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Deurbanizing for conservation and adapting: framing ecological restoration as a nature-based solution in La Pletera salt marsh, Catalonia (Spain)

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Tackling climate change and biodiversity loss are two of the great global challenges of the 21st century. The nature-based solutions (NbS) approach creates an opportunity to meet efforts on the two agendas while producing other co-benefits beyond climate resilience and biodiversity conservation. This opportunity becomes even more relevant in areas with both high climate vulnerability and special interest for conservation. Coastal wetlands in the Mediterranean basin are under severe threat from urban sprawl, mass tourism and climate change. Coastal lagoons, dune systems and halophilic ecosystems are considered as priority habitats of community interest for conservation by the European Habitats Directive. In the Catalan coast, these ecosystems are fragmented and isolated, and ecological protection and restoration efforts are essential. In this context, the present work analyzes the case of de-urbanization and ecological restoration of La Pletera salt marsh by the Life Pletera project (2014–2018), interpreting it within an NbS approach and assessing its effectiveness as a strategy for climate adaptation and biodiversity conservation. The analysis brings insights for the effectiveness assessment of the project during the first years after implementation, gathers elements on the factors and constraints that made its implementation possible and reflects on future challenges so that its effectiveness is lasting in the medium and long term.

KEYWORDS

nature-based solutions, ecological restoration, ecosystem services, climate change, wetlands

1 Introduction

The climate emergency is one of the major global challenges in the 21st century. Given its ecological and socio-economic complexity, both climate adaptation and mitigation efforts require coordinated action at different decision-making levels (Ostrom, 2014). Since the Paris Agreement, in 2015, the European Union (EU) has advanced in implementing its climate policy. In 2019, the EU launched the European Green Deal outlining an action plan that commits EU countries to reducing greenhouse gas emissions by at least 55% by 2030 and achieving emission neutrality by 2050 (European Commission, 2021a). Furthermore, the European Commission urged member states to build a climate-resilient Europe by adopting a new adaptation strategy. These commitments were reaffirmed by the economic recovery plan for the COVID-19 pandemic (Next Generation EU), allocating 30% of funds to climate change mitigation (European Commission, 2021b).

Concurrently, the nature-based solutions (NbS) approach has gained traction over the past decade among the strategies to address both climate mitigation and adaptation challenges (European Commission, 2021c). Essentially, NbS are solutions that tackle social challenges by drawing inspiration from or using ecosystems' processes and functions (Chausson et al., 2020). The NbS approach critiques the hegemony of hard engineering solutions, arguing that they are often expensive, require frequent maintenance and provide benefits solely to humans (Seddon et al., 2020). Once the interactions within biological communities and between these and the abiotic environment are the basis of an ecosystem function, promoting an NbS potentially converge towards biodiversity conservation agenda objectives (Pörtner et al., 2023).

Within the spectrum of NbS, ecological restoration is an important strategy that can align both climate and conservation goals (Sowińska-Świerkosz and García, 2022). In 2021, the European Biodiversity Strategy set goals and guidelines for 2030, involving protection and restoration of threatened ecosystems across the continent (European Parliament, 2021). In June 2024, the European Parliament approved the Nature Restoration Law, which set targets to restore at least 20% of terrestrial and aquatic ecosystems by 2030 (European Parliament, 2024).

Despite the rapid expansion of NbS literature, there is still a scarcity of studies presenting frameworks and criteria to classify and provide guidelines for NbS implementation (Sowińska-Świerkosz and García, 2022). One of the first documents proposing specific and detailed criteria is quite recent: the IUCN Global Standard for NbS, published in 2020 (IUCN, 2020). The literature is also relatively scarce in evidence on effectiveness of NbS based on implemented case studies (Chausson et al., 2020). In this sense, it is essential to monitor and assess key ecosystem parameters in order to correlate the impacts of the NbS on the structure and functioning of the ecosystem, and also the expected improvement in targeted ecosystem services and biodiversity gains (Seddon et al., 2020). Experimental and modelling analysis, using different tools (e.g., remote sensing; machine learning) and methods (e.g., simulations; statistical correlations) have been demonstrating how interventions in ecosystem's morphology, topography, land cover, community composition etc. might be effective NbS targeting water management goals, such as reducing flooding risks and controlling erosion process (Pirone et al., 2024; Lense et al., 2023; Espinal-Giron et al., 2023; Tan et al., 2023; Ascenso et al., 2021; Lama et al., 2021; Wu et al., 2018).

