

## PRACTICE INSIGHTS

# A practical toolkit for wetland management and conservation: Lessons from reclassifying urban land into a protected area

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## Abstract

1. Wetlands are vital for preserving the health of our planet and sustaining both human and wildlife populations, yet they continue to be lost and degraded at alarming rates. In Spain—where over 60% of wetlands have disappeared in the last 50 years—the conversion of urban land into protected wetland is exceedingly rare.
2. This study documents the remarkable case of *Charca de Suárez* in southern Spain, a site once designated for urban development, reclassified in 1999 as a 'Concerted Nature Reserve'. This research compiled a set of tools and strategies used to restore and manage the *Charca de Suárez* wetland, based on 2 years (2021–2023) of input from staff, researchers, managers, volunteers and visitors.
3. The resulting toolkit integrates infrastructure development, hydrological and biological restoration, long-term biodiversity monitoring, adaptive management and environmental education, with a strong emphasis on inclusive community engagement to foster local stewardship of the reserve.
4. Biodiversity outcomes demonstrate significant improvements, especially in populations of threatened bird and butterfly species, confirming the ecological effectiveness of the implemented strategies. The reserve now provides habitat for more than half of Andalusia's threatened species and is currently under consideration for inclusion in the European Natura 2000 network.
5. *Practical implication.* The *Charca de Suárez* case shows that even land once destined for urban development can be turned into thriving wetlands. Its multifaceted management model, combining ecological restoration with community involvement, offers an adaptable framework to guide wetland conservation and inspire recovery efforts worldwide.

## KEYWORDS

*Charca de Suárez*, conservation, management, nature reserve, restoration, wetlands

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## 1 | INTRODUCTION

Wetlands are among the most productive and valuable ecosystems on Earth (Ramsar Convention on Wetlands, 2018). Thus, wetlands provide vital ecosystem services that support both environmental health and human well-being (Valuing wetlands, 2021; Xu et al., 2020). They naturally filter pollutants and sediments, reduce flood risks by absorbing excess rainfall, recharge groundwater supplies and store carbon to help regulate the climate (Zhang et al., 2025). These ecosystems also offer essential habitats for diverse plant and animal species, sustain fisheries and food production, prevent soil erosion and create opportunities for recreation, tourism and cultural activities (Wood et al., 2024). Protecting and restoring wetlands is essential to maintaining these benefits, which are critical to local communities, economies and global ecological stability.

Despite their importance, they are disappearing at an alarming rate three times faster than forests (Ramsar Convention on Wetlands, 2018). The Wet Extent Trends (WET) Index shows an annual loss rate of 0.78%, compared to 0.24% for forests (Food and Agriculture Organization of the United Nations, 2016). Since 2000, the rate has worsened, ranging from 0.85% to 1.60% per year. Between 1970 and 2013, total wetlands in the Mediterranean region declined by 48%—a greater loss than in Africa (42%), Asia (32%) or Europe (35%) (Dixon et al., 2016; UN World Conservation Monitoring Centre, 2017). Since 1700, an estimated 3.4 million km<sup>2</sup> of inland wetlands have been lost—mainly to cropland—supporting evidence from 189 reports that global wetland loss ranges from 54% to 57% (up to 87%), with the most rapid declines since 1900 (Davidson, 2014; Fluett-Chouinard et al., 2023).

The continued loss and degradation of wetlands threaten not only wildlife but also human livelihoods and resilience to climate change. Restoration efforts are essential to recover lost ecosystem services, enhance biodiversity and secure a sustainable future. The United Nations and other international bodies have emphasized the urgency of wetland restoration, calling for immediate action to reverse current trends and protect these vital ecosystems for future generations (Ramsar Convention on Wetlands, 2021).

### 1.1 | A brief historical perspective on Spanish wetlands

In Spain, more than 60% of wetlands have disappeared in the past 50 years (Gallego-Fernández et al., 1999). Gaining a clear understanding of the historical context is crucial for assessing long-term trends, human impacts and the ecological status of wetlands. Until the mid-20th century, wetlands in Spain were heavily targeted by legislation promoting their drainage due to concerns about unsanitary conditions, such as paludism (Sousa et al., 2009). Legislation such as the Water Laws of 1866 and 1879, the Port Law of 1880, and others promoted extensive wetland destruction by granting 99-year ownership to those who converted wetlands into agricultural land (Fornés et al., 2021). This legal framework, combined with the rise

of heavy agricultural machinery, led to a significant destruction of wetlands, including Antela, La Nava, La Janda, the Tablas de Daimiel and the Doñana marshes, among many others (Fundación Global Nature, 2024). The trend of destruction persisted until 1985 when the 1985 Water Law repealed earlier laws, requiring administrative authorization for any actions affecting wetlands, including groundwater. This marked a shift towards recognizing wetlands' natural and scenic value. By 2001, an amendment to the 1985 Water Law expanded requirements to include “sustainable management and recovery” of wetlands. Although draining wetlands remained permitted under specific conditions, public perception began to change (Dobkowski & Cazorla González, 2024).

### 1.2 | Shifting perspectives: From wetland loss to restoration and conservation

Since 2000, European habitat protection has been guided by key directives like the Habitats Directive (Council of the European Communities, 1992; 92/43/EEC). This Directive, alongside the Birds Directive (Council of the European Union, 2009), forms the basis of Natura 2000—the largest coordinated network of protected areas in the world—requiring EU member states, including Spain, to designate and manage Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) for strict and sustainable protection. However, a major milestone in protecting continental waters in Spain and Europe was the 2000 implementation of the Water Framework Directive (WFD, European Parliament and Council, 2000; 2000/60/EC). Although not wetlands-specific, the WFD protects aquatic ecosystems by improving water quality and requires registering protected areas, ensuring wetlands within Natura 2000 receive special consideration. More broadly, the WFD established a comprehensive framework for all water bodies, emphasizing ecological health and sustainable use. Spain adopted the WFD into national law by 2003, shifting from supply-focused to sustainable, integrated river basin management, with goals of achieving “good status” for waters and reducing pollution.

More recently, the Spanish government has proposed the Strategic Plan for Wetlands 2030, aiming to repeal provisions allowing for wetland drainage (MITECO, 2023). This plan seeks to prevent, halt and reverse wetland loss and degradation, ensuring the maintenance of habitats and species, promoting recovery and enhancing the recognition of their ecosystem services. It also aims to fulfil Spain's commitments under the Ramsar Convention on Wetlands and the EU Biodiversity Strategy 2030.

