions and values vary across different spatial contexts.

Mapping various perceptions and values associated with urban wetlands can provide valuable insights for land and water management, facilitating the identification of land use conflicts and compatibilities (Brown, Pullar & Hausner, 2016). In Chile, urban areas' expansion over wetlands has led to the emergence of diverse neighborhood typologies with distinct socio-economic classes, education levels, interests, and levels of accessibility to wetlands. Mapping the perception of wetlands in various urban neighborhoods is key for garnering public support for wetland restoration, management, and planning water-sensitive cities.

One promising methodological approach to address this challenge is using a Public Participation Geographic Information Systems (PPGIS). PPGIS has been employed to map land use preferences, values, and preferences associated with specific locations, wildlife conservation, the identification of land use conflicts, and the mapping of relationships between governance, planning, values, and preferences (Brown, Hausner, Grodzińska-Jurczak, Pietrzyk-Kaszyńska, Olszańska, et al., 2015; Brown, McAlpinec, Rhodesc, Lunneyd, Goldingayf, et al., 2019; Karimi, Tulloch, Brown & Hockings, 2017; Karimi & Brown, 2017; Hausner, Brown & Lægreid, 2015; Kobryn et al., 2017; Engen, Runge, Brown, Fauchald, Nilsen & Hausner, 2018).

PPGIS offers several advantages over traditional social assessment methods, as it enables us to spatially view perceptions from people and understand whether other variables such as proximity to the wetland influence the type of neighborhood.

The biophilia hypothesis and place-based theory

The use of PPGIS can be supported by current theories in landscape research, such as the Biophilia Hypothesis and place-based theoretical models, which contribute to nature-based thinking. These frameworks imply the valuation of nature in relational terms, focusing on relationships rather than specific objects (Chan et al., 2016). They consider not only the instrumental and technological aspects of nature, such as ecosystem services and nature-based solutions, but also the intrinsic and cyclical aspects of nature (Randrup et al., 2020). This holistic perspective encompasses instrumental, intrinsic, and relational elements (Himes & Muraca, 2018). While nature-based solutions offer a novel approach to address the challenges posed by urban growth and climate change on water ecosystems, their application remains limited to European cities with strong urban governance (Moosavi, Browne, & Bush, 2021). Consequently, in the face of public policy uncertainties, nature-based thinking has emerged as a way to promote more sustainable, healthy, and inclusive cities (Randrup et al., 2020).

In this study, we employ the framework of biophilic values from Kellert and the PPGIS approach to understand how individuals from different neighborhoods in Chile perceive the value of wetlands near their residences. Kellert and Wilson (1993) propose that the values people assign to the natural environment reflect universal and functional expressions of our species' dependence on the natural world (p. 44). Due to our innate tendency to connect with life and lifelike processes, landscapes are not only perceived for their utility but also for other types of values, such as beauty and spiritual inspiration. Kellert (2009) suggests that our affiliation with the natural world is based on nine evolutionary human values (Table 1), including utilitarian, naturalistic, ecologistic-scientific, aesthetic, symbolic, humanistic, moralistic, dominionistic, and negativistic values. This biophilic values framework lets us examine wetlands as interconnected webs of relational values, enabling a comprehensive understanding of how individuals and groups appreciate them. This framework categorizes values as both universal and context-dependent, recognizing that values are not isolated but can coexist and even contradict each other within the same individuals or groups.

Research on urban wetlands demonstrates that the values associated with wetlands are diverse and depend on socio-cultural variables such as age, gender (Kaplowitz & Kerr, 2003), place familiarity, environmental education (Nassauer, 2004), and socio-demographic factors like income (De La Barrera et al., 2016). While utilitarian values related to wetlands, such as drainage, have traditionally prevailed in Western societies (Dobbie & Green, 2013), studies conducted in Spain, Australia, New Zealand, and the USA suggest a deeper engagement with wetlands, emphasizing aesthetic and ecologistic-scientific values (Dobbie & Green, 2013; Pueyo-Ros, Ribas, & Fraguell, 2016; Zorrilla-Miras et al., 2014). In the Chilean context of our study area, a profound engagement with urban wetland areas may serve as a basis for biodiversity conservation and contribute to an overall higher quality of life.

Table 1 outlines a comprehensive typology of biophilic values based on the framework from Kellert and Wilson, providing descriptions and wetland-specific examples. Utilitarian value is represented by the material benefits wetlands offer, such as water provision and flood control. Naturalistic value stems from direct contact with nature, exemplified in wetlands by intriguing landscapes. The Ecologistic-Scientific value highlights

Table 1 Typology of biophilic values

Biophilic value	Description (Kellert & Wilson, 1993)	Example in wetlands (provided by the authors)
Utilitarian	The value for the natural world through providing benefit in a material sense and which could be useful	Wetlands can provide water and contribute to controlling floods
Naturalistic	The value obtained from direct contact with nature and accompanied by exploration and curiosity that can evoke a sense of fascination, wonder and awe	The landscape of trees and grasses can create mysterious places that stand out
Ecologistic-Scientific	The value of getting satisfaction achieved from the study of nature that eases problem solving and other cognitive functions	Access to wetland areas can increase our ecological understanding about birds and other species
Aesthetic	The value which provides visual satisfaction and appeals to the beauty observed in the natural world	Wetlands provide natural scenes with water features, which are usually preferred more by people
Symbolic	The value observed in natural symbols that provide a way of communication and expressing our thoughts	The changing colors of wetlands areas can be seen as a means of productive seasons
Humanistic	The value observed in the strong attachment to individual elements of the environment, most commonly animals	Wetland areas can contain swans and herons, species which are highly attractive to people
Moralistic	The value of feeling a strong sense of ethical responsibility and affiliation for the natural world	Several community groups are formed in wetland areas in urban environments with the aim to protect nature
Dominionistic	The value that raises the desire to dominate or master the natural environment	The desire to access the wetland
Negativistic	The value obtained in environments that convey negative feelings such as fear, aversion and antipathy	Some urban wetland areas are dry in summer seasons, accumulating trash

satisfaction from studying nature, applicable to wetlands through ecological understanding gained from observing species. The aesthetic value relates to visual satisfaction, with wetlands offering scenes with water features. A symbolic value is expressed through natural symbols, as seen in wetlands with changing colors signifying seasons. Humanistic values involve strong attachments to environmental elements, like attractive species in wetland areas, while moralistic values are evident in community groups formed to protect wetland nature. A dominionistic value is characterized by the desire to master the natural environment, exemplified by the aspiration to access wetlands. The negativistic value arises in environments with negative feelings, such as trash accumulation in dry urban wetland areas during summer. Overall, this typology illuminates diverse ways individuals value and engage with wetland ecosystems through various biophilic dimensions.