There are an increasing amount of evidence on the potential of created and/restored ponds and wetlands as NbS for climate resilience and beyond (Cuenca-Cambronero et al., 2023; Bartrons et al., 2024). It is estimated that 35% of global halophytic marshes have already been lost (Pendleton et al., 2012), which is the reason why several habitats associated with this ecosystem type are classified as priorities for conservation under the European Habitats Directive (92/43/EEC).

In the Catalan territory, La Pletera salt marsh represents one of the last examples of such an ecosystem. Besides its importance for biodiversity conservation, La Pletera also provides a range of ecosystem services relevant for climate adaptation and presents both aesthetic and recreational values for human populations (Pueyo-Ros et al., 2018b). La Pletera salt marsh is located on the northern coast of Catalonia (Spain) and was restored by two European Life projects. The first in 1999–2002 (Life Ter Vell-Pletera, LIFE99NAT/E/006386) and the second in 2014–2018 (Life Pletera, LIFE13 NAT/ES/001001). In particular, the latter is an emblematic demonstration project of de-urbanization and ecological restoration on the Catalan coast, focusing on a highly valuable ecosystem type threatened by human pressure, mainly mass tourism and climate change (Pueyo-Ros et al., 2018a). In this context, the present paper considers the ecological restoration of La Pletera salt marsh as an NbS case study. The paper describes the adjustments in the ecosystem structure and the conservation measures taken during its implementation and discuss how it could be related to improved cultural and regulating/maintenance ecosystem services. To do so, we adapted criteria from the literature to interpret the restoration project as an NbS and used technical reports, related scientific literature and focus group as data sources. The results and insights might be integrated in future NbS effectiveness assessments.

1.1 Nature-based solutions, ecological restoration and ecosystem services

The first mentions of NbS date back to the late 1990s, but it was only from 2009 onwards that the approach gained widespread attention, promoted by multilateral institutions such as the World Bank and the International Union for Conservation of Nature (IUCN) (Potschin and Haines-Young, 2016; Blesh and Barrett, 2006). The approach gained prominence in the scientific and policy communities from 2015 onwards, when it was adopted as a guiding strategy in EU R&D programs (European Commission: Directorate-General for Research and Innovation et al., 2020).

The NbS approach is more a practical one than theoretical, linking science, policy, and practice in a direct manner (Kabisch et al., 2017). On the one hand, the term "solution" implies a problem, a social challenge to be addressed (Potschin and Haines-Young, 2016). On the other hand, the adjective "nature-based" highlights that ecological systems are the reference organizing the solution design. A widely used definition is presented by the European Commission "(…) actions that simultaneously address environmental, social, and economic challenges, maximizing benefits provided by nature (…) inspired, supported, or copied from nature" (European Commission, 2022).

Climate resilient cities are using the nature-based approach in their designs (Lafortezza et al., 2018). There are a wide range of urban challenges that NbS can address by: mitigating urban heat islands, moderating flood and storm surge sensitivity, treating wastewater, creating green spaces that enhance the psychological well-being of local populations, among others (Frantzeskaki, 2019; Mexia et al., 2018). In coastal zones, NbS implemented in critical areas such as the coastline, mangroves, and marshes are crucial actions to minimize population and infrastructure vulnerability to sea level rise, storm surges, marine intrusion and storms (Lindoso et al., 2023; Blackwood et al., 2022; Meulen et al., 2022; Sanchís and Ibáñez, 2024).