Despite growing conservative awareness, wetland restoration remains challenging due to ecological complexity, difficulties in restoring natural hydrology and pressures from climate change, land use and limited resources. Even with growing experience, many projects still face unclear goals, insufficient monitoring and maintenance shortcomings. Social, legal and economic obstacles persist, making long-term success uncertain. While scientific and practical understanding has advanced, achieving effective and sustainable restoration continues to be a complex and ongoing endeavour. In

particular, the conversion of urban land into protected wetlands is a globally rare and challenging achievement. In Spain, two notable exceptions are *Clot de Galvany* and *Charca de Suárez*—the focus of this study—which stand out as successful cases where heavily degraded urban areas have been transformed into functioning wetlands despite strong development pressures (Salizzoni et al., 2020; Vera González et al., 2015). Our study aims to compile the key restoration actions carried out in *Charca de Suárez* into a practical toolkit intended to serve as a model for other threatened and degraded wetlands worldwide facing intense human pressure.

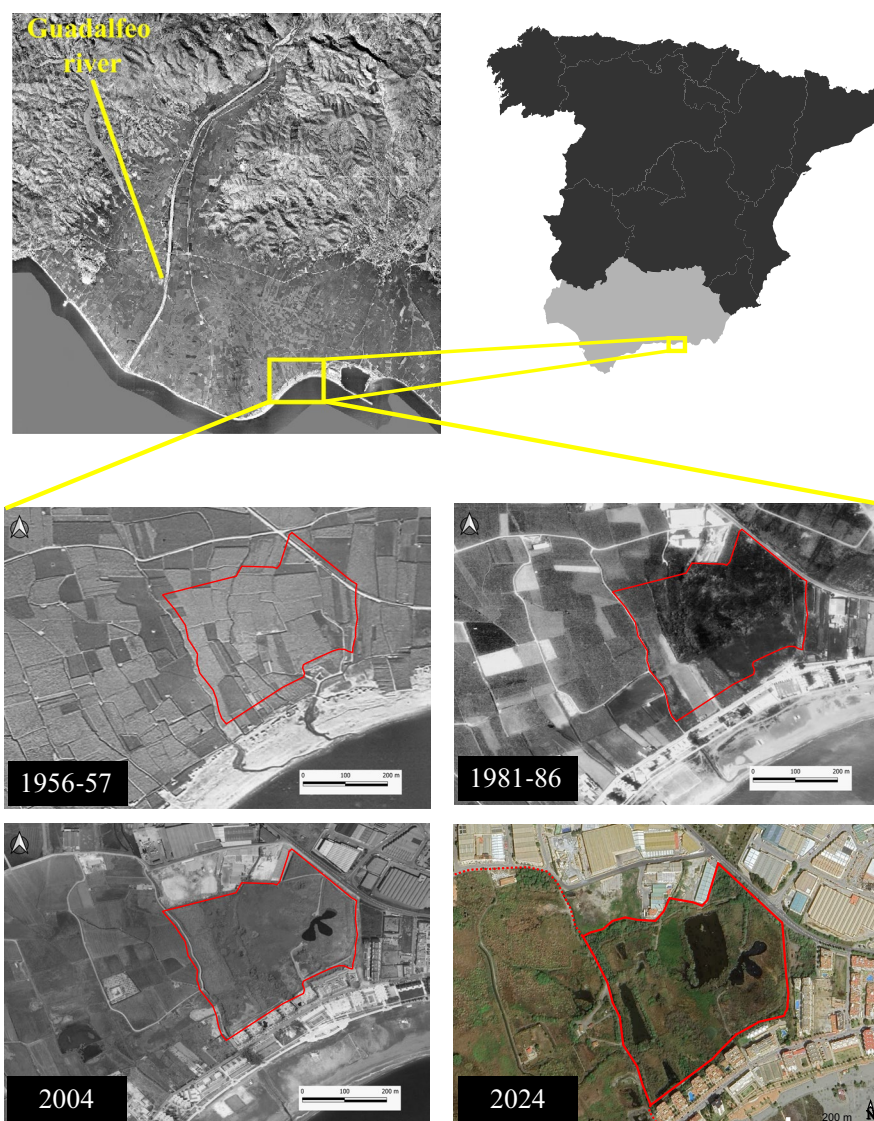
## 2 | MATERIALS AND METHODS

### 2.1 | Study site

*Charca de Suárez*, a key wetland in the *Guadalfeo* River delta, is located on the river's left bank and is separated from the sea by a 150-metre-wide strip of land. This hypogenic wetland is fed

by the *Motril-Salobreña* aquifer, which receives recharge from river infiltration, irrigation and hillside runoff. The water level in the restored wetland is now regulated by floodgates, ensuring near-permanent yet fluctuating water levels (Blanco-Coronas et al., 2020).

Like many Spanish wetlands, it has experienced widespread degradation and now stands as the last remaining area of what was once a vast floodplain (Figure 1; magnified region of the *Guadalfeo* River). The draining of these areas began during the Arab colonization before the 15th century, and by the late Middle Ages, sugarcane was cultivated as a monoculture, a practice that has continued for centuries (Figure 1; 1956–1957). Channels and irrigation ditches were built to manage river floods. In the 20th century, river channelling further restricted lateral runoff and sediment transport. Since 2004, flow is regulated by the nearby *Rules* dam, disrupting the natural sediment transport that sustained the delta against the sea's erosive forces. As a result, the pond now covers just 14.7 hectares, down from over 1000 hectares in the 18th century due to drainage, water diversion and land filling.



**FIGURE 1** Map depicting the location of the studied ecosystem in Spain. The insets of the *Guadalfeo* river delta show a magnification of the *Charca de Suárez* area at different periods, with orthophotos from (a) 1956–1957 (American flight), (b) 1981–1986 and (c) 2004 (National Aerial Orthophotography Plan) retrieved from the *Instituto Geográfico Nacional* database (<https://www.ign.es/web/visualizadores-tematicos>) and (d) 2024 (Google Earth Pro v.7.3.6.9796, March 13, 2024). Solid red lines represent current boundaries of the natural reserve, while the dotted line marks part of the area proposed for future expansion.

