

High Andean wetlands at the climate crisis crossroads and mining extractivism: the Parque Andino Juncal case

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Abstract

High Andean wetlands play a strategic role in water provision, climate regulation and biodiversity conservation. Located in the Valparaíso Region of the Central Andes of Chile, Parque Andino Juncal encompasses part of a hydrological network composed of rivers, ravines, glaciers, high Andean peatlands (vegas) and springs. Established in 2004 as a privately led conservation initiative open to the public, the park was designated a RAMSAR site in 2010. Since 2017, it has gained greater visibility as a sustainable tourism project, drawing visitors primarily from the Valparaíso Region, but also from other parts of Chile and abroad. This initiative integrates tourism with passive restoration practices. Considering the alarming vulnerability of the vegas due to climate change – particularly glacial melt and prolonged drought periods – it is essential to consider both the climatic and the anthropogenic factors threatening these ecosystems to develop climate adaptation and resilience strategies. Parque Andino Juncal offers one such alternative. However, its development may be hindered by the installation of mining projects in the area. In this context, our objective is to highlight the importance of maintaining private protected areas such as the one presented here, as they serve as strategic spaces for monitoring and mitigating the effects of climate change on fragile and vital ecosystems.

Profile

Protected area

Parque Andino Juncal

Mountain Range

Andes, Chile

Introduction

High Andean wetlands are a global priority for ecological restoration due to their role in climate regulation, water provision, carbon storage and biodiversity support. In recent years, ecosystems associated with these wetlands have gained visibility because of their increasing vulnerability to climate change (Anderson et al. 2010; Zeballos et al. 2014). One of the most visible physical effects of climate change is glacial retreat and the consequent shifts in water availability (Podgórski et al. 2023). Likewise, water bodies fed by glacial melt have undergone significant transformations. The composition and ecology of high Andean wetlands, also known as vegas, depend on hydrology, topography and disturbance regimes (Méndez 2007; Méndez 2009; Ontivero et al. 2022).

Although high-altitude wetlands are priority ecosystems, in the Valparaíso Region (Chile) their protection is limited to the designation of state or APPs, among which the private reserve of Parque Andino Juncal stands out. Spanning 13,796 hectares in the eponymous valley, it was declared a RAMSAR site of international importance in 2010. This convention fosters international cooperation and provides a protective framework that promotes the conservation and rational use of wetlands (Astrálaga 2006).

The hydrological value associated with the more than twenty glaciers and wetlands present in this valley is considerable, as they provide a vital contribution to the water supply and ecosystem services for



Figure 1 – Canchitas vegas, Quebrada de Navarro. © Calderón Archina 2025

the entire Aconcagua basin (Crespo et al. 2020; Fundación Plantae 2024). Furthermore, the park forms part of the region's biocultural heritage, shaped by the interaction of geophysical, ecological and cultural processes. This landscape reflects the territorial practices and biocultural traditions of herders and drovers who, for generations, have engaged in transhumance across the cordillera. It also holds high cultural value

for the inhabitants of the Aconcagua Valley, especially Indigenous peoples living in these territories, as well as community and environmental organizations.

The High Andes of Chile are characterized by extreme climatic conditions and unstable substrates, making the distribution and composition of plant communities sensitive to rising temperatures and declining precipitation (Cavieres et al. 2021). Recent studies have examined the dynamics between climatic variables, local water availability and the effective extent of these ecosystems (Marcosig & Liaudat 2021). As a result, the widespread and significant retreat of glaciers and ice bodies caused by climate change (Ferri et al. 2020) presents new hydrological scenarios and challenges for natural resource management and conservation. Within Parque Andino Juncal, one key landscape unit is the *Juncal Norte* Glacier, which in recent years has shown a marked reduction in surface area due to rising temperatures (Dirección General de Aguas (DGA) 2022).