Some authors argue that where NbS are technically feasible, they are preferable to grey infrastructure solutions once they are relatively inexpensive, have low maintenance costs, and entail multiple benefits for both human systems and ecosystems (Anderson et al., 2022; Seddon et al., 2020). However, in densely urbanized areas where adequate space for maintaining a functional ecosystem is scarce, it may be more appropriate to formulate solutions that combine grey infrastructure and NbS (Chausson et al., 2020; Sowińska-Świerkosz and García, 2022).

Ecological restoration strategies emerge as an NbS approach. Ecological restoration involves recovering biological communities and

ecological functions of an ecosystem that existed prior to disturbance (Carlucci et al., 2020; Engst et al., 2016). This outcome can be achieved through reintroducing key species, facilitating natural recolonization processes, and making structural interventions in landscape morphology (Quintana et al., 2018a; Chazdon and Guariguata, 2016; Rodrigues et al., 2009). Ecological restoration potentially enhances functional traits linked to Ecosystem Services (ES) (Carlucci et al., 2020).

The concept of ES has been widely used to describe the benefits, both direct and indirect, that ecosystem functioning provides to human populations (Costanza et al., 1997). The Millennium Ecosystem Assessment (MEA, 2005) highlights the ES approach as a bridge between the environment and human well-being. According to the latest classification of the Common International Classification of Ecosystems Services (CICES v. 5.1), they can be classified into three major categories: (i) provisioning services (products obtained from ecosystems); (ii) regulation and maintenance services (ways ecosystem structure can mediate and moderate environmental aspects that impact human well-being, as health, safety and comfort); (iii) cultural services (non-material outputs of ecosystems that influence human psychological and physical well-being) (Haines-Young and Potschin, 2018).

Biodiversity and ecological processes are the pillars from which ES emerge (Potschin and Haines-Young, 2016). Despite advancing the analytical integration of society and nature—both in political and scientific debates—the ES approach has been criticized for its utilitarian perspective, emphasis on ecosystem economic valuation within a flow-stock logic, and its limited openness to social science approaches, worldviews and values other than economics (Díaz et al., 2018).

Since 2017, the Nature's Contributions to People (NCP) approach has been promoted by the International Platform on Biodiversity and Ecosystem Services (IPBES) as complementary to the ES concept (Pires et al., 2020). The concept of NCP, in general terms, is similar to that of ES: it analyzes the benefits nature provides to people and classifies these benefits into corresponding categories (NCP materials, non-materials, and regulatory). However, the approach goes further and aims to expand the epistemological and ontological boundaries of understanding the human–nature relationship, which is seen bidirectional way and beyond a utilitarian perspective (Díaz et al., 2018). It also seeks to include social science approaches and non-scientific forms of knowledge (e.g., indigenous knowledge) (Dean et al., 2021; Kadykalo et al., 2019). While acknowledging the criticisms that originated the NCP approach as pertinent, this study adopts in the following discussion the more widely-used term "ecosystem service" to refer to the benefits that ecosystems provide to people.

2 Materials and methods

2.1 The case study

The salt marsh of La Pletera is located in the municipality of Torroella de Montgrí, on the northern coast of Catalonia (Figure 1). It covers 63 hectares, bordered by agricultural fields to the west, a residential urban area to the north, the Mediterranean Sea to the east, and the Ter river to the south. La Pletera is part of the Natura 2000 Network and it is within the Montgrí, Illes Medes, and Baix Ter Natural Park, created in 2010.

The local climate is Mediterranean. The autumn is the rainiest season (October has the highest average precipitation), while the driest months correspond to summer (July with the lowest average precipitation). The salt marsh hydrology is irregular, characterized by episodic flooding with long periods of confinement. Flooding events are mainly determined by marine storms and heavy rains (Geoservei, 2016; Menció et al., 2017; Meredith et al., 2022a, 2022b). The low topographical level of the marsh compared to its surroundings favors drains and concentrated the surface runoff from rainfall towards it. The biological community is adapted to the high hydrological irregularity, high soil salinity, and long periods of anoxia during confinement periods (Bou et al., 2018; Cabrera et al., 2019; Quintana et al., 2021; Badosa et al., 2006).