*Charca de Suárez* has also faced pressure from urban development; the 1990 Motril urban plan designated it for residential and industrial use (Figure 1; years 1981–1986). Environmental groups like *Buxus* and *Agnaden* protested the draining efforts, halting development. In 1996, the municipality began the process to declare *Charca de Suárez* as a 'Concerted Nature Reserve', a status officially granted in 1999—making it Spain's rare case of land reclassification from urban to protected status. The wetland has been partially restored through basin re-excavation (Salizzoni & Pérez-Campaña, 2019) and is currently pursuing recognition within the European Natura 2000 Network to enhance its protection (Figure 1; years 2004 vs. 2024). Although protected, the reserve remains vulnerable to coastal development, notably the proposed 'Marina Playa Granada' with over 750 yacht moorings. Promoted as eco-friendly, the project threatens to isolate the reserve, compromising its ecological connectivity and long-term viability.

Since its protection, the biodiversity and ecological health of this natural area have improved, making it one of the most important biodiversity refuges in southern Europe despite its small size (Salizzoni & Pérez-Campaña, 2019). Covering only 14.7 hectares, the wetland hosts approximately 250 vertebrate species, many of which are rare or threatened. Notably, around 200 birds have been recorded in the area (Cabrerizo & Villar-Argaiz, 2025), including 51 species listed as threatened in the Andalusian Red Book, such as the crested coot (*Fulica cristata*), which is part of ongoing reintroduction efforts (Cordero-Ayuso, 2022) and is classified as critically endangered in Europe (BirdLife International, 2021). *Charca de Suárez* provides vital breeding and refuge habitats for amphibians and reptiles facing habitat loss elsewhere. It also plays a key role as an essential stopover for migratory birds from Europe and Africa, offering resting and feeding opportunities during their seasonal journeys. In addition, the reserve supports a few threatened plant species, with *Zannichellia contorta*—endangered in Spain—as the most significant, and other locally important but less threatened species like *Cladium mariscus* and *Sparganium erectum* (Lista Roja de la Flora Vascular de España, 2023).

## 2.2 | *Charca de Suárez* governance

The wetland is one of the only five natural areas in the Spanish region of Andalusia designated as 'Concerted Nature Reserves'. This protection category, unique to the region and introduced in Law 2/89, applies to areas not meeting criteria for other protection statuses but still needing special measures (MITECO, 2023). Local landowners, like Motril City Council for *Charca de Suárez*, must request this status through a collaboration agreement with the Andalusian Council of Environment (Florida Trujillo & Lozano Valencia, 2005). At *Charca de Suárez*, the local government sets objectives and actions based on broader regional and national plans. The management committee, made up of Motril's Environmental Department staff, implements these actions (Salizzoni & Pérez-Campaña, 2019). A joint monitoring committee, consisting of six

members from the Andalusian Environmental Agency, Motril City Council and local associations, evaluates management effectiveness twice a year (Cordero-Ayuso, 2022). This governance model ensures protection even during political changes (Salizzoni et al., 2020).

## 2.3 | Toolkit for hands-on management

The management methods implemented in *Charca de Suárez* can be grouped into two main categories. The first involves assembling a comprehensive toolkit of key measures that have contributed to the successful restoration of the ecosystem. The second—detailed below—focuses on the temporary monitoring of key indicator species, such as birds and butterflies, among others, used as proxies for assessing ecosystem health, alongside basic physicochemical water monitoring.

For the first category, this study made a substantial effort to document and describe the full array of approaches and tools implemented to support the restoration, sustainable use and restoration of the *Charca de Suárez* wetland. Over a period of 2 years (2021–2023), knowledge and practices were gathered from a diverse group including permanent staff, researchers, site managers, volunteers and visitors. This collaborative effort aimed to capture the specific techniques and experiences developed to address the complex interconnections among ecological, economic and social factors influencing wetland environments. By compiling and integrating these approaches, the study offers a comprehensive, adaptive and participatory framework for wetland management—intended to serve as a valuable model for preserving ecological integrity and guiding wetland conservation efforts in other regions. Table 1 outlines key aspects of hands-on management successfully implemented at *Charca de Suárez*, with potential for replication and adaptation in similar wetland contexts.

### 2.3.1 | Waterbird monitoring survey

On a monthly basis, waterbird censuses were conducted at each lagoon using fixed-point observations. Surveys took place in the early morning, when bird activity is typically at its peak, using binoculars (Bushnell Trophy 10×42 magnification, UK; Pentaflex 8×42 magnification, Pentax, Japan) and a telescope (Kowar Prominar TSN-773, TE-11WZII 25–60× wide eyepiece, Japan). At each observation point, all waterbird species observed or heard over a period of 45 min were recorded, along with the number of individuals.

### 2.3.2 | Butterfly monitoring survey

Butterfly monitoring followed the standardized methodology developed by Pollard and Yates (1994), which consists of walking along

TABLE 1 Summary of actions and effective management strategies implemented in *Charca de Suárez*.