In addition to the biophysical effects of climate change, open-pit mining projects in mountain areas exert further pressure on these ecosystems, as well as on both human and more-than-human communities and the ways of life tied to these environments (Uribe-Sierra et al. 2023). Given the interplay between biodiversity and the cultural diversity of human groups that have long inhabited the Andes, this region has developed a biocultural heritage encompassing a variety of belief systems and worldviews, along with complex ancestral knowledge and practices, such as techniques for managing animals and landscapes (Leguía et al. 2021). Because of its environmental, cultural and affective significance, since 2024 multiple organizations and residents have mobilized to defend Juncal Norte Glacier against the proposed operations of the US-based mining company Nutrex, which has been conducting exploratory drilling near the park since 2017. This illustrates that, despite its RAMSAR designation, areas such as Parque Andino Juncal remain vulnerable in the absence of specific glacier protection legislation and in the face of the legal primacy of subsurface mining rights over conservation rights.

Parque Andino Juncal

In Chile, most protected natural areas are publicly owned and managed by the National Forestry Corporation (CONAF). A smaller proportion consists of private protected areas (APP), such as Parque Andino Juncal in the Valparaíso Region (<https://parqueandinojuncal.cl/>). Officially designated a RAMSAR site in 2010, the park has operated since 2015 as a private conservation area open to the public. It is privately owned by members of the Kenrick family, who decided to carry out a conservation project in the area. They manage the reserve themselves with the help of a small number of rangers and volunteers, and their source of funding is the entrance fee they

charge for access to the park. According to the definition of the International Union for Conservation of Nature (IUCN), a protected area is a clearly defined geographical space, recognized, dedicated and managed, by legal or other effective means, to achieve the long-term conservation of nature and its ecosystem services and associated cultural values. Recently, In Chile, a law regulates state and APPs (Ley 21600). However, this initiative does not have that specific recognition yet. In 2024, it was included in the Top 100 Green Destinations, a ranking that highlights tourist destinations implementing innovative and effective practices for more responsible and sustainable tourism.

The park is in the upper Juncal River basin, one of the main tributaries of the Aconcagua River. Its primary mission is to protect the Juncal watershed. The basin lies in the Valparaíso Region of central Chile (32° 53' S; 70° 08' W), between 2,000 and 5,000 m asl, covering approximately 220 km², of which the park occupies around 137.96 km² – roughly two-thirds of the basin. During the summer and in periods of low precipitation, this glacial system contributes up to 67% of the total flow of the Aconcagua River. It supplies drinking water to an estimated 1.5 million people across the basin, according to the Aconcagua Observatory of Socio-environmental Conflicts, and to approximately 200,000 people through the basin's rural water systems (APR).

The main boundaries of the park are the Juncal River to the west, the Republic of Argentina to the east, and the *Monos de Agua* stream to the south. It lies within the high Andean biogeographic province, recognized for its ecological uniqueness and low representation within Chile's national system of protected areas (Moreira-Muñoz & Troncoso 2014). The climate is dry and arid, with winter precipitation and high diurnal temperature variation, and the landscape includes shrublands, grasslands, rock outcrops, wetlands and glaciers (Zapararte et al. 2022). As shown in Figure 2, Parque Andino Juncal includes wetlands of significant ecological importance such as the *vegas* Los Nacimientos, Mardones and Canchitas, along with smaller ones like La Paz and La Roca. Associated with this, vegetation surveys show that there are around 200 plant species in wetlands and on slopes (Cádiz-Veliz & Muñoz 2025). The site is habitat for a significant group of fauna and flora, including endemic species such as the short-tailed snake (*Tachymenis chilensis*), as well as endangered species such as the matuasto (*Phymaturus flagellifer*) (RAMSAR 2010) and gato andino (*Leopardus jacobita*).

The RAMSAR site Parque Andino Juncal is the only protected area for Andean flora in the Aconcagua River basin and the mountain range of the Valparaíso region. The zonal vegetation is known as *Andean scrub* (Muñoz-Schick et al. 2000). This vegetation belt is distributed along the high slopes of the Andes Mountain range, from approximately 32 degrees to 35 degrees South, starting at an elevation of 2,000 m asl. It has been calculated that this belt is protected on only 2.4%