When considering quality of life issues, place-based approaches provide tools and a framework for understanding how people relate to and cope with social-ecological changes, such as wetland degradation. Place-based approaches posit that the perception of urban wetlands is influenced by location and spatial factors (Cantrill, 1998). Physical space plays a role in shaping perception and use of the landscape, suggesting that the distribution of different urbanization typologies within and around natural wetlands can affect public perceptions and use of such environments. Researchers have found that perception of water bodies is influenced by proximity factors (Brody, Highfield & Alston, 2005; Pedersen, Weisner & Johansson, 2019) such as distance and accessibility. When

close to residential areas, wetlands have high cultural ecosystem service values that have also been perceived to have restorative qualities (Pedersen et al., 2019). People are more attached to waterscapes when they live in their proximity (Manuel, 2003), which in turn creates positive attitudes towards resource protection (Johnson, Faggi, Voigt, Schnellinger & Breuste, 2014). Brody et al. (2005) suggest that proximity effects on wetlands perception are likely influenced by the high density of neighborhoods and the social networks which facilitate the sharing of information among residents.

According to a place-based understanding, environmental values are not randomly distributed across the landscape but tend toward spatial clustering (Brown, Reed & Harris, 2002). The clustering of perceptions is crucial to understand that environmental perceptions are spatially dependent (Brody et al., 2005). Thus, examining perception in our study area, which include different neighborhood typologies, is necessary to understand "hot spots," or spatial concentrations of similar responses that characterize public perception and influence the use of the surrounding environment.

Objectives of the study

The objective of this study is to investigate the distribution of biophilic values of wetlands in San Pedro de la Paz, a coastal city in the Concepción Metropolitan Area (CMA) in southern Chile. By employing the biophilic values framework from Kellert and utilizing a PPGIS approach, we aim to explore whether there is a correlation between the values of individuals (specifically, biophilic values) and different neighborhood typologies of San Pedro de la Paz. Neighborhood typological variations in distance and accessibility for the wetland area, and with regards to socio-demographics aspects, could explain the distribution of public perceptions about wetlands in San Pedro de la Paz, in a similar manner as has been reported in previous studies (e.g. Nassauer, 2004; De La Barrera et al., 2016; Manuel, 2003; Brody et al., 2005). The study seeks to enhance our understanding of the spatial factors that influence individuals' perceptions and connections with wetlands, contributing to the knowledge of how neighborhood characteristics shape the relationships which people have with these natural environments.

Methodology

Study area

San Pedro de la Paz is a primarily residential city within the Concepción Metropolitan Area (Fig. 1), and has recently presented relevant urban growth over wetlands. San Pedro began to develop in 1950 due to migration. In 1960, a 9.6 Mw earthquake and tsunami left much of the population homeless. The accelerated urbanization process that was already taking place was incremented by the lack of housing left by this catastrophe. This led to the extraction of natural resources in the area, promoted by the real estate markets and public policies in the field of housing construction for different socio-economic groups (Pérez & Salinas, 2007). As a result, diverse neighborhood types were developed, which varied in socio-demographic aspects and urban form. The urbanization process lacked planning strategies for residential areas' size, as well as their location and access to services (e.g. shops, schools, wetland area).

The neighborhood identification process in San Pedro de la Paz involved: a) a bibliographic review of articles, reports, books, and municipal material in order

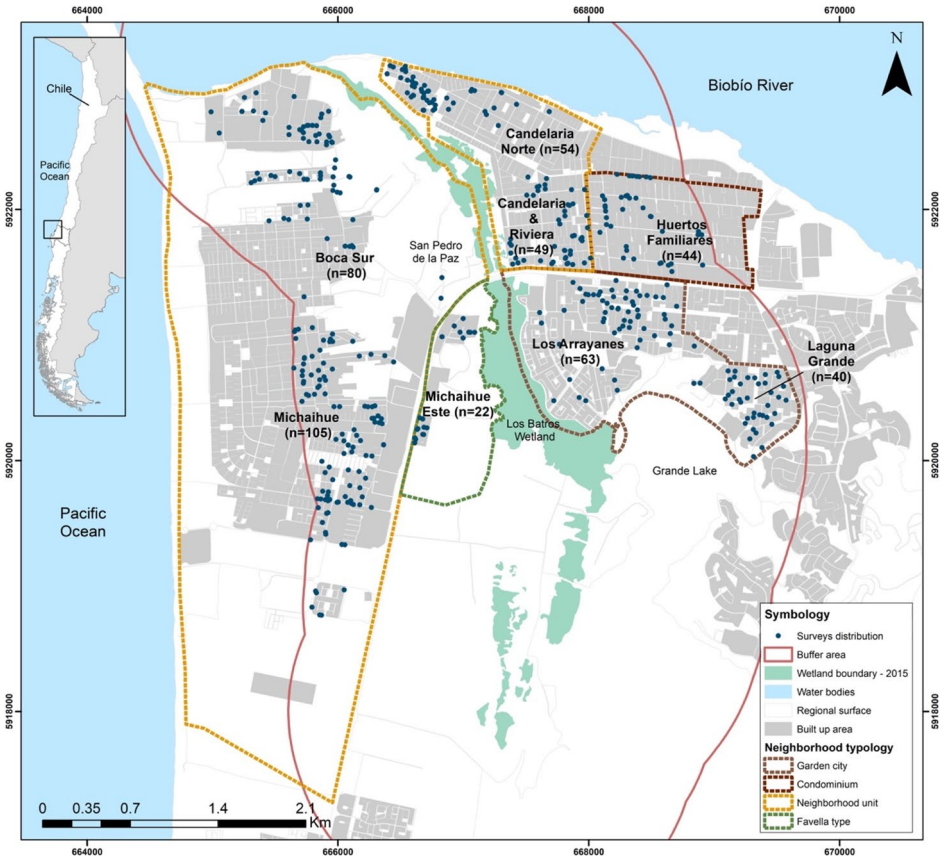

Fig. 1 Los Batros Wetland, neighborhood typologies and perception sample (n)

to understand its urbanization process; b) interviews with professionals from the Municipality of San Pedro de la Paz in order to find out the criteria used to define the current neighborhoods; and c) a focus group with academics and urban planners, in order to relate information previously collected and define the criteria for defining neighborhood typologies. Laboratory and field work was also carried out. Following this process, four typologies were obtained (Table 2).