| Areas of focus  | Management strategies                                                                                                                           | Specific actions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Infrastructure  | Facilities for educational or tourist activities                                                                                                | <i>Educational observatories</i> with folding windows, recycling bins, netting and bench-table sets<br><i>Visitor center</i> with solar-powered energy, reception hall, exhibition space, education center, library and administration office<br><i>Rest area</i> with shade, tables and benches<br><i>Public toilets</i> with litter bins<br><i>Butterfly garden-house</i><br><i>Coastal garden</i> featuring native species<br><i>Efficient low-intensity, low-consumption lighting at the entrance/exit area</i><br><i>Graphic signposting</i> with distance indicators, travel directions, maps, meeting points, points of interest, emergency exits, usage rules and interpretation panels for reserve species and features<br><i>Elevated open-air observatory</i> built from dredged material |
|                 | Facilities for scientific activities                                                                                                            | <i>Restricted-access scientific observatory</i> via an elevated walkway camouflaged in vegetation<br><i>Laboratory and animal recovery center</i><br><i>Botanical garden</i> with enclosures and natural fauna<br><i>Semi-natural experimentation area</i><br><i>Greenhouse</i> serving as a nursery and seed bank for plant species                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                 | Infrastructure for wildlife                                                                                                                     | <i>Artificial resting sites</i> in mid-wetland island<br><i>Perches</i> made from local materials of varying thicknesses<br><i>Birdhouses</i> providing safe nesting sites for birds<br><i>Waterers</i> for dry seasons<br><i>Insect hotels</i> providing shelter and nesting sites for various beneficial insects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                 | <i>Eco-friendly construction:</i> Recycled materials and selected colours, volumes, textures and locations that respect the natural environment |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Soil resources  | Basin remodelling                                                                                                                               | Creation of new water bodies (planning, soil surveys and field inspections)<br>Excavation of accumulated sediments, fill material and reshape the basin<br>Application of substrates (e.g. sand, sediment) and soil amendments<br>Installation of ditches and stop-logs to regulate water levels                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Water resources | Hydrological connectivity                                                                                                                       | <i>Restoration and maintenance of irrigation channels and ditches:</i> (i) Removal of circulation obstacles through sediment dredging and excess vegetation removal, (ii) construction of drainage gates, (iii) remodelling of channel morphology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                 | Water quality                                                                                                                                   | <i>Monthly assessments (biweekly during emergencies) of water quality:</i> physicochemical parameters and biological indicators<br><i>Water renewal:</i> Regulation of channel gate aperture                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                 | Water quantity                                                                                                                                  | <i>Monitoring wetland and groundwater levels</i> using piezometric gauges<br><i>Water level maintenance:</i> Supply water via channel redirection or well pumping if levels drop, and close channel gates to prevent water inflow if levels rise                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Flora           | Macrophytes                                                                                                                                     | <i>Biomass control:</i> Physical methods, such as manual removal and selective extraction of target vegetation<br><i>Reutilization of plant waste:</i> Composting through stacking or covering with crushed plant material<br><i>Restoration of threatened hydrophytes:</i> Translocation and cultivation of hydrophytes, either indirectly in acclimatization ponds or directly in new water bodies                                                                                                                                                                                                                                                                                                                                                                                                 |
|                 | Algae                                                                                                                                           | <i>Physical methods:</i> Manual removal with nets<br><i>Ecological methods:</i> Shading watercourses by planting along waterways                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                 | Trees                                                                                                                                           | <i>Maintenance:</i> Control of collapse risk, irrigation, pruning, replacement of losses and staking<br><i>Natural regeneration:</i> Do not remove dead trees, as their remains provide organic matter and facilitate nutrient recycling<br><i>Plantings:</i> Planting native deciduous species to create heterogeneous groves                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                 | Allochthonous species                                                                                                                           | <i>Eradication of isolated cases:</i> Removal of individual plants with a manual saw, followed by replacement with native species<br><i>Eradication of entire populations:</i> (i) Removal of cane ( <i>Arundo donax</i> ) and areas invaded by tall grasses through mechanical clearing of the site; (ii) Increase in reed ( <i>Phragmites australis</i> ) plantings; (iii) Control of helophytes (e.g. <i>Typha domingensis</i> ) through manual cutting at the rhizome level; (iv) Shading with blankets as early response strategy for small invasive plants; (v) Introduction of competitive species like bur-reed ( <i>Sparganium erectum</i> ) and yellow iris ( <i>Iris pseudacorus</i> )                                                                                                    |

(Continues)

TABLE 1 (Continued)

| Areas of focus                  | Management strategies               | Specific actions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Wildlife                        | Regular population monitoring       | <p><i>Birds</i>: Banding sessions, capture with invisible nets, and release; monthly surveys and observations along transects</p> <p><i>Herpetofauna</i>: Monthly censuses of key amphibians (Southern frog–<i>Hyla meridionalis</i>) and reptiles (Common chameleon–<i>Chamaeleo chamaeleon</i>; Grass snake–<i>Natrix natrix</i>)</p> <p><i>Fish</i>: Biweekly sampling of endangered species (Fartet–<i>Aphanius iberus</i>) using traps</p> <p><i>Butterflies</i>: Semiannual sampling of daytime species and monthly sampling of nocturnal species using UV light traps and sheets to attract insects</p>           |
|                                 | Rehabilitation programs             | <i>Injured wildlife</i> : Collaboration with the endangered species recovery center (CREA) and periodic veterinary assistance. Presence of the Greek tortoise ( <i>Testudo graeca</i> ) in semi-freedom at the botanical garden                                                                                                                                                                                                                                                                                                                                                                                          |
|                                 | Captive breeding and reintroduction | <i>Endangered species</i> : Introduction and monitoring of the Crested coot ( <i>Fulica cristata</i> ) and the Fartet ( <i>Aphanius iberus</i> )                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                 | Prevention                          | Informational posters and campaigns on the negative effects of introducing non-native species. Installation of small mesh nets in the canal connecting to the sea                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                 | Monitoring                          | Daily control and detection of exotic individuals or populations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                 | Capture                             | Use of trapping methods, selective hunting or electric fishing                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                 | Sanctions                           | Fines for individuals introducing non-native species                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                 | Adoptive parents program            | Adoption of animals by individuals who commit to not releasing them into the wild                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                 | Euthanasia                          | Referral of animals to specialized centers for euthanasia                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Science and adaptive management | Adaptive Management                 | Decisions based on research and scientific knowledge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                 | Shared governance                   | Involvement of multiple stakeholders in maintenance and decision-making                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                                 | Collaboration                       | Partnerships with universities, vocational centers, scientific institutions, public bodies, private companies, organizations, associations and individuals                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                                 | Space Sustainability                | Long-term processes with broad participation, wealth distribution and environmental protection                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                 | Urban Resilience                    | Multifunctional land providing various ecosystem services                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                 |                                     | Redundancy and modularization for backup functions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Social-cultural                 | Environmental education             | Adaptive co-management designed as a continuous learning experiment                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                 |                                     | Biological and social diversity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                                 |                                     | Multilevel planning and governance with a decentralized, participatory approach                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                                 | Ecotourism                          | <i>Outreach on cross-cutting aspects</i> : (i) <i>Ecological</i> –functioning of food chains, organic waste recycling, ecosystem services, biodiversity concepts and local species examples; (ii) <i>Cultural</i> –customs and lifestyles related to the floodplain, traditional plant uses and linguistic origins of ecosystem elements; (iii) <i>Historical</i> –evolution of floodplain agriculture and social involvement in space protection; (iv) <i>Social</i> –sustainable development, mental health, urban planning and environmental issues from invasive species, water pollution and climate change effects |
|                                 |                                     | <i>Creation of outreach materials</i> : Leaflet, brochures, bird and vertebrate guides, educational activity booklets, poetry books featuring birds and informational panels                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                 |                                     | <i>Educational programs</i> : (i) Formal programs for students in educational centers; (ii) Non-formal programs for tourists through guided visits and awareness campaigns for the local community                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                 |                                     | <i>Time restrictions</i> : Limited access during the breeding season of endangered species (March–May)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                 |                                     | <i>Access restrictions</i> : Zoning into reserve areas, regulated public use areas and freely accessible public areas                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                 | Social inclusion                    | <i>Guided tours</i> : Awareness and outreach for pre-booked groups                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                 |                                     | <i>Carrying capacity</i> : Maximum group size of 25 people                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                                 |                                     | <i>Mandatory conduct rules</i> : Explanation of access rules provided by monitors and signage at the start of the tour                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                 |                                     | <i>Linguistic diversity</i> : Information translated into English.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                 |                                     | <i>Functional diversity</i> : (i) <i>Reduced Mobility</i> –Wide, flat paths for wheelchair access, handrails and high benches for support; short circular routes; (ii) <i>Visual impairment</i> –Self-guided itinerary with audio explanations from QR code scans; availability of binoculars and telescopes for birdwatching during guided tours                                                                                                                                                                                                                                                                        |
|                                 |                                     | <i>Economic diversity</i> : Free access and guided tours                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                                 |                                     | <i>Academic diversity</i> : Methodology and program information adapted to the interests and knowledge levels of students at different educational stages: primary, secondary, vocational, adult education and university                                                                                                                                                                                                                                                                                                                                                                                                |
|                                 |                                     | <i>Gender diversity</i> : Equal representation of males and females in all management bodies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                 |                                     | <i>Neurodiversity</i> : Specialized programs with easy-to-understand information (pictograms, images and drawings) and visit anticipators                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