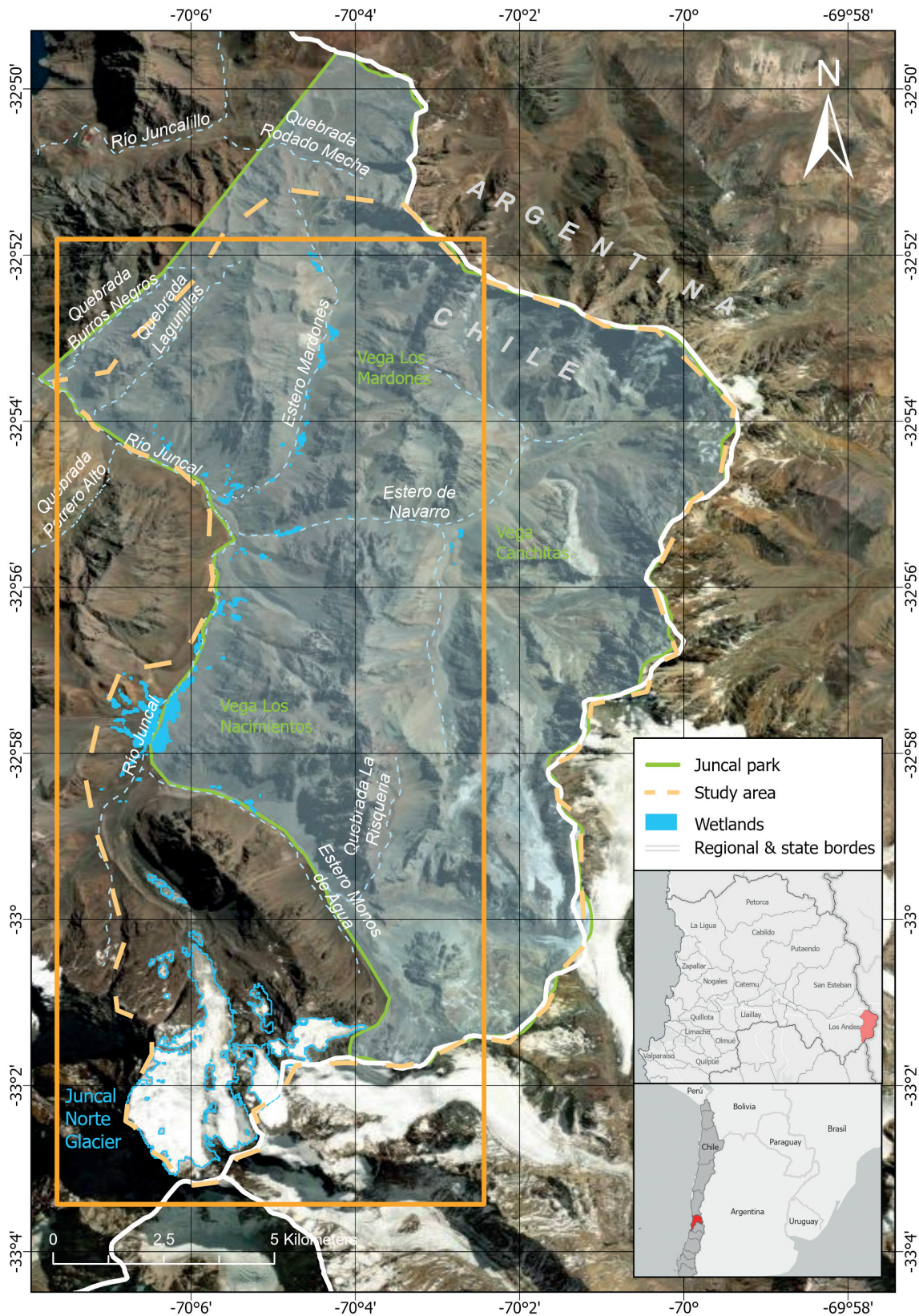


Figure 2 – Parque Andino Juncal, context map. The orange box outlines the excerpts shown in Figure 6. Data base: Esri World Imagery; <https://gadm.org/>. Created by Pablo Mansilla.

of its surface (Luebert & Plischoff 2017). In addition to the mentioned dominant species, other characteristic species are *Mutisia sinuata* Cav., *Mutisia subulata*, *Rhodolirium montanum* Phil., and *Tropaeolum polyphyllum*