Table 2 presents a typology of neighborhood groups surrounding the Los Batros wetland, categorized into four distinct groups: Garden City (GC), Condominium (CO), Neighborhood Unit (UN), and Favela (FA). Each category is defined by specific criteria such as housing density, population density, urbanization characteristics, housing type, and available services. The Garden City exhibits a low housing density of 18.94 housing units per hectare, emphasizing a self-contained neighborhood designed to maximize the benefits of nature, reminiscent of the city of health and pleasure. In contrast, the Condominium features a higher housing density of 28.58 units per hectare, forming an enclosed neighborhood under real estate co-ownership with private and common areas. The Neighborhood Unit, a result of industrial demand in the 1960s, comprises attached, two-story houses with functional characteristics. Finally, the Favela is characterized by the lowest housing density (1.65 units per hectare) and population density, representing irregular and private subdivisions

Table 2 Typology of neighborhood groups around Los Batros wetland

Criteria	Garden city (GC)	Condominium (CO)	Neighborhood unit (UN)	Favela (FA)
Housing density (housing unit/hectare)	18.94	28.58	19.22	1.65
Population density	52.3	75.12	55	4.68
Urbanization characteristics	Self-contained neighborhood aimed at capturing the benefit of nature the most. Related to the city of health and the city of pleasure	Enclosed neighborhood of homes grouped under the real estate co-ownership regime, with private and common property areas, like those documented in the case of North American gated communities	Functional neighborhoods created by the industrial demand of workers in the 60 s	Irregular and private subdivisions of the land, with public plots that do not comply with urbanization standards. A type of marginal urbanization, that emerged due to invasion, private and irregular subdivisions
Housing type	Detached, one- or two-story houses, with backyards and front yards, linearly distributed	Houses and blocks grouped in an enclosed plot (by fences or walls), including front yard and backyard	Attached, two-story houses, with backyards, linearly distributed	Detached, one story self-constructed houses, randomly distributed
Services	Includes private educational establishments, parks, commercial properties, electricity, drinking water and sewage	Includes public educational establishments, parks, commercial properties, electricity, drinking water and sewage	Includes public educational establishments, commercial properties, electricity, drinking water and sewage	Includes electricity and drinking water
Representative image				

A relevant surface of the urban expansion that has taken place over wetlands in San Pedro includes the GC and CO typologies. Source: Elaborated based on Muñoz (2018) and field work

that emerged due to invasion, featuring detached, self-constructed houses randomly distributed. The table also outlines the types of services available in each category, ranging from private educational establishments in Garden City to basic amenities like electricity and drinking water in the Favela. This typology provides a comprehensive overview of the diverse urbanization patterns surrounding Los Batros wetland, highlighting variations in housing, services, and development characteristics across different neighborhood groups.

The Los Batros wetland in San Pedro de la Paz is a palustrine system, which is composed of a water body named Estero Los Batros, grasslands areas, and the Chica and Grande lagoons (Fig. 1). Los Batros wetland has been reduced from 504 to 133 ha, due to infill for new built-up areas (Rojas, Martínez, Fuente & Rueda, 2017a). We have defined a buffer area of 1500 m from the urban wetland as a study area, which includes 83,016 inhabitants and 26,837 dwellings, distributed among eight neighborhoods with an average density of 55 inh/ha. The study of biophilic value distributions amongst the neighborhood typologies of San Pedro de la Paz can provide relevant information on how different community groups affiliate with urban wetland landscapes.

Questionnaire

Considering that PPGIS is a useful tool to relate data from different origins on space, and that the Kellert Framework is an approach to study relational views of nature, we developed a questionnaire to collect spatial, perceptual, and socio-demographic data in eight neighborhoods, categorized in the four neighborhood typologies described in Table 2.

For spatial data gathering, we followed the recommendation by Brown et al. (2019) and included household sampling to achieve greater geographic and socio-demographic representation. We selected neighborhoods located between 250 and 1500 m from the wetland area to explore whether proximity affected wetland values. For this reason, we mapped the location of participants. Like other studies (Brody et al., 2005; Pedersen et al., 2019), the questionnaire addressed interviewees' location.

Perceptual data was collected in a questionnaire including three sections. First, we included a set of 18 sentences (items) that address the biophilic values, and which were previously elaborated and used by Delavari-Edalat and Abdi (2010) (See Appendix A). These were rated according to the level of agreement with each sentence by using a five-point Likert scale, where 1 is the lowest level of agreement and 5 the highest. Second, based on studies by Brody et al., (2005) and Pedersen et al. (2019) a set of questions were prepared to address physical and visual accessibility to the wetland area, in terms of high, medium and low accessibility. Third, questions were included about wetland visits' frequency and purpose, in line with Manuel (2003).

The questionnaire also included a section to collect socio-demographic data, as suggested in prior studies which used PPGIS and/or wetlands as a case study (e.g., Brody et al., 2005; De la Barrera et al., 2016; Scholte et al., 2016). These details included questions about age, gender, income, education level, occupation, length of residency, place of growth, and level of participation in social and environmental groups.

Sample

We employed the methodological parameters established by Rojas et al. (2017b) for determining the perception sample. The target population (N) consisted of individuals aged 18 years or older, regardless of gender, who served as heads of households in the eight neighborhoods surrounding the Los Batros wetland (see Fig. 1). To calculate the sample size (n), we applied the equation for finite populations (Eq. 1) and obtained a sample of 457 respondents. The surveys were distributed in a manner that reflected the relative population size of each neighborhood: Condominium ($N = 2{,}533$; $n = 44$), Neighborhood unit ($N = 18{,}475$; $n = 288$), Garden City ($N = 4{,}250$; $n = 103$), and Favela type ($N = 1{,}579$; $n = 22$). A minimum sample size of 20 subjects per neighborhood was set as a prerequisite for conducting statistical analyses.

$$n \geq \frac{\mathrm{N}z^2{}_{1-a/2}\ \mathrm{PQ}}{z^2{}_{1-a/2}\ \mathrm{PQ} + d^2(\mathrm{N}-1)} \tag{1}$$

In Eq. 1, n corresponds to the sample size, N is the population size (26,837), Z is the normal distribution value (95%), P is the estimated population proportion (50%), d is the precision (5%), and Q the proportion of unfavorable results in the population ($\mathrm{q} = 1 - \mathrm{p}$).

Public participation geographic information systems (PPGIS) data analysis

We used spatial autocorrelation analysis to explore the presence of systematic spatial variation in the biophilic values. For this purpose, Hot Spot Analysis Getis-OrdGi* statistical and descriptive maps were used to develop an indicator to associate the neighborhood typologies' geographic locations with the data collected on biophilic values.