TABLE 1 (Continued)

| Areas of focus | Management strategies | Specific actions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|----------------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                | Citizen participation | <p><i>Volunteer activities:</i> Tasks include monitoring, planting, facility maintenance, cleaning paths and channels, removing <i>Typha</i> sp. and <i>Ceratophyllum demersum</i> from ponds, preparing cane for crafts, conducting herpetofauna censuses and photography</p> <p><i>Initiatives for emotional connection:</i> (i) "The Forest of Life" project; (ii) "The Pool of the Senses" program; (iii) Poetic signs related to specific birds and species identification panels with watercolour drawings; (iv) Documentary graphic archive; (v) Animal of the Month feature; (vi) Special events for environmental commemorations; (vii) Silence Experiment; (viii) Sharing personal anecdotes during visits</p> |

fixed routes (transects) several times during the growing season. In our study, biweekly surveys were conducted from March to October along two transects: CS1 (1.12 km) and CS2 (1.37 km). During each transect, all adult butterflies of each species observed within a standardized area—2.5 m on either side of the transect line, 5 m ahead and 5 m above—were counted while walking at a steady pace. Species identification, when needed, was done using a butterfly guide for Spain and Europe (Tolman & Lewington, 2011). Wildlife monitoring was conducted without the need for special fieldwork authorization, in accordance with Decree 23/2012 of the Regional Government of Andalusia.

### 2.3.3 | Physicochemical monitoring

Temperature, pH, dissolved oxygen and salinity were measured using a multiparameter pocket probe (PCSTestr-35, Eutech, Thermofisher, USA). Inorganic nutrients (phosphate, nitrate and nitrite) were analysed using standard protocols for freshwater samples (APHA, AWWA, WEF, 2017).

## 3 | RESULTS AND DISCUSSION

*Charca de Suárez* wetland offers a valuable example of how targeted management interventions can facilitate the recovery of degraded or threatened wetlands. The primary goal of this work is to identify and document the key measures that have successfully contributed to the recovery of this site since its protection in the early 21st century. Today it stands as a biodiversity hotspot, supporting a notable share of the region's ecological richness. This study highlights the key measures implemented since the site gained protected status in the early 21st century, emphasizing their role in fostering ecological resilience. The transformation of *Charca de Suárez* into a regional biodiversity hotspot underscores the effectiveness of these strategies and suggests their potential applicability to similar wetland systems facing environmental pressures. Table 1 highlights the main components of the hands-on management approach applied at this wetland, each of which is discussed in detail below. Additionally, Figure 2 presents photographs illustrating various management actions carried out at the site.

### 3.1 | Infrastructure

The constructions at *Charca de Suárez* focus on minimizing waste by emphasizing reuse and recycling, embodying a circular economy that conserves materials and reduces production costs (Ogunmakinde et al., 2021). Infrastructure choices—such as materials, colours, volumes, textures and locations—are designed to minimize environmental impact (Cole et al., 2021). A 2-meter-high metal perimeter fence surrounds the reserve, supplemented by dense vegetation to reduce noise pollution. Inside, a network of paths features compacted earth for easier access by pedestrians, bicycles and maintenance vehicles. Low-intensity, low-consumption lighting is installed at key points like entrances and exits (Madrona Moreno et al., 2010). The facilities supporting educational, outreach and tourist activities include: observatories, visitor centre, laboratory and animal recovery centre, rest areas, restroom facilities, gardens, butterfly house, greenhouse and graphic signages. Wildlife-specific structures at *Charca de Suárez* include wooden perches for birds, nest boxes for birds and bats, seed feeders and bird drinkers and insect hotels for nesting (Table 1).

### 3.2 | Soil and water resources

To restore *Charca de Suárez*, excavation reshaped their basins and created new water bodies (Madrona Moreno et al., 2010). The shallow water table allowed groundwater to flood the area (Blanco-Coronas et al., 2020). However, managing the dredged sediments, which are voluminous, complex in contaminants and highly moist, poses challenges (Cai et al., 2021). At *Charca de Suárez*, the sediments were piled up to create a plateau for elevated observatories, and sand substitutes to form sinuous shorelines and expand interior islands, providing refuges for birds and reptiles (Salizzoni & Pérez-Campaña, 2019; Solanki et al., 2023). Additionally, these structures help mitigate wind-induced erosion and preserve habitats (Solanki et al., 2023). To ensure the effective functioning of wetlands, it is essential to maintain uncontaminated water resources (Cai et al., 2021). Enhancing hydrological connectivity—both structurally and functionally—is key to achieving this (Meng et al., 2020). Structural connectivity involves maintaining and restoring the network of irrigation ditches and embankments that ensures continuous water flow (Meng et al., 2020). Many of these elements are cultural



**FIGURE 2** Photos of the *Charca de Suárez* illustrating various management actions: (a) wildlife observatory, (b) creation of new water bodies by excavation and reshaping with dredged sediments, (c) water channels and embankments, (d) manual removal of macrophytes, (e) bird perches, (f) water quality monitoring, (g) guided tours. Photos© E. Bautista Herruzo.

heritage features that have deteriorated due to neglect (Toja, 2017). Restoration efforts in this wetland included removing obstacles to water circulation, such as dredging sediments and clearing excessive vegetation, constructing manholes or gates, and reshaping channels to connect all water-regulated areas (Cai et al., 2021; Madrona Moreno et al., 2010).