Cav., among others. These species are visited by an assemblage of pollinators that includes native species of birds, bees, wasps, butterflies and beetles (Figure 3). Among plant species, there are some interesting cases



Figure 3 – Native and endemic plants and characteristic birds and pollinating insects of Parque Andino Juncal: a) *Alstroemeria parvula* Phil.; b) *Mutisia sinuata* Cav.; c) native bee *Megachile semirufa* Sichel; d) native jewel wasp (*Chrysis* sp.); e) periquito cordillerano, *Bolborhynchus aurifrons* Lesson; f) *Tropaeolum polyphyllum* Cav.; g) *Rhodolirium montanum* Phil.; h) *Chuquiraga oppositifolia* D. Don. © Moreira Muñoz

of restricted endemism that are at the same time considered as endangered, such as *Ivania juncalensis* Al-Shehbaz (Cádiz-Véliz et al. 2022) and *Alstroemeria parvula* Phil (Muñoz-Schick et al. 2011).

The Parque Andino Juncal project combines integrated conservation measures, aligned with the guidelines of the IUCN, with ecological tourism. They apply a passive restoration strategy, that involves the recovery of environments through the elimination of agents

of disturbance, with the aim that the ecosystems will recover naturally. Tourism serves as the primary source of funding, supporting the salaries of park rangers and ongoing maintenance tasks. Parque Andino Juncal remains open from approximately October to April; during the rest of the year, the road and the visitor centre are closed because of winter conditions.

In line with the IUCN approach, the park has established zoning between recovery areas and buffer



Figure 4 – Vegetation types, wildlife and wetland landscape at Juncal Andean Park: a) *Senecio bonariensis*; b) *Calceolaria biflora* and *Werneria pygmaea*; c) *Hordeum comosum*; d) *Tropaeolum polyphyllum*. © Calderón Archina and Leandro Álvarez 2025

zones. The recovery areas include exclusion zones located near the wetlands, designated for passive restoration, where high-Andean wetland vegetation (locally known as *vegas*, see Figure 1) are dominated by species such as we show in Figure 3 and *Carex gayana*. This conservation approach involves physical barriers that restrict access, thereby promoting vegetation regrowth after decades of grazing-related impacts. The buffer zones are concentrated along the main trail leading to the glacier viewpoint and the designated camping area. Notably, a daily visitor cap of no more than one hundred people has been implemented to help control and minimize ecological impact.

Recently literature showed the resilience capacity of wetlands to respond to and recover from various anthropogenic and environmental disturbances (Jacob et al. 2025). Some of these studies highlighted that designing specific strategies, as we describe, helps to build and improve resilience in complex socio-ecological systems such as wetlands and enhances biodiversity conservation (Kopprio et al. 2014; Mustonen & Kontkanen 2019; Reid & Shafiquil Alam 2017).

Geohistorical context

“The place is full of human history”, says Tomás, the administrative coordinator of Parque Andino Juncal. His words encapsulate thousands of years of human presence in the Juncal Valley, beginning with archaeological settlements dating back at least 10,000 years (Planella & Stehberg 1997). However, the site only became more visible and accessible toward the end of the nineteenth century, when the entrepreneurial Clark brothers acquired a concession to construct the ambitious Trans-Andean Railway. This railway connected the cities of Los Andes, Chile and Mendoza, Argentina. It was inaugurated in 1910 and operated until 1984, with intermittent closures due to adverse mountain weather conditions.

In 1911, the British business family Kenrick Lyon purchased the land now comprising the park for commercial purposes, as the railway line passed directly through it. Near the property there operated the Juncal railway station, later renamed Hermanos Clark station, which served as a major operations hub (Lacoste 2013). In July 1984, a landslide destroyed the Chilean



Figure 5 – Juncal Norte Glacier. © Calderón Archina 2025

section of the railway (Urzua 2015). From that point until the early twenty-first century, the land now constituting the park experienced various land uses, including mining and livestock grazing. Specifically, within the current park grounds, a gypsum mine and later a brick factory were established. Today, the former brick kiln functions as a base camp for visitors.