Hotspot spatial analysis was useful for identifying the spatial patterns that mediate biophilic values among different neighborhood typologies by spatial cells. We used a spatial autocorrelation index based on locations as suggested by Brody et al. (2005). The application of this index in our study provides a useful tool for the statistical modeling of responses from people, helping us understand why and where perception occurs. The Hotspot analysis can indicate if the spatial influence of social networks (people living surrounding the wetland), geographic location, proximity (distance), and other spatial factors can cause biophilic values to unfold as a clustered pattern across San Pedro de la Paz, rather than being randomly dispersed. Hotspot analysis can illustrate spatially correlated perceptions with z-scores and p-values by cells.

The analysis indicates whether there is a strong or weak relationship between high (and low) biophilic hotspot values, in 250-m cells, and the locations of users at point level in neighborhood typologies. The index value thus indicates a tendency toward clustering in perception. A positive or significant hotspot indicates a high index value, and that this hotspot is surrounded by other features with high values as well. In contrast, a negative index value indicates a tendency toward dispersion in responses by people without a significant spatial relationship.

Descriptive statistical analysis

After considering the relationship between spatial and biophilic data, we delve into how the variation in perceived accessibility, and neighborhoods' socio-demographic differences, explain the spatial results of biophilic values.

Accessibility and visitation purpose

We used Analysis of Variance (ANOVA) to explore whether there were significant differences among cluster groups of biophilic values that can explain the spatial-biophilic relations. For this purpose, visual and physical accessibility, in terms of high, medium, or low accessibility, were used as dependent variables, and the neighborhoods as independent variables. To explore the effect of visitation purpose upon spatial-biophilic relations, we followed the same procedure by using the visitation purposes indicated by the inhabitants as dependent variables.

Socio-demographics

ANOVA and T-Test were used to explore whether there were significant differences among the socio-demographic variables that can further explain the spatial-biophilic relations. For this purpose, aspects that affect perception of wetlands observed in previous studies by Nassauer (2004), De la Baerrera et al. (2016) and Scholte et al. (2016), among others, were used as independent variables. These include place of growth (e.g. urban, rural), income level (e.g. ABC1, C2, C3, D, E, from higher to lower income (Rojas et al., 2017b), education level (without education, primary and secondary, and higher education), type of occupation (e.g. unemployed, employed in the primary sector, secondary sector, tertiary sector), and length of residency (e.g. less than one years, between one and ten years, more than ten years). Variables related to the participation of people in community groups were included as well (e.g. Brody et al. 2005) such as participation in social groups (yes, no); participation in environmental community groups (yes, no), and participation in Los Batros Wetland community group (yes, no).

Analyses were performed in SPSS, and for the case of ANOVA, the Tukey post-hoc test was used for multiple comparisons to explore group differences.

Results

Respondents were mostly female (60%), between 30 to 74 years old (83%), and with dwellings located in urban areas (95%) (Table 2). The main differences among neighborhood typologies were observed in three categories: education level, place of origin, and income. People living in the garden city (GC) and condominium (CO) typologies have higher levels of education (46% of each type have postgraduate studies); their place of origin was mostly urban areas (GC = 88%, CO = 86%), and the majority of them are within the higher income categories (GC = 58% and CO = 51%). In contrast, people living in the neighborhood unit (NU) and favela (FA) either lack formal education or have received incomplete primary education (NU = 52%, FA = 57%); their

place of origin is mostly in rural areas (NU = 66%, FA = 62%), and their income is within the lower categories (NU = 64%, FA = 67%).

Distribution of perceived biophilic values of Los Batros wetland

Results of the spatial autocorrelation analysis with hotspot indicate that values' spatial distribution and the diversity of values with agreement vary among neighborhood typologies. The maps in Fig. 2 show the spatial cluster of agreement, neutrality, and disagreement with each value. When the hotspot has a higher percentage of confidence level (i.e. cell color is more intense) the clustering represents the significant high values for the hot spot in agreement or hot spots, neutral (neither agree nor disagree), and disagreement or cold spots (meaning a smaller *z score)*. Confidence level percentages equal to or greater than 90% indicates a significant cluster of biophilic values by cell.

Respondents within the garden city typology (GC) agree with all the biophilic values. Agreement with the naturalistic, aesthetic, symbolic, and dominionistic values is more intense (99% confidence level); nonetheless, none of these values show a wide distribution within this typology. On the contrary, agreement with the ecologistic-scientific, moralistic and humanistic values is less intense (between 90 and 95% confidence level) and more geographically distributed, which indicates a higher representation among people's perceptions. In particular, the intensity of agreement with the ecologistic-scientific value is among the lowest, but has the highest distribution, which can be interpreted as the highest representation. Agreement with the negativistic value shows the lowest intensity (90% confidence level) and less spatial distribution.

The condominium typology (CO) presented the lowest level of agreement with biophilic values. The aesthetic value was the predominant biophilic tendency (90% confidence level). On the other hand, perceptions of disagreement are associated with the utilitarian, moralist and dominionistic values, and with a significant intensity (90% to

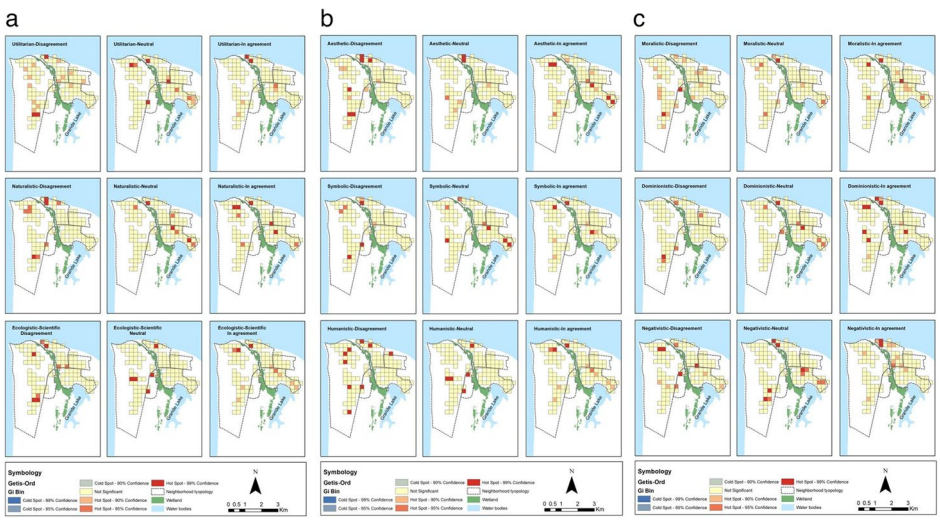

Fig. 2 **a**. Clusters of biophilic values (Utilitarian, Naturalistic, Ecological–Scientific) for urbanization typologies. **b**. Clusters of biophilic values (Aesthetic, Symbolic, Humanistic) for urbanization typologies. **c**. Clusters of biophilic values (Moralistic. Dominionistic, Naturalistic) for urbanization typologies

95% confidence level). Of these values, the utilitarian is the most distributed, indicating greater representativeness. Hotspots of neutral perception with the naturalistic value were observed in this typology as well (90% confidence level).