Functional connectivity is achieved by managing water quality and quantity (Meng et al., 2020). Water quality is monitored monthly (biweekly during emergencies) based on parameters set by the Andalusian Wetlands Management Program (Madrona Moreno et al., 2010), including visual characteristics, physico-chemical metrics (e.g. pH, conductivity, temperature, oxygen levels, nutrients, heavy metals, pesticides) and biological indicators (e.g. chlorophyll-*a*, bacteria, macroinvertebrate and macrophyte indices) (Blanco-Coronas et al., 2020). Over the course of the year, the mean surface water temperature ranges from 14.5 to 27.2°C

in winter and summer, respectively, in the reserve's channel network, and from 16.0 to 30.4°C in the permanent lagoons. The pH varies between 7.8 and 8.5 in the channels and between 8.0 and 9.3 in the lagoons. Conductivity ranges from 835 to 1677  $\mu\text{Scm}^{-1}$  in the channels and from 910 to 1900  $\mu\text{Scm}^{-1}$  in the lagoons. Mean minimum-to-maximum salinity ranges between 0.50 and 0.56  $\text{g L}^{-1}$ ; dissolved oxygen varies from 3.63 to 11.20  $\text{mg L}^{-1}$ ; phosphate ranges between 0.5 and 5  $\text{mg L}^{-1}$ ; and combined nitrate plus nitrite concentrations range from 0.22 to 2.30  $\text{mg L}^{-1}$  (*Charca de Suárez*, unpublished data). Collectively, these parameters indicate moderate water quality with relatively high nutrient levels, likely from surrounding land and irrigation inputs.

The hydrological functioning is closely linked to the presence of irrigation channels and underground wells (boreholes). Today at least one main canal crosses the reserve from north to south, feeding flood-prone areas, recharging the aquifer and maintaining

the moisture for local vegetation and wildlife. These irrigation channels are also used to recirculate water into the main lagoons at *Charca de Suárez* when inorganic nutrient concentrations are high, serving as a management strategy to control and prevent algal blooms that can lead to massive eutrophication and other associated impacts, such as species mortality. Water regimes are monitored using piezometric gauges in water bodies and wells (Madrona Moreno et al., 2010) and controlled by canal gates (Meng et al., 2020). In emergencies, if levels drop significantly, water is redirected from canals or pumped from wells (Meng et al., 2020); if levels rise excessively, gates are closed to prevent surface water entry (Blanco-Coronas et al., 2020). Although there is ongoing debate about modernizing the irrigation system by piping canals to improve agricultural efficiency, ecologists and scientists agree on the importance of the traditional water system for maintaining the hydrological and ecological balance of the reserve (Blanco-Coronas et al., 2020).

### 3.3 | Flora

The dominant macrophytes in *Charca de Suárez*—including riparian (e.g. *Salix purpurea* and *neotrichia*), emergent (e.g. *Typha* sp., *Phragmites* sp.), submerged (e.g. *Ceratophyllum demersum*) and floating species (e.g. *Lemna* sp.)—play vital roles in water purification, oxygen production and nutrient and contaminant absorption (Cai et al., 2021; Kurniawan et al., 2021). However, their rapid growth in nutrient-rich waters can obstruct light, impede water flow and disrupt nutrient circulation (Alam et al., 2021), requiring regular maintenance (Madrona Moreno et al., 2010). At *Charca de Suárez*, physical removal of these rapidly growing plants is favoured over chemical and biological methods, with the harvested biomass being reused for animal feed, biochar, biofuels and organic fertilizers, thereby supporting a circular economy approach (Kurniawan et al., 2021). Also, composting excess vegetation boosts soil fertility and biodiversity while reducing groundwater pollution (Amuah et al., 2022; Ayilara et al., 2020). In *Charca de Suárez*, composting is conducted by stacking surplus macrophytes or covering them with shredded plant material, producing natural fertilizer (Ayilara et al., 2020). Restoration techniques focus on replanting submerged macrophytes (e.g. *Potamogeton pectinatus*, *Ceratophyllum demersum*) to act as natural filters (Cai et al., 2021; Rodrigo, 2021; Yanran et al., 2012). Eutrophication, a recurring issue, is addressed through ecological strategies like shading watercourses with plants like *Tamarix canariensis*, and replanting species like *Iris pseudacorus* that help absorb excess nutrients. *C. demersum* helps control eutrophication through allelopathic compounds that suppress phytoplankton and cyanobacteria (Dong et al., 2019). It also offers spawning and shelter sites for fish, while its foliage and fruits serve as a key food source for birds. However, excessive growth can harm biodiversity by outcompeting other plants and causing anoxia. To prevent this, surplus *C. demersum* is regularly removed manually in *Charca de Suárez* and subsequently used for compost production.