During flooding events easterly winds—locally known as "llevant"—prevail and are responsible for sea storms (locally called "llevantada") associated with coastal flooding. When these produce waves higher than 3 meters, they can breach the dune barrier and flood the salt marsh (Pascual, 2020). The seasonal rise in sea level during the autumn and the winter months can sum up to the sea-origin floods. When heavy rains coincide with sea storms, more significant floods occur. According to Martinoy and Pascual (2004), between 1966 and 2003, 145 flood episodes were recorded: 116 (80%) linked to marine storms and 47 (30%) associated with heavy rains (> 50 mm). Out of these, flooding resulting from the combination of both occurred on 18 occasions. The frequency of floods during this period varied from 1 to 8 episodes per year, with years with 3–4 episodes being more frequent.

La Pletera marsh is vulnerable to several human pressures and to climate change. Its proximity to the sea and high dependence on meteorological conditions make it susceptible to changes in sea level and precipitation patterns. At the same time, the La Pletera area has high recreational value (Pueyo-Ros et al., 2018b). Tourist and resident visits (especially during summer) exert pressure on the habitats and biological communities of the marsh (Quintana et al., 2018b).

The area of La Pletera was partially urbanized in the late 1980s, when a first block of houses was built and the urban infrastructure for five more blocks was implemented (Quintana et al., 2024). The economic crisis in real-estate sector that followed the Barcelona Olympic games (1992) postponed the construction of the remaining blocks. After a long period of paralysis and legal disputes over land expropriation, a consortium of civil society stakeholders and the local government implemented two projects funded by the European Life program (Quintana et al., 2018b). The projects aimed to restore the ecological functionality of the salt marsh and to improve the quality of its ecosystem services, including climate services and protection against extreme weather (Gispert et al., 2021). The first one was the Life Ter Vell-Pletera project (1999–2003), during which only a few, but important interventions, were made, notably the creation of a new lagoon belt. The second one was the Life Pletera project (2014–2018) which made major restoration interventions, consisting in the removal of urban infrastructure (breakwater, paved streets, road accesses and filling material dumped into the salt marsh). The latter project interventions will be the core of analysis of the present work.

2.2 Analytical framework

To classify the ecological restoration of La Pletera salt marsh as a nature-based solutions (NbS), the present study employs a set of criteria suggested in the literature, in particular adapting the framework presented by Sowińska-Świerkosz and García (2022). In order to do this, we converted the framework in guiding questions and