In the neighborhood unit typology (NU), the naturalistic, aesthetic, symbolic, humanist, and dominant values were perceived in agreement and with greater intensity (over 90% confidence level). At the same time, these values are observed with greater spatial dispersion, thus being the most representative of the typologies. However, a different perception is observed between the northern and southern zones of this typology, which is worth highlighting due to the large size of the area covered by the neighborhood unit. In the north, perception agreement with the naturalistic, ecologistic-scientific, aesthetic, symbolic, humanistic, utilitarian, moralistic, and dominionistic values is intense (99% confidence level). In the south, there is disagreement with the same values with confidence level between 95 and 99%.

In the case of the favela (FA), no significant perception was found in agreement with the biophilic values. In general, residents of the favela had a neutral position in biophilic value perceptions, particularly regarding the utilitarian, environmentalist, and humanist values (99% confidence level).

Accessibility and purpose of visitation effect on biophilic values distribution

Consecutive analyses of ANOVA with a post-hoc Tukey test suggest that differences between neighborhood typologies have an effect on perceived accessibility and frequency of visits to the wetland.

For visual accessibility, significant differences were found among neighborhood types (ANOVA ($F=11.385$, $p=0.000$), specifically between GC and FA ($p=0.000$), CO and FA ($p=0.000$), NU and CO ($p=0.003$), and NU and FA ($p=0.002$). Visual accessibility to the wetland is mostly difficult for people living in GC (83%) and CO (100%). 56% of the people living in NU also reported that visual accessibility is difficult. By contrast, over 50% of the people living in FA find that visual accessibility to the wetland area is easy (38%) or moderate (19%).

Regarding physical accessibility, ANOVA ($F=6.153$, $p=0.000$) reported statistically significant differences among neighborhood types as well. A post-hoc Tukey test revealed significant differences between V and NU ($p=0.000$) and C and FA ($p=0.03$). In the GC typology, most of the people find that access to the wetland is easy (63%), and 75% use it for recreation (Fig. 3). For people living in condominiums, physical accessibility is easy (42%) to moderate (30%), and recreation is their most mentioned reason for visiting as well (60%). In NU and FA, physical accessibility was found to be difficult (NU = 42%, FA = 53%) and moderate (NU = 18%, FA = 14%), and people use it more for shortcuts and work purposes (NU = 59%, FA = 43%) than for recreation (NU = 17%, FA = 33%).

Wetland socio-demographic effect on biophilic values distribution

Further ANOVA and T-tests suggest that only the income level, education level, length of residency, and place of growth variables have significant differences among neighborhood typologies, which might also explain the variation found in the biophilic values distribution (Table 3). In particular, Table 3 shows that the Garden City and Condominium

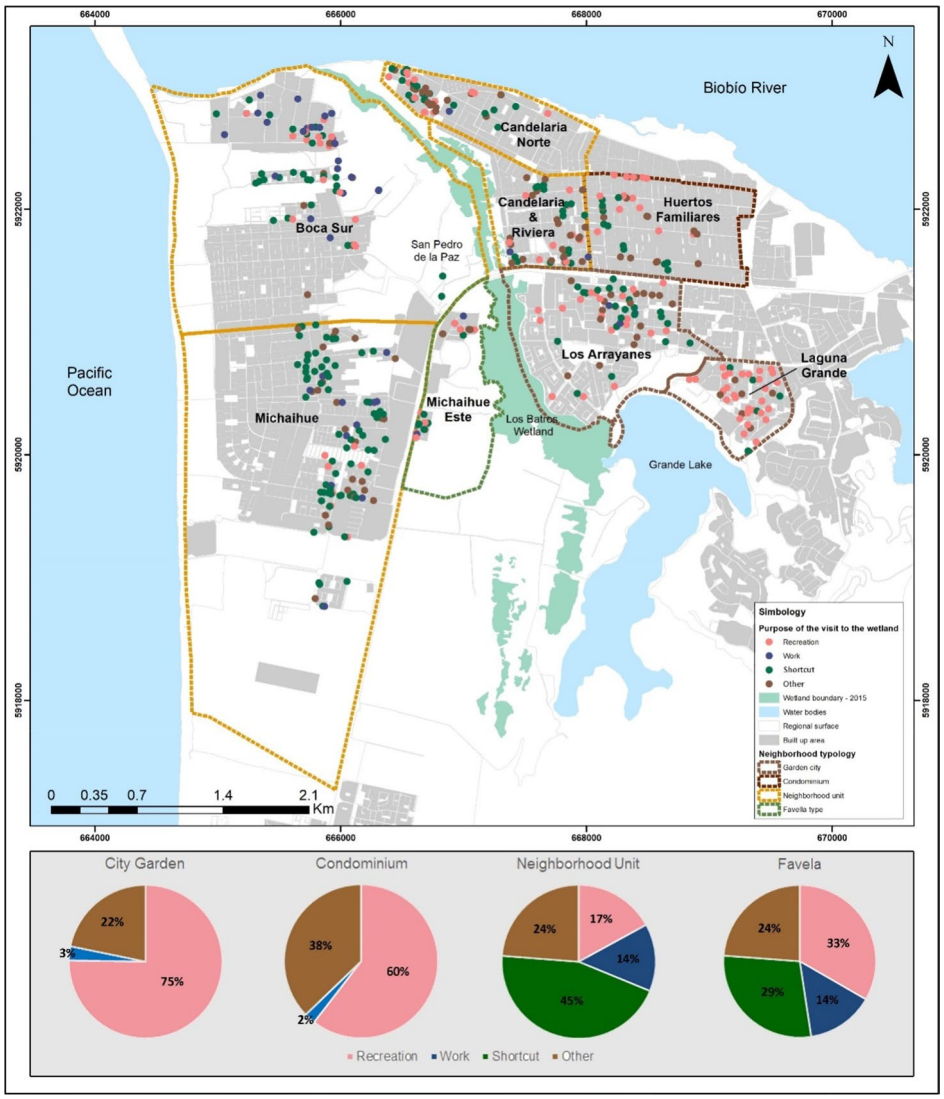

Fig. 3 Distribution of visitation purpose

Table 3 Socio-demographic variables with significant differences among neighborhood typologies

Variable	F	*p* value	CG	CO	NU	FA
1.Income Level	*48,842*	0,000	NU** FA**	NU** FA**	GC** CO**	GC** CO**
2.Education Level	*34,244*	0,000	NU** FA**	NU** FA**	GC** CO**	GC** CO**
3.Length of residency	*9,739*	0,000	NU**	GC**	GC** FA*	NU*
4.Place of growth	23,060	0,000	w/i	w/i	w/i	w/i

** *p* value = 0,000; *p* value = 0,015

typologies tend to have significant differences among these variables with the Neighborhood Unit and Favela typologies.