Regarding livestock activities, these represent a longstanding practice dating back to the colonial era, sustained for centuries due to high demand for cattle from Cuyo in Chile's central valley (Michieli 1994; Escolar 1996). The cross-border livestock trade was primarily managed by *baqueanos* and *arrieros*, known for their expertise in mountain navigation and animal husbandry (Escolar 1996). *Baqueanos*, traditionally local scouts or trackers, are highly skilled in navigating rugged terrains, while *arrieros* are muleteers or herders who lead livestock caravans across long Andean routes. A central component of their practice is transhumance, still maintained today, involving the seasonal movement of herds from high-altitude grazing areas in summer (*veranadas*) to lower elevations in winter (*invernadas*), and back again. This cyclical migration allows herders to exploit forage that grows at different altitudes, especially in *vegas* situated near meltwater streams (Hevilla & Molina 2010). For this reason, the wetlands of the Juncal Valley have long been essential summer grazing grounds. Over centuries, *arrieros* have become the most historically established seasonal inhabitants of these inter-Andean valleys.

Grazing in the *vegas* was one of the main challenges the park faced when establishing itself as a protected area. In 2003, when Catherine Kenrick Lyon inherited the property, she initiated substantial changes in land management – a process that took several years. Among the most pressing obstacles were livestock

grazing and hunting. “You could not just tell the *arrieros* not to pass. For them, this is mountain land, and they have always brought their animals here... It was the same with the military and hunters”, explains Martín, head ranger at the park since 2017. Today, thanks to the dialogue built with *arrieros* over the years, a good relationship has been maintained. This agreement allows them to continue bringing cattle to graze near the park during summer, ensuring that the animals do not enter the protected reserve. In some sections, the boundary is marked by fencing, while in others, it is defined by natural features such as the river. When livestock occasionally cross into the reserve, *arrieros* retrieve them promptly. Park staff not only note the respectful collaboration but also highlight the *arrieros*' extensive knowledge of the mountain environment.

Effects of Climate Change on the Juncal Norte Glacier

The results of this study show that multiple processes operate simultaneously at different scales, shaping territorial patterns of degradation (glacial loss) and regeneration (*vega* expansion) in high mountain environments. Across the entirety of Parque Andino Juncal, there has been a sustained 53% decrease in ice cover and a significant 49% expansion of wetlands, particularly in the Los Nacimientos *vega*, which has doubled in surface area with a 58% increase. Specifically, Juncal Norte Glacier (Figure 5) has undergone a sustained 34% reduction in surface area, consistent with previous studies (DGA 2022). At the same time, new pressures have emerged due to the expansion of mining activity at the national level and the resulting social conflicts.

The analysis of glaciers and high Andean wetlands (*vegas*) was conducted using Landsat sensor imagery (TM, ETM+ and OLI) processed via Google Earth Engine – GEE (Gorelick et al. 2017; Amani et al. 2020). For the period 1986–2025, cloud-free mosaics were generated for the austral summer months (December–March), minimizing interference from seasonal snow. Spectral indices were applied to these image composites: NDVI (Normalized Difference Vegetation Index) to identify active vegetation (threshold >0.35) and NDSI (Normalized Difference Snow Index) to delineate glaciers and ice bodies (threshold >0.65) (Marcosig & Liaudat 2021; Zalazar 2023). The resulting layers were vectorized using QGIS 3.0 to quantify surface changes, considering ENSO influence (NOAA data).

Significant changes were recorded in glacial and wetland cover in Parque Andino Juncal between 1986 and 2025. Overall, glaciers progressively lost surface area, while wetlands expanded (Figure 5 & 7). Juncal Norte Glacier experienced a 34% decrease in surface area (from 11.5 km² to 7.6 km²), while the Los Nacimientos *vega* increased in area by 73% (from 43.1 ha to 74.8 ha) (Figure 6). The retreat of Juncal Norte Glacier was pre-