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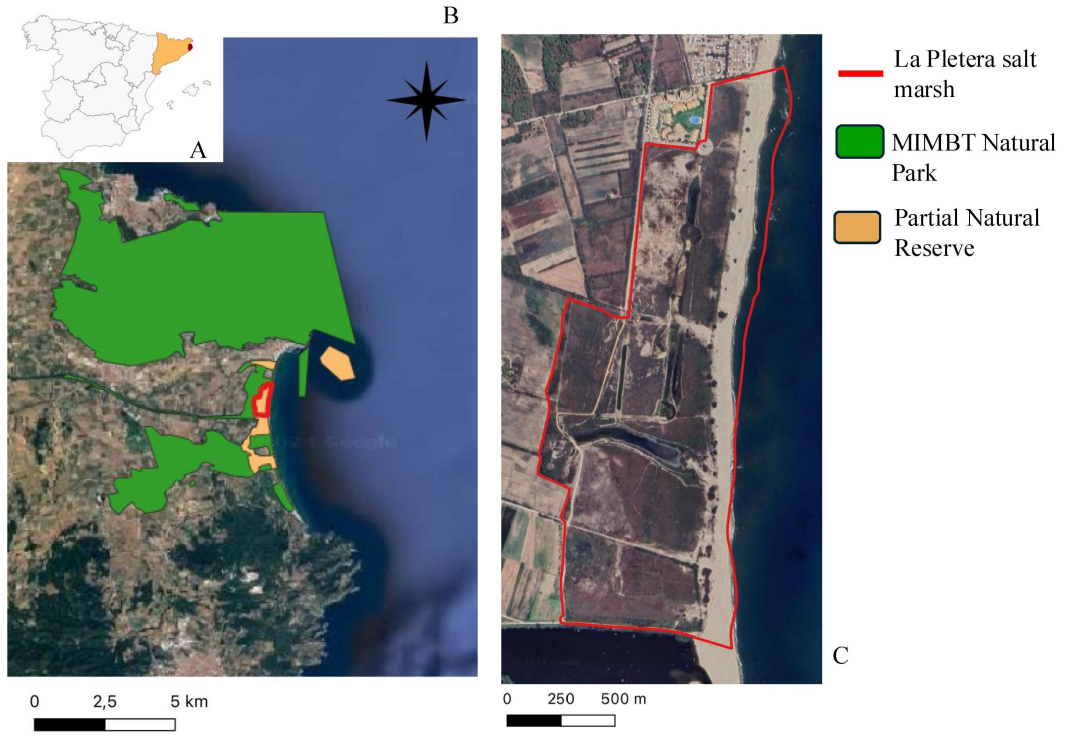

FIGURE 1
(A) Case Study (red) location in Spain (grey) and in Catalonia (orange). **(B)** The La Pletera salt marsh's location within the Montgrí, les Illes Medes and el Baix Ter (MIMBT) Natural Park's mosaic of protected areas. **(C)** The La Pletera salt marsh's limits (red line) and its surrounds. *North*: urban area; *East*: Mediterranean sea; *South*: Ter river; *West*: crop fields.

applied them using the information available in the Life Pletera project reports (Life Pletera, 2018a) and on the related scientific literature produced afterwards (Table 1). In addition, the socio-political dimension of the NbS implementation was analyzed by information collected in two focus groups involving 28 institutional stakeholders, among which: entrepreneurs linked to the tourism sector; members of the local civil society (some of whom participated directly or indirectly in the social, political, and scientific mobilization that enabled the Life projects) and governmental stakeholders related to the management of the Natural Park. The first focus group was conducted in November 2021 and the second one in November 2022. Both took part under the PONDERFUL project. Table 1 summarizes the guiding questions and the source of the information used. Even though the secondary data available are not enough for a conclusive assessment on the NbS' effectiveness, it allows a discussion on the related restoration's impacts on both the ecosystem structure and functions, as well on the social and political process underlying its implementation.

TABLE 1 **Guiding questions adapted from the literature and the information sources used for describing the Life Pletera restoration project as an NbS.**

Guiding questions	Information source
Is it Inspired by nature?	• Technical reports
Does it respond to societal challenges?	• Technical reports
Does it provide multiple benefits?	• Technical reports • Related scientific literature
Is it cost-effective?	• Technical reports
Is it ecological effective?	• Technical reports • Related scientific literature
Is it social effective?	• Related Scientific literature • Focus groups
Is it political effective?	• Related Scientific literature • Focus groups
Is the scale of project appropriate to the stated societal challenge?	• Technical reports • Related Scientific literature

3 Results and discussion

3.1 Inspired by nature and response to societal challenges

A first aspect to be considered to classify an intervention as an NbS is the formulation of clear and *a priori* goals related to one or more societal challenges to be tackled (Dumitru and Wendling, 2021). The Life Pletera project (2014–2018) meets this criterion, explicitly setting as a main goal restoring the ecological functionality of the salt marsh in response to climate change challenges (sea level rise and increase in frequency/intensity of sea storms) (Life Pletera, 2018b).