Note to Table 3: Reported variables are those with significant differences among neighborhood typologies only. The last four columns report the significant differences found among neighborhood typologies for each variable. Variables 1 to 3 show results from ANOVA and Post-hoc Tukey Test. Variable 4 shows results from T-test. W/i indicates without information.

Indeed, the Homogeneous Subsets results from the Tukey HSD show that for the income level, education level, and length of residency variables, GC and CO tend to form a subset which is significantly different from the subset formed by NU and FA (Fig. 4). The income level is significantly higher in GC and CO than in the subset NU and FA. 68% of people in GC and 51% in CO are within the two higher income levels, while 64% of NU and 67% of FA are within the two lower income levels. While higher education characterizes almost half of the population in GC (46%) and CO (46%), the NU and FA typologies are also mostly characterized by people with secondary and high school education (NU = 82%; FA = 76%). For the case of length of residency, CO is linked to the two subsets, with 63% of their population living in this neighborhood type for over 10 years. Similarly, in GC, 75% of the population has lived in this neighborhood for the same period, along with 63% of people in NU. For FA, this number increased to 85% for those who have lived in the area for over 10 years. In addition, 88% of people within GC and 86% in CO have grown in urban areas, whereas only 66% of NU and 62% of FA responded likewise.

Discussion

The use of the Kellert framework and the PPGIS approach revealed that the distribution of Biophilic values varied among neighborhood typologies. Participants perceived the Los Batros Wetland as a non-homogeneous area. We were able to understand that

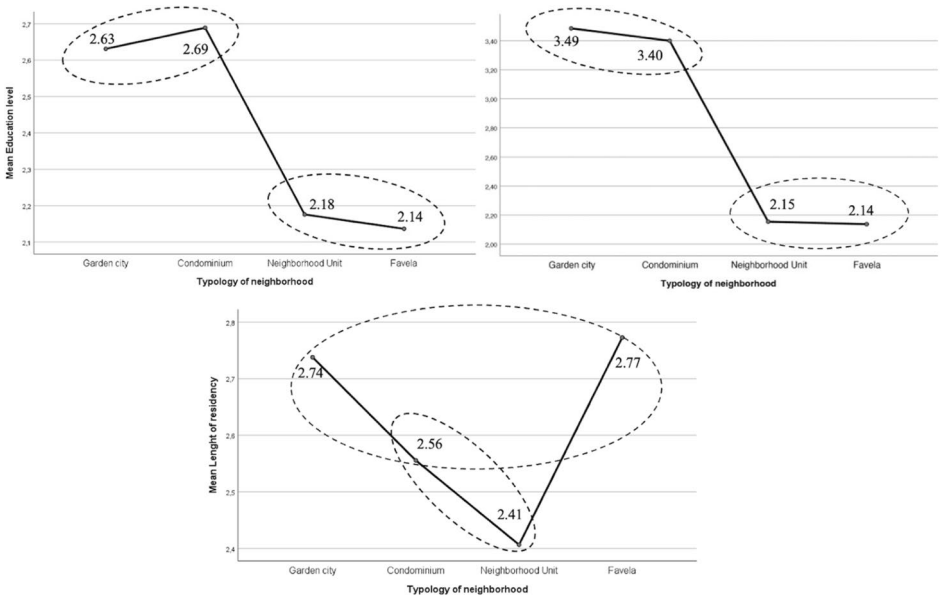

Fig. 4 Subset of neighborhood typologies and mean values. The subsets of the Tukey tests are illustrated in dash lines

characteristics of the inhabitants among neighborhood typologies such as income, education, length of residency, and place of growth vary, ultimately influencing the distribution of biophilic values. In addition, we revealed that the locations where people live have an important effect as well, as was found by others in other contexts (Brody et al., 2005; Pedersen et al., 2019). This is an important finding in the Latin American context, where variations in housing type, socio-demographics and services among neighborhoods are enormous.

Our results show that the higher the income and the education level, the more people have grown in urban areas and the higher the length of residency, physical accessibility and proximity to the wetland area, the higher the percentage of agreement with a diverse type of biophilic values (e.g. garden city). However, when a neighborhood with these characteristics is not next to the wetland, as with the condominium, agreement with biophilic values diminishes considerably, and the aesthetic value prevails over others. Moreover, in areas where income and education levels are lower, fewer people have grown in urban areas, and the urban form of the neighborhood makes physical access and use of the wetland difficult (e.g., lack of paths and bike trails), people agree considerably less with biophilic values (neighborhood and favela typologies), regardless of high length of residency as with the favela.

This finding supports ideas posed in the study by Scholte et al. (2016), which indicated that responses to wetlands from the public are influenced by different perceptions and motivations. In that study, researchers show that wetland values are in a continuum between eco-centric and anthropocentric value orientations, i.e. between those that emphasize the intrinsic values of nature and those that stress cultural and economic perspectives. In our study, this continuum is also observed between garden city residents with predominantly ecologistic-scientific values, and condominium and neighborhood residents where utilitarian values are more significant.

The highest differences among the socio-demographic characteristics of neighborhood typologies found in this study lay on education and income. Regarding education, the findings of our study support the results from other studies indicating that education influences public attitudes toward wetlands, since education can trigger concern for environmental protection and care for environmental quality (e.g. Jones & Dunlap, 1992). All biophilic values were perceived by the inhabitants of the garden city, which presents higher education levels. This was not the case in the favela, which presents lower education levels and where no significant perception was found in agreement. As Kaplowitz and Kerr (2003) suggest, education in our study could trigger concern and awareness about the Los Batros wetland among people, an idea which can be explained by the type of visitation purpose observed in this typology. This relates to recreation in nature (e.g. observation of birds), unlike those in the favela, which are associated with work (e.g. vegetable cultivation) and to take a shortcut (e.g. from home to the bus station).