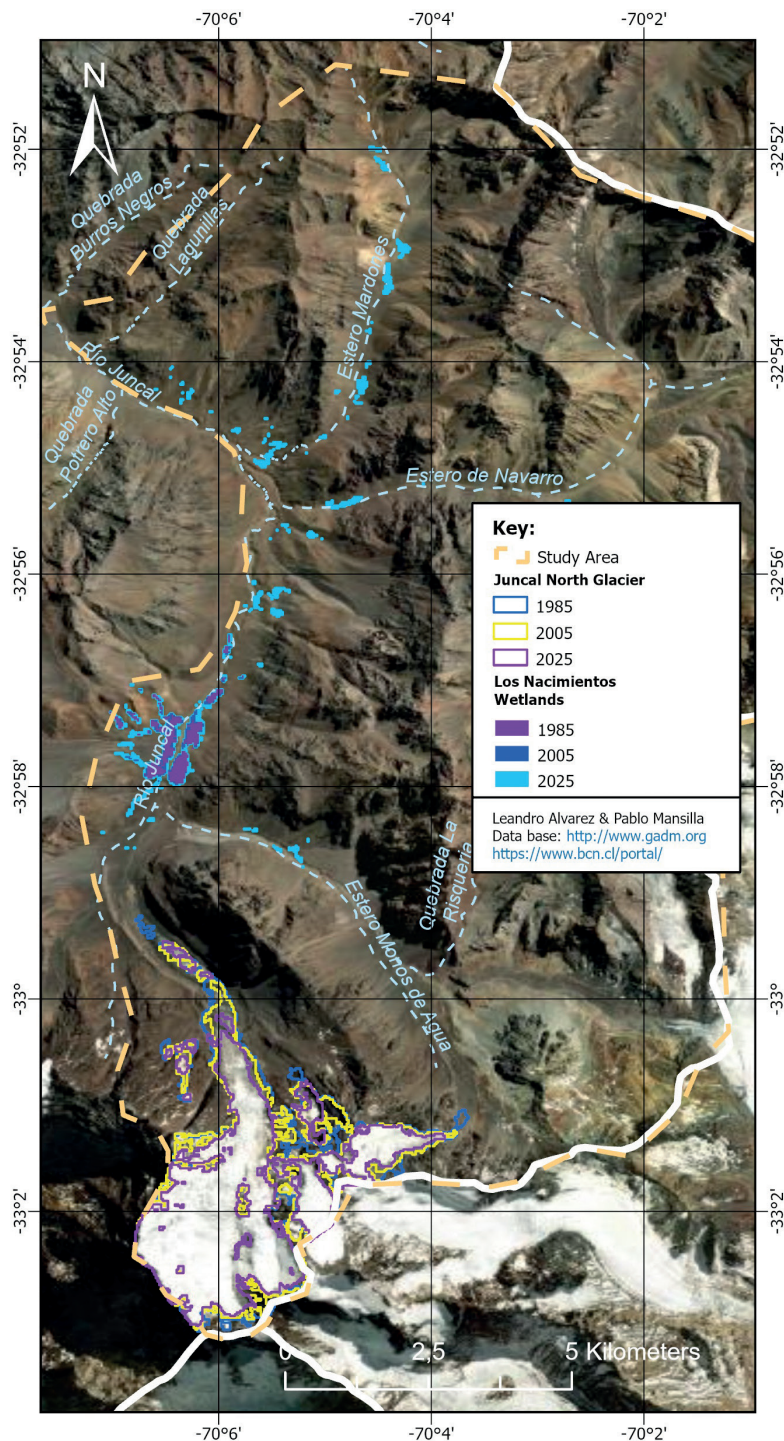


Figure 6 – Spatial dynamics of Juncal Norte Glacier and Los Nacimientos wetlands from 1985 to 2025 within Parque Andino Juncal, Valparaíso Region, Chile. See Figure 2 for the overview of the area.

viously documented by DGA (2022), which reported a 30% loss in glacial mass. These studies also note substantial variability in the advance and retreat dynamics of glaciers in the area. Our findings align with those of Zalazar (2023), who suggests that glacier retreat may increase local water availability, promoting the expansion of adjacent wetlands, which helps explain the sustained growth of Los Nacimientos.