Regarding the premise of being nature-inspired, it implies that the intervention should promote living and functional ecosystems, which

excludes certain strategies such as biomimetics or those benefiting from natural processes but not relying on ecosystems, such as wind or solar energy production (Sowińska-Świerkosz and García, 2022). In this sense, the scope of an NbS may involve (i) subtle or minimal interventions, such as legal protection of a target ecosystem, (ii) management approaches with some degree of intervention in an existing ecosystem (iii) extensive and structural interventions, such as ecological restorations and the creation of new ecosystems (Eggermont et al., 2015; Ryfisch et al., 2023).

The restoration of La Pletera salt marsh encompasses measures covering all these categories. In the La Pletera Life project (2014–2018), a first set of actions consisted of extensive and structural interventions, especially in the stages of de-urbanization and expansion of the permanent and semi-permanent lagoon system (Quintana et al., 2018a; Martinoy and Pascual, 2018). These actions eliminated all built urban infrastructure, and the land topography—raised during urbanization—was lowered to its original level. Artificial lagoons—totaling 21—were created and organized in parallel bands to the beach, emulating the natural structure of a coastal marsh. Many of them were constructed with their deepest points expressly located below sea level, ensuring permanent inundation in their deepest zones, even during dry years. Additionally, the two natural lagoons were restored. A second set of measures was the restoration of the dune ridge. Sand traps were installed to retain sand for dune formation and stabilization (Roig-Munar et al., 2020). The ecosystem improvements will be assessed in the following sections.

3.2 Source of multiple benefits

Another key criterion in classifying an intervention as an NbS is the production of multiple benefits beyond the targeted social challenge, in all ecological, economic, and social dimensions, balancing trade-offs among them (Sowińska-Świerkosz and García, 2022). In particular, an NbS should represent an effective gain in biodiversity and have positive effects on improving human well-being (European Commission, 2021c). Previously to the Life Pletera project, 34 habitats were identified within the 63 ha comprising the salt marsh. Half of this area was covered by habitats considered of interest under the European Habitats Directive (92/43/EEC), three of which are classified as of priority natural habitat (coastal lagoons, Mediterranean salt steppes, and wooded dunes) (Bou et al., 2018).

During the Life Pletera project, a detailed inventory of habitats was conducted, collecting information on species composition and conservation status. In parallel, actions such as the removal of ruderal vegetation and the restoration of the original topography allowed the gradual recolonization of pioneer species of halophilic vegetation typical of coastal marshes (Bou et al., 2018). In addition to this, the expansion of lagoon and dune habitats mentioned earlier was carried out. Within the vertebrate community, special attention was given to the Spanish toothcarp (*Aphanius iberus*), an endemic fish species of Mediterranean coastal systems whose original distribution area extended from northern Catalonia to the southern coast of Spain (Gonzalez et al., 2018). The species conservation has suffered significant setbacks due to habitat loss and fragmentation as well as competition with invasive species (Sgarzi et al., 2020). La Pletera salt marsh hosts one of the last populations of *A. iberus* on the Catalan coast, which increases the ecological value of the salt marsh (Pou and Cruset, 2018). Therefore, the creation of new lagoons with depocenters below sea level aimed to expand the habitat and create refuges during the confined period of the lagoons, enhancing the adaptive capacity of the Spanish toothcarp population to the irregular hydrological regime.

In addition to *A. iberus*, the salt marsh also hosts other significant species, mainly birds and invertebrates. It serves as a stopover for migratory birds traveling between Europe and Africa during spring and autumn, as well as an important breeding area for resident species such as the Kentish plover (*Charadrius alexandrinus*) (Quintana and Marí, 2004). The species nests on the ground and is threatened by habitat degradation. La Pletera salt marsh is one of the last locations in Catalan territory where it breeds (Riera and Riera, 2004). Moreover, aquatic fauna (both, invertebrates and vertebrates) include a rich representation of brackish Mediterranean species (Quintana and Marí, 2004), which was highly reduced due the human pressure over their habitats. Among the interventions promoted by the Life Pletera project are actions aimed at reducing the pressure of human recreational use on these habitats. For example, signage and recreational infrastructure in the area were improved, including demarcation of routes with ropes and signs to restrict visitors circulation in sensible areas.