### 3.4 | Wildlife

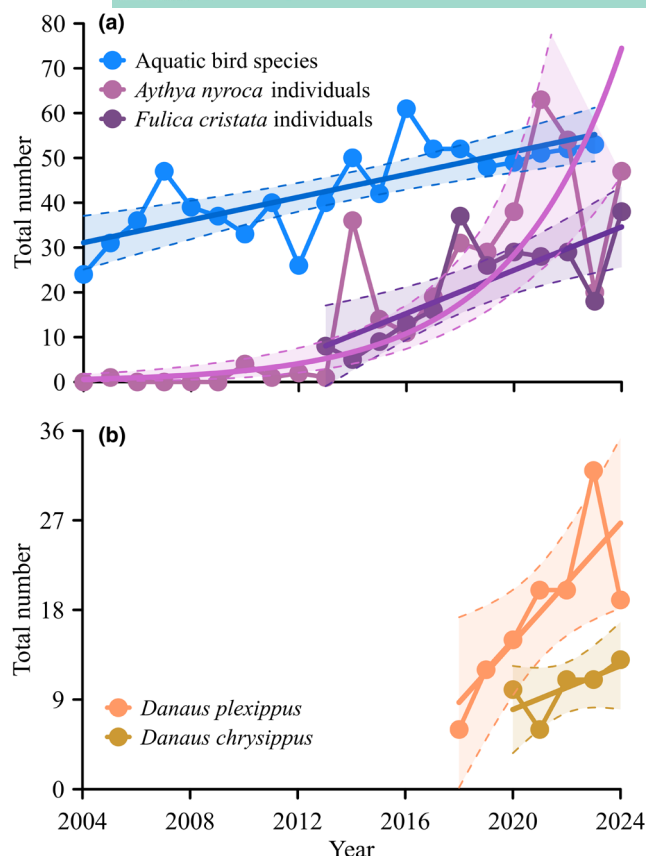
Wildlife monitoring at *Charca de Suárez* aims to understand species distribution, ecology and phenology for better conservation (Cordero-Ayuso, 2022). Methods include bird ringing and monthly bird transects, herpetofauna censuses of flagship amphibians (e.g. *Hyla meridionalis*) and reptiles (e.g. *Chamaeleo chamaeleon*, *Natrix natrix*), biweekly fish sampling of threatened species (e.g. *Aphanius iberus*) and biannual butterfly surveys using ultraviolet light (Cordero-Ayuso, 2022; Madrona Moreno et al., 2010). Specific programmes include wildlife rehabilitation (Willette et al., 2023), endangered species reintroduction (Cordero-Ayuso, 2022) and invasive species control (Madrona Moreno et al., 2010) (Table 1).

Long-term censuses of birds and butterflies at *Charca de Suárez* provide strong evidence of the wetland's progressive ecological recovery since its designation as a protected area in the early 21st century. Since 2004, we have observed a consistent increase in the total number of waterbird species recorded at *Charca de Suárez* ( $R^2=0.55$ ,  $p<0.001$ ; Figure 3). This upward trend is especially significant in two critically endangered and protected species: the ferruginous duck (*Aythya nyroca* Guldensadt, 1770;  $R^2=0.68$ ,  $p<0.0001$ ) and the red-knobbed coot (*Fulica cristata* Gmelin, 1789;  $R^2=0.55$ ,  $p<0.01$ ). A positive trend was also observed in butterfly populations, particularly for the plain tiger (*Danaus chrysippus* Linnaeus, 1759;  $R^2=0.45$ ,  $p=0.21$ ) and the monarch butterfly (*Danaus plexippus* Linnaeus, 1759;  $R^2=0.64$ ,  $p<0.05$ ), although the former did not reach statistical significance (Figure 3).

Biodiversity records at *Charca de Suárez* include 189 birds, 48 aquatic plants, 25 mammals, 22 diurnal butterflies, 19 filamentous protists, 18 reptiles, 8 amphibians and 5 fish (Figure 4). Of these, a substantial proportion—ranging from 13 species in butterflies to 72 species in birds, and up to 83% in reptiles—are classified as critically endangered, vulnerable or listed under conservation concern. In summary, the long-term monitoring efforts have revealed significant increases in species richness and population abundance, indicating that conservation measures have been effective in restoring the wetland's natural balance. The consistent upward trends documented by these censuses underscore the positive impact of sustained protection and habitat management on the wetland's biodiversity.

### 3.5 | Science and adaptive management

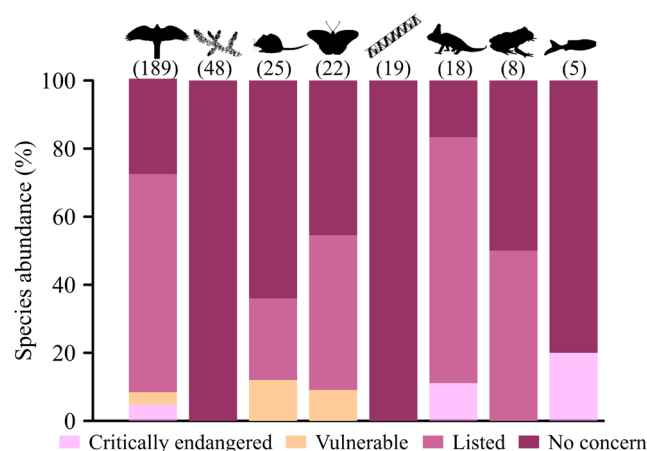
At *Charca de Suárez*, adaptive management is used to address problems while learning from actions taken (Westgate et al., 2013). This approach involves: (1) exploring options, (2) weighing their pros and cons, (3) implementing actions, (4) monitoring results and (5) adjusting the plan based on outcomes (Westgate et al., 2013). It enhances understanding of ecosystems by studying key organisms as indicators of ecological processes (Aspizua et al., 2010) and stressors (Birge et al., 2016) and allows flexible responses to changes and uncertainties (Ahern, 2011; Toja, 2017). Examples in *Charca de Suárez* include: (i) recirculating water through channels to renew lagoon



**FIGURE 3** Temporal trends in (a) the abundance of aquatic bird species *Aythya nyroca* and *Fulica cristata* and (b) the butterflies *Danaus plexippus* and *Danaus chrysippus*. Data points represent individual census records, with fitted regression lines shown for each species (*A. nyroca*:  $R^2=0.68$ ,  $p<0.001$ ; *F. cristata*:  $R^2=0.55$ ,  $p<0.01$ ; *D. plexippus*:  $R^2=0.64$ ,  $p<0.05$ ; *D. chrysippus*:  $R^2=0.45$ ,  $p=0.21$ ). Shaded areas indicate 95% confidence intervals.

water, reduce residence time and prevent eutrophication, in line with legislation (RD 47/2022, 2022); (ii) controlled pond experiments on the impact of *Gambusia affinis* on native *Aphanius iberus*, with preliminary results (Medina-Sánchez, pers. comm.) recommending limiting *G. affinis* to protect *A. iberus*; (iii) periodic re-excavation of certain lagoons to promote a variety of microhabitats supporting species with different ecological needs (e.g. waders, diving birds); (iv) installation of nest boxes to support insectivorous birds and bats for mosquito control; (v) creation of aquatic corridors and use of channel gates to connect habitats and maintain optimal water levels; (vi) establishment of submerged vegetation microzones and resting areas for fish and amphibians; and (vii) visitor restrictions during breeding periods to protect sensitive species like the horned coot.