During the initial period (1986–2005), the expansion of *vegas* was closely linked to El Niño events, which brought increased winter precipitation (Marcosig & Liaudat 2021). However, between 2005 and

2025, following the establishment of the protected area, this pattern changed: *Vegas* continued to expand even during La Niña phases, such as that of 2021–2022. This shift is associated both with glacial retreat and with active conservation measures, such as livestock exclusion, which have supported wetland recovery. According to Catherine Kenrick Lyon, maximum temperatures in the park reached 28 °C in January 2025, indicating extreme conditions that also impact these ecosystems. Within this context, the 2023 El Niño event triggered a marked resurgence in *vega* surface area following the previous drought, highlight-

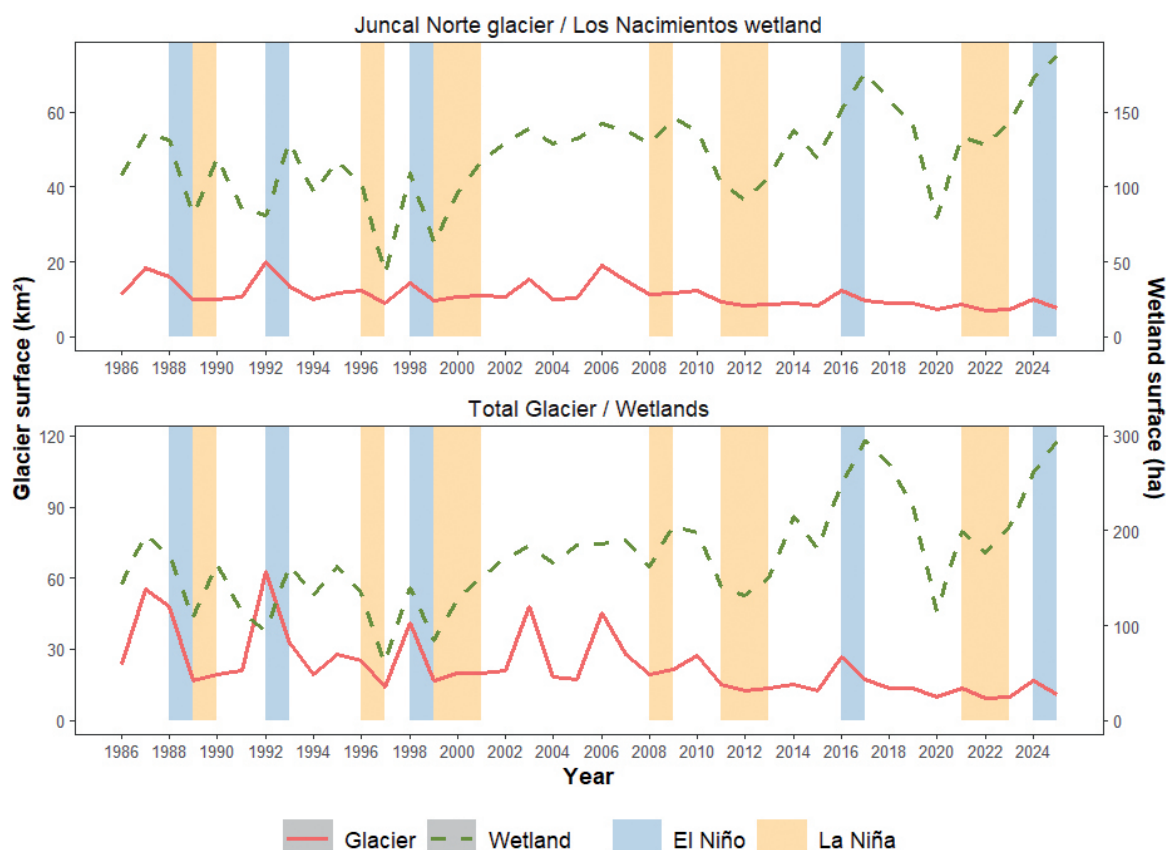


Figure 7 – Time series showing the evolution of glaciers, ice bodies and wetlands (above), and specifically the Juncal Norte Glacier and Los Nacimientos vega (below), for the period 1986–2025. Data source: <https://ggweather.com/enso/oni.htm> / Layers Processing: Leandro Alvarez

ing increased ecosystem resilience as a result of park management practices.