With regards to income, previous studies have observed that wealthier individuals are more concerned about the environment and place more importance on wetland areas (e.g. Kaplowitz & Kerr, 2003) as observed in the garden city and condominiums

neighborhood typologies in our study. This is not the case in the favela typology, where education is low (predominantly secondary education level), and both the physical and visual access to wetland areas is difficult (53% physical, 43% visual) to moderate (14% for both). People living in the favelas also have the lowest income (E = 43%; D = 24%) of all the neighborhood typologies, and they are not in agreement or disagreement with any value, unlike people living in the other typologies. Favela residents live directly next to the wetland area; however, its configuration, without paths or agriculture that physically connect people to the wetland, may hinder the relationship between the favela with the wetland. More research is needed to understand the impact and interaction of socio-demographic and accessibility variables on wetland perception and valuation.

Place of growth and length of residency are factors that also vary by neighborhood typology; however, their variation among neighborhood typologies is not as radical as in the case of education and income to assure their effect on biophilic value distributions. However, delving into these variables' effects on the perception of wetlands is relevant in the context of neighborhoods, since wetland studies have usually focused on studying individual perception, where age, gender, and even ethnicity are found as the higher influential variables (e.g. Rojas et al. 2017b). When grouping individuals into neighborhood typologies, as we did in this study, other variables emerge as the most relevant. We can thus suggest that the effect of neighborhood types and characteristics on perception surpasses the effect that age or gender may have individually, which is valuable information for urban planners in contexts where urbanization expands to natural systems such as wetlands. In this case, the type of urbanization and configuration of space might matter more than the denizens' age or gender for wetlands conservation. Further studies should be developed on this idea bearing in mind that it might be only related to the Latin American context, where differences between neighborhoods and socio-spatial segregation are very high, compared to the European context for example.

Physical distance to wetlands, a factor related to spatial proximity and accessibility, may help further explain these results. Indeed, respondents' location has been found to play a critical role in defining public awareness of water bodies (e.g. Brown et al., 2002), as well as a factor that influences expectations for improving the water body and commitment to collaboration (Johnson et al., 2014). The garden city next to the wetland has one of the lowest housing and population densities, and is characterized by its detached houses with front yards and backyards. This setting creates a physically permeable neighborhood type, with access to trails and bike paths that lead to the wetland area, giving people direct contact with nature. The inhabitants of this neighborhood reported the easiest physical accessibility to the wetland (63% of respondents) compared with other neighborhood typologies. Its configuration and location next to the wetland may have triggered participants' agreement with diverse values. Hence, in the garden city typology, closeness to the wetland, easy accessibility and residents' high education level have contributed to build a diverse type of relationship between the community and the wetland.

The opposite occurred in the condominium typology, where people disagree with the utilitarian, moralistic and dominionistic values, by contrast with garden city residents. Even though it is formed by a highly educated group, the condominium typology lacks proximity to the wetland and its inhabitants reported an easy and moderate access. Nonetheless, 60% of participants in the condominiums visited the wetland area for recreation, motivated by its beauty, relating to the aesthetic value of the wetland as reported before. The need for contact with nature within a highly educated community group (70.5% had a graduate or postgraduate degree) living in a condominium environment surrounded by walls and bars, may have triggered this response.

The proximity and configuration of the neighborhood also seem to differentiate inhabitants' perceptions between the northern and southern parts of the neighborhood unit. This typology is mostly occupied by people with a lower education and income than people living in the garden city and condominium. Visual access in this area is difficult (42%) and moderate (18%). In the southern section of the neighborhood unit, accessing the wetland is difficult due to the existence of a high-speed highway, and the favela neighborhood in between. In the northern section (Fig. 3), physical access is moderate because agriculture is intensively developed in between the neighborhood unit and the wetland, which assures the community livelihood and subsistence. This situation creates a type of community garden, which is known to develop a sense of community and belonging (Kingsley, Townsend & Henderson-Wilson, 2009). Large-scale agriculture has been previously associated with high relative cultural ecosystem services values in wetland areas (Pedersen et al., 2019). This might be the case for respondents from the northern area of the neighborhood unit. They agree with the symbolic value (among others such as the naturalistic, aesthetic, humanist, and dominant values), suggesting that the wetland is part of their life and identity. By engaging in horticultural activities, individuals can access good health and a better quality of life (Pedersen et al., 2019) that can coexist with a variety of biophilic needs. In fact, people living in this area access the wetland for multiple purposes (shortcut = 45%; recreation = 17%; for working = 14%), unlike people living in the garden city and condominium typologies, where recreation is mostly preferred (> 75%).

It is also notable that in the neighborhood unit typology, the values observed in agreement are those with greater spatial dispersion (Fig. 2), thus being the most representative of the typologies. The bond that may exist among participants due to agricultural activities in the wetland might be creating a strong social network. According to Brody et al. (2005), such a network facilitates information sharing. Participants from the neighborhood unit typology reported the largest percentage of participation in community organizations (35%) and also participation in Los Batros community groups (12%), which might be triggering a similar perception amongst residents.

In relation to the benefits that green areas have on people observed by other scholars, it is complex to directly relate them to the results of this study. For example, Kabisch et al. (2021) showed that green areas have an effect on cardiovascular health

in older people, while Kabisch & Kraemer (2020) indicate that park design elements motivate physical activities. It is difficult to compare these studies with urban wetlands in the Chilean context, since most of them (as with Los Batros Wetland) have not been transformed into parks, i.e. they lack paths, formal access, and other infrastructure characteristic of greens areas (Fig. 5). Other studies related to nature access can be more in line with our study, in particular those which show that accessibility to nature implies benefits to human health (e.g. Marselle et al., 2021). Nonetheless, part of Los Batros wetland has been recently transformed into a park (following the application of this study). Future studies thus leave the opportunity available to investigate whether improved wetland accessibility changes the distribution of biophilic values among different neighborhood typologies. Recent studies in Chile show this might be the case. The development of formal green areas in Valdivia, a city south of Concepción, increased accessibility to these spaces (Rojas, Páez, Barbosa & Carrasco, 2016). Similarly, in Concepción, next to San Pedro, wetlands with urban infrastructure and formal access increased community resilience capacity after disaster (Villagra & Dobbie, 2014; Villagra & Alves, 2016).

Methodological considerations

The PPGIS approach was useful to map and understand the distribution of Biophilic values in such a diverse urban environment with different socio-demographic characteristics and urban form. However, there are some downsides to using PPGIS in the Chilean context. Due to the neighborhoods' lack of homogeneity, the densest and most populated areas (where it was possible to obtain a better distribution of the questionnaire) were better represented than the less dense and unpopulated areas. An interesting question for future studies is how to define a neighborhood typology that allows a homogeneous distribution of data in a context with such a diverse and complex urban form, as is the case in this study and in other Latin American cities (Ezquiaga Arquitectura Sociedad y Territorio S.L., 2015).