*Charca de Suárez* also employs co-management, involving stakeholders like workers, residents, visitors and students in decision-making and conservation activities (Alikhani et al., 2021). Participants gain practical skills, education or project experience, fostering shared responsibility for the area (Mojica Vélez et al., 2018). This network supports essential activities like monitoring and maintenance (Salizzoni & Pérez-Campaña, 2019). Collaboration with



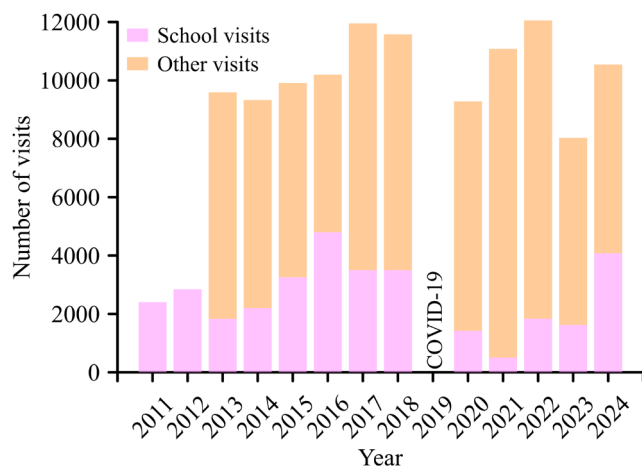
**FIGURE 4** Abundance of major animal and plant groups at *Charca de Suárez*. From left to right: birds, aquatic plants, mammals, butterflies, filamentous protists, reptiles, amphibians and fish. Classification of birds, mammals, amphibians, reptiles and fish follows the Andalusian Catalogue of Flora and Fauna, while butterflies are categorized based on IUCN criteria. Numbers in brackets represent the total number of species recorded for each group at the site. Silhouette images are sourced from PhyloPic.

universities, agencies and other entities through agreements enhances knowledge-sharing and sustainable management (Cordero-Ayuso, 2022). The focus is on resilience (Mojica Vélez et al., 2018), allowing the reserve to recover from disturbances without losing its core functions (Ahern, 2011). Key resilience strategies include multifunctional land use, adaptive co-management design and a multilevel planning and governance characterized by a less hierarchical, decentralized participatory approach (Ahern, 2011; Salizzoni et al., 2020).

### 3.6 | Social-cultural

#### 3.6.1 | Environmental education and ecotourism

The site also plays a key role in environmental education and ecotourism, with an average of approximately 10,000 visits annually (Figure 5). Of these, 20%–50% are educational visits by primary, secondary and university students, while the remainder comprises tourists and members of the local community. Environmental education has been a key focus at *Charca de Suárez*, promoting understanding of environmental issues and the relationship between society and nature (Hernández Salas et al., 2020). Topics cover ecology (food webs, recycling, ecosystem services, biodiversity), culture (customs, plant uses, linguistic origins), history (agricultural evolution and community involvement) and sustainability (urban planning, invasive species, climate change) through interactive learning (Martínez Castillo, 2007). Educational materials, available online and on-site, include brochures, poetry books, guides, workbooks and information panels (e.g. <https://medioambiente.motril.es/medio-ambiente/charca-de-suarez/laminas-de-aves-de-la-rnc/>).



**FIGURE 5** Annual number of visits to *Charca de Suárez* from 2011 onward, categorized into school visits and other types of visits.

Activities led by trained monitors are divided into two types: formal programs, designed for schools and institutions, lasting 2–3 h with customized materials, and non-formal programs, aimed at tourists and locals, lasting about 1.5 h, focused on raising environmental awareness.

The designation of *Charca de Suárez* as a protected area has increased tourism. While ecotourism aims to protect landscapes, it can still cause issues like waste and erosion, highlighting the need for regulation (Agüera, 2014). Visitors can access the wetland freely or in groups with time and area restrictions. Guided tours, limited to 10–25 participants, require reservations. Capacity limits are based on previous reports, and conduct rules are enforced to ensure responsible behaviour (Madrona Moreno et al., 2010). Following these regulations can benefit the local economy and support conservation efforts (Alikhani et al., 2021).

### 3.6.2 | Social inclusion

To enhance participation opportunities, it is important that the “space is open to everyone” by ensuring accessible infrastructure, information and support services (Gupta & Vegelin, 2016). *Charca de Suárez* promotes social inclusion through several initiatives: linguistic, accessibility, economic, educational, gender, neurodiversity (Table 1).

### 3.6.3 | Citizen participation

Volunteering fosters community engagement in conservation, with activities like monitoring, planting and maintenance, allowing individual and group participation (Cordero-Ayuso, 2022). The “Friends of Charca” group requires just one annual commitment, encouraging involvement. *Charca de Suárez* promotes place attachment—emotional bonds with the location (Cole et al., 2021)—through initiatives

such as: Forest of life, *Charca* of the senses, poetic signage, documentary archive, animal of the month, silence experiment, personal anecdote stories or special events.

## 4 | CONCLUSIONS

Any conservation policy that excludes people is bound to fail. *Charca de Suárez* stands as an exceptional example of how citizen participation, led by a motivated group, transformed a once devastated area into a biodiverse oasis. The nearby town of Motril, the second biggest city in Granada province, has developed a strong sense of connection and belonging to the wetland, viewing it as part of their territory for both locals and tourists to enjoy. This local stewardship contrasts with other reserves, where the connection feels diffuse and less personal. Involving residents in habitat protection is key to ensuring the reserve's future. This study aims to raise awareness about protecting this site and provides a toolkit of essential management strategies for other degraded wetlands.

### AUTHOR CONTRIBUTIONS

Manuel Villar-Argaiz, Eva Bautista Herruzo and Marco J. Cabrerizo conceived the study, conducted data collection and analysis and drafted the manuscript with input from José Larios Martín and Alicia Cordero. All authors contributed to the interpretation of results and reviewed and approved the final version of the manuscript.

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### CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

### PEER REVIEW

The peer review history for this article is available at <https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.70119>.

### DATA AVAILABILITY STATEMENT

Wildlife data are publicly available at <https://doi.org/10.5281/zenodo.15860692> (Cabrerizo & Villar-Argaiz, 2025).

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