Furthermore, as a natural coastal landscape, the salt marsh has scenic and recreational value. As a natural space, it serves as an educational tool on environmental topics. Also, it has economic value for nature-based tourism activities (Quintana et al., 2018b). Optimizing these intangible ecosystem services was also targeted by the restoration projects. The delimited trails are used by residents and tourists for various sports activities, walking pets, accessing the beach, and as a social meeting point and leisure area (Pueyo-Ros et al., 2018b). The paths also cross different habitats and feature observation points for fauna/flora, including a bird observatory built from previous urban infrastructure (Life Pletera, 2018a). Additionally, the routes were marked with informative signs about the ecological importance of observed fauna and flora, as well as information about the de-urbanization process. Pueyo-Ros et al. (2018b) assessed the uses and perceptions associated with the salt marsh de-urbanizing and restoration. The authors identified tranquility as the most valued aspect by users of the space. The authors also identified that improved sensory landscape (visual, sound, and olfactory), birdlife, and proximity to the beach added significant aesthetic value accordingly with the visitors.

3.3 Economic cost and funding governance

The effectiveness of NbS is context-specific and encompasses various aspects: adequacy to local ecological conditions, technical feasibility, social acceptance, bottom-up political process, cost-effectiveness, and optimization of co-benefits (Sowińska-Świerkosz and García, 2022; IUCN, 2020; Short et al., 2019; Somarakis et al., 2019; Xing et al., 2017). Cost-effectiveness is a highlighted aspect in the literature (Sowińska-Świerkosz and García, 2022). Xing et al. (2017) argue that the cost should be comparable or lower than conventional approaches that achieve equivalent results. In this sense, cost-effectiveness assessment should consider the entire life cycle of an NbS, from implementation to maintenance (Sowińska-Świerkosz and García, 2021). Although maintenance

costs tend to be lower compared to grey infrastructure, they are more significant than often perceived (Somarakis et al., 2019).

The Life Pletera project cost €2,528,148. Figure 2 presents the investment allocated in the project by cost category and cost share among stakeholders. The main investment source was the European Union (75%) through the Life program. Local, provincial, and Catalan governments contributed a significant portion, supplemented by resources from the University of Girona (UdG) and the construction company. Regarding cost categories, about 70% of the budget was allocated to the removal of pre-existing urban infrastructure, topography adjustment, and creation of new lagoons. Typical actions in ecological restoration projects, such as native vegetation reconstitution and dune system recovery, represented a minority cost in the project (3%). Actions aimed at improving associated cultural ecosystem services, such as physical and psychological well-being, summed up 12% of the total project cost (i.e., implementation of visitor infrastructure and educational activities). A significant portion of the investment (17%) was allocated to planning (preliminary technical studies), project management, and monitoring of both socioeconomic and ecological impacts.

3.4 Ecological effectiveness

The results of hydrological models and initial monitoring of socio-environmental impacts suggest that the Life Pletera project was successful in restoring key structural and functional traits of the salt marsh ecosystem, essential to achieving its initial goals and produced a series of co-benefits. In just 2 years (2016–2018), the dune system restoration resulted in a global increase of 71.5% in the volume of sand retained by the system, with maximum gains in the northern fringe (+166%). There was also a global average increase in dune height of about 1 m compared to pre-intervention heights (Roig-Munar et al., 2020; López-Dóriga et al., 2019). The set of major structural interventions (de-urbanization, the return to the original topographic level, and the expansion of the lagoon system) restored the natural salt marsh hydrological dynamics, distributing water inputs in a laminar manner, reducing flooding in nearby urban and rural areas (Figure 3). All together, these actions potentially improved the water regulation services, especially those associated with coastal protection against sea storms and sea level rise, a palpable climate adaptive benefit from the project.