Conflicts over mining extractivism

Since 2017, the mining company Nutrex SpA has sought to establish operations in the Juncal Valley. It began with an exploration project covering approximately 8,000 hectares adjacent to Parque Andino Juncal. In 2023, the company submitted a request for an exploitation concession over the conservation area. The owners of the park appealed the request through legal channels, but the court ruled in favor of the company's continued operations. Faced with the possibility of active concessions and subsequent exploratory drilling, various sectors of civil society mobilized publicly to denounce the damage such activity would cause. The mining claims are located directly on high Andean wetlands and glacier surfaces (Fundación Plantae 2024), which would disrupt watercourses, alter wetland functioning and impact endemic and endangered species such as the Andean cat (*Leopardus jacobita*). Additionally, the project would undermine long-standing biocultural practices, including traditional hiking routes.

At the beginning of 2024, widespread demonstrations took place both in major cities of the Valparaíso

so Region and within Juncal itself in response to the imminent installation of the project (see Figure 8). A large group of activists and residents camped for two weeks at the entrance to the park to block access to the mining personnel. The encampment brought together rural inhabitants, environmentalists, Indigenous communities and academics. Also, present was the *Defensa Aconcagua Coordinating Committee*, a coalition of over 20 socio-environmental initiatives and collectives active in the Aconcagua Basin. Due to the mobilization and resulting public pressure, the company's personnel temporarily withdrew from entering the park. Nevertheless, the project remains active and could resume at any time. Under the current legal framework, mining claims can now be formalized through Geographic Information Systems without the need for physical presence on the land. This may be seen as a strategy to reduce or bypass social mobilization. Even so, the reserve's owners, valley residents and activists remain on high alert in defense of Parque Andino Juncal. It is important to say that, in Chile, legislation establishes that mining concessions are independent from surface land ownership, and in cases of conflict between surface and subsurface uses, mining activity takes precedence.

Private management of High Andean Wetlands in a context of glacial retreat

In a global context of glacial retreat and adverse climatic conditions, the high Andean wetlands of Parque Andino Juncal have undergone significant recovery in recent decades. Notably, Juncal Norte Glacier experienced a sustained 34% reduction in surface area between 1986 and 2025, while the Los Nacimientos *vega* expanded – even during drought years linked to La Niña events – suggesting that resilience mechanisms have been strengthened through protected area management. This case illustrates how private conservation-oriented management can enhance ecosystem resilience under challenging climate scenarios.

A central factor in this recovery has been the exclusion of livestock, alongside active habitat monitoring and protection, which has restored the role of wetlands as ecological refuges while maintaining essential functions such as water provision and carbon sequestration. Additionally, this adaptive management model has supported the return and persistence of emblematic native species such as the Andean cat (*Leopardus jacobita*), puma (*Puma concolor*) and guanaco (*Lama guanicoe*), whose presence has been documented with increasing frequency in recent years.

This case demonstrates that, even on a small scale, APPs can play a crucial role in conserving fragile ecosystems in the face of climate change. The positive outcomes of such management are evident not only in the ecological recovery of wetlands, but also in their strengthened capacity to respond to extreme climate disturbances recently observed. In this way, Parque Andino Juncal serves as a replicable model for adaptive conservation initiatives in other sectors of the Andean cordillera.

It is important to emphasize the park's positive effects and the urgent need to support conservation initiatives in vulnerable ecosystems – especially given the mining company's intent to operate near Juncal Norte Glacier. Although social mobilization has so far prevented mining personnel from accessing the site, the company holds a judicial mandate to proceed. This would directly impact high mountain ecosystems, including *vegas* and stream systems, as well as the plant and animal species that inhabit them – such as the endangered Andean cat. Thanks to the collective resistance of various social actors defending the Juncal River and the Aconcagua Valley – including a two-week encampment at the park entrance and additional actions in Viña del Mar and other urban centres – the mining project was temporarily halted. However, the state of alert continues, as the project may resume once the mining claim is formalized, and currently no measure exists to prevent it apart from the social pressure that began one year ago.



Figure 8 – Park entrance and camping area during the protest in 2024. © Calderón Archina 2025

Founding

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