It is also important to consider the face validity of the instrument when studying areas with different socio-demographic conditions. For instance, the questionnaire included a biophilic value scale in English prepared by Delavari-Edalat and Abdi (2010). The scale was adapted in Spanish and submitted to an internal discussion by our interdisciplinary group of researchers (Mårtensson et al., 2019). The whole questionnaire was

Fig. 5 View of Los Batros wetland next to the garden city neighborhood typology

subsequently tested in the city of Concepcion by the interviewers, to verify the understanding, intent, and precise wording of survey questions (Larson, Corley, Andrade, Hall, York, et al., 2019). However, there are other ways to increase the face validity in future studies with such a diverse socio-demographic study group. For instance, the inclusion of photographs, focus groups (Eisenhauer & Nicholson, 2005), or expert judgments (Larson et al., 2019) can be of great use.

Conclusions

Overall, this study has utilized the biophilic value framework from Kellert and a PPGIS approach to investigate the perception and values of a wetland in San Pedro de la Paz, Chile. The findings indicate that residents around Los Batros Wetland exhibit a diverse range of biophilic values, and these values are not randomly distributed across the landscape but show spatial dependence. Proximity, accessibility, and socio-demographic variables such as education and income have been identified as the main factors influencing the values which people show towards the wetland.

A significant outcome of this study is the identification of clusters of wetland values associated with different neighborhood typologies. This information can be valuable for wetland planning, management, and protection campaigns, particularly for areas like Los Batros Wetland with multiple stakeholders. By considering conflicting and shared values assigned to the wetland, decision-making processes can better ensure conservation and well-being. Applying the relational framework from Kellert has granted a deeper understanding of the significance people attribute to wetlands and what is considered appropriate in their relationship with these environments.

The integration of biophilic value measurement and PPGIS studies can provide insights into how spatial patterns influence wetland perception, facilitating their effective protection and management. This is particularly important given that many wetland studies often overlook the combined analysis of perception and land use. Recognizing the relationship between biophilic values and spatial patterns can encourage the planning and management of wetlands as crucial green infrastructure that enhances overall quality of life. The results also support the concept of Nature-based Thinking, which emphasizes the importance of naturalistic and wilderness aesthetics in urban areas.

Based on the findings, it is recommended to implement policies that take into account spatial "hot spots" and different neighborhood types, along with biophilic strategies. Such approaches can assist planners and local communities in reaping the health and well-being benefits of living in closer proximity to nature while effectively managing their natural environments.

Appendix

A—Instructions to evaluate biophilic values

Indicate your degree of agreement with the following sentences in relation to the Los Batros Wetland.

5-Completely agree.

4-Agree.

3- Neither agree nor disagree.

2-Disagree.

1-Completely disagree.

Biophilia Value	Original sentence from Delavari-Edalat and Abdi (2010)	Translation into Spanish used in this study (*)
Utilitarian	We should save trees because they are useful resources for human	Debemos salvar el humedal porque es un recurso útil para mi barrio
	We should care only about the trees which are useful for us	Necesitamos preocuparnos solo de áreas del humedal que son de utilidad para nosotros
Naturalistic	I enjoy planting trees	Disfruto cuidando del humedal
	I like to collect things from trees	Me gusta recolectar cosas del humedal
Ecological-scientific	I like to learn more about different type of trees	Me gustaría aprender más sobre el humedal
	We need more knowledge about trees	Necesitamos conocer más sobre el humedal
Aesthetic	I like walking in nature and looking at trees	Me gusta caminar por el humedal y observarlo
	I am amazed of the individuality and beauty of each tree	Estoy sorprendido/a de la belleza del humedal
Symbolic	Being in forest brings me closer to God	Al estar en el humedal me siento más cercano/a a mis creencias espirituales
	I would like to plant a tree in memory of a loved one	Me gustaría destinar un espacio del humedal en memoria de un ser amado
Humanistic	We have a duty to save woodlands	Tenemos el deber de cuidar el humedal
	I have sympathy for campaigners to save trees	Tengo simpatía por los defensores del humedal
Moralistic	I feel a deep connection to a specific tree	Siento una fuerte conexión con el humedal
	I feel sad when a tree looks sick	Me siento triste cuando el humedal está sucio y contaminado
Dominionistic	We are a small part of nature and nature controls us	Somos parte del humedal y éste influye en nosotros y el entorno en que vivimos
	Trees influence human behaviors	Podemos cambiar el humedal para satisfacer nuestras necesidades
Negativistic	I think parks are scary at night	El humedal me da susto en la noche
	I think parks are places for criminals	El humedal es un lugar de criminales

(*) The translation was made by the research team. It included to change the focus of the original sentences from trees to wetlands.

Authors' contributions
Paula Villagra: Conceptualization, methodology, formal analysis, writing – original draft, visualization, supervision. Carolina Rojas: Conceptualization, methodology, formal analysis, resources, writing – review, visualization, funding acquisition. Susana Alves: Conceptualization, methodology, writing – review. Octavio Rojas: Investigation, data curation.

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Availability of data and materials
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics of approval and consent to participate
This research is not present a conflict of interest and it was approved by the ethics committee of Pontificia Universidad Católica de Chile.
All the author are consent the publication of their profile pictures.

Competing interests
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Publisher's Note

Paula Villagra Architect and Landscape Architect, PhD in Architecture and Planning. She researches urban and community resilience to natural hazards along with landscape perception in hazardous environments. Her research focus is on the adaptation capacity of human communities through integrated landscape analysis using a socio-spatial methodological approach. Recently, she has integrated the use of gamification and digital technologies into her research with the aim to foster resilience capacities in communities through a trans-disciplinary approach. Her research has been published widely in renowned international journals and has been presented in conferences worldwide.

Carolina Rojas Her research lines focus on urban sustainability and sustainable urban mobility, with a special emphasis on the impacts and effects of urbanization on natural water ecosystems, measures of accessibility to open and green spaces in sustainable modes, and climate change adaptation actions to achieve more sustainable, resilient, and water-sensitive cities. She has published over 35 impactful scientific articles (WoS) and has participated in national and international scientific events. She has also been actively involved in public policies, such as the development of the Urban Wetlands Protection Law and the implementation of 17 Sustainable Development Goals (SDGs). Her recent research is related to the conservation of urban wetlands in Chile and Latin America, accessibility indicators for Chilean cities' transportation systems, cli mate change adaptation measures such as nature-based solutions, and the effects of Covid-19 on households' carbon footprint in terms of energy and mobility to assess the environmental impacts of cities.

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Susana Alves Environmental Psychologist examining how natural landscapes and outdoor spaces can promote human health and psychological well-being. Strong components of my work are the use of a multi-method approach to research, the emphasis on policy-related social problems, and the aim to promote culturally meaningful social and environmental interventions for diverse groups of people.