Regarding habitats restoration, between 2007 and 2018 there was substantial increase in natural habits, which expanded from 18 ha (33%) to 24 ha (41%) (Figure 4). The impact on the conservation of Habitats of Community Interest (HCI) was of noteworthy: the coastal lagoons, for instance, had its surface area increased about four times (Bou et al., 2018). Furthermore, there is evidence that soils in the more mature habitats of the salt marsh act as carbon sinks, contributing to climate mitigation efforts. Local assessment indicates that *Elymus elymoides* and *Arthrocnemum fruticosum* meadows can work as carbon sinks, storing an average of 28.86 kg/ha and 15.12 kg/ha, respectively (Gispert et al., 2021).

3.5 Socioeconomic and political effectiveness

Preferences, level of acceptance, and engagement of local actors in the formulation, implementation, and management of NbS are also key to intervention effectiveness (Ferreira et al., 2020). Solutions lacking social acceptance risk failure or being ineffective (Sowińska-Świerkosz and García, 2021). Top-down approaches are inefficient and can exacerbate social conflicts, economic inequalities, and environmental injustices (Sowińska-Świerkosz and García, 2022). Although they are usually slower processes, cross-sectoral and multi-actor approaches are more recommended (Buijs et al., 2019; Ugolini et al., 2015). The participation of universities and research centers is beneficial, contributing technical knowledge, innovation, research, and problem-solving solutions (Ugolini et al., 2015).

In 2022, an estimated total of 126,000 visitors came to La Pletera, of which about 75% were on foot and 25% by bicycle. Pueyo-Ros et al. (2018a) applied econometric models to assess visitation preferences after the Life Pletera project ended. The model input was perceptions collected in 232 questionnaires with saltmarsh users. The results pointed out that while restoration did not significantly alter the recreational value of the space, it increased visitation motivated by improved ecological and scenic values. Overall, the Life Pletera project received a very positive average evaluation from users (average of 8 out of 10), especially among those with a preservationist preference profile (Pueyo-Ros et al., 2018b). The restoration project is also in line with the local tourism development model, which has transitioned from an intensive "sun and beach" model—predominant between 1960 and 1990—towards a model based on cultural and natural heritage tourism (Capellà, 2012). In this context, natural areas have economic value, making restoration projects like Life Pletera socially and politically more acceptable.

Regarding stakeholder's engagement, the Life Pletera project implementation involved collaboration and coordination among multiple stakeholders and decision-levels. As shown in Figure 2, funding came from different sources, from European to different subnational governments (local, provincial, and community) and research institutions. The project management was under the local government responsibility while technical and scientific execution was coordinated by the University of Girona. Furthermore, the favorable social and political conditions that made possible the Life project were a result of local stakeholders' engagement and a long bottom-up process that goes back in time.

The roots of this process can be traced to the environmental movement and social mobilization that flourished in Catalonia in the 1970s and 1980s (Gil-Farrero, 2023). The timeline traced during focus groups revealed that the boom of the "sun and beach" tourism model on the local natural heritage mobilized civil society. Three important institutional milestones were identified: first, in 2002, the revision of the Urban Plan of the Torroella de Montgrí municipality reclassified La Pletera land as non-urban. The second milestone was in 2004, when the Spanish Ministry of the Environment definitively recognized the extent of the maritime-terrestrial public domain, covering the La Pletera area, granting an official protection status at the Spanish level and favoring the maintenance of the area as a natural space. This measure also solved a critical legal and financial impediment to restoration, as the La Pletera lands were in litigation with the former landowners since the urban plan revision. In 2010, another milestone was added: the incorporation of La Pletera in the creation of the Montgrí, Medes Islands and Baix Ter Natural Park, under the management of the Catalan government. A key feature of this process is the local government advocacy in coordination with civil society for legal protected status in higher levels of decisions (Catalonian and Spanish governments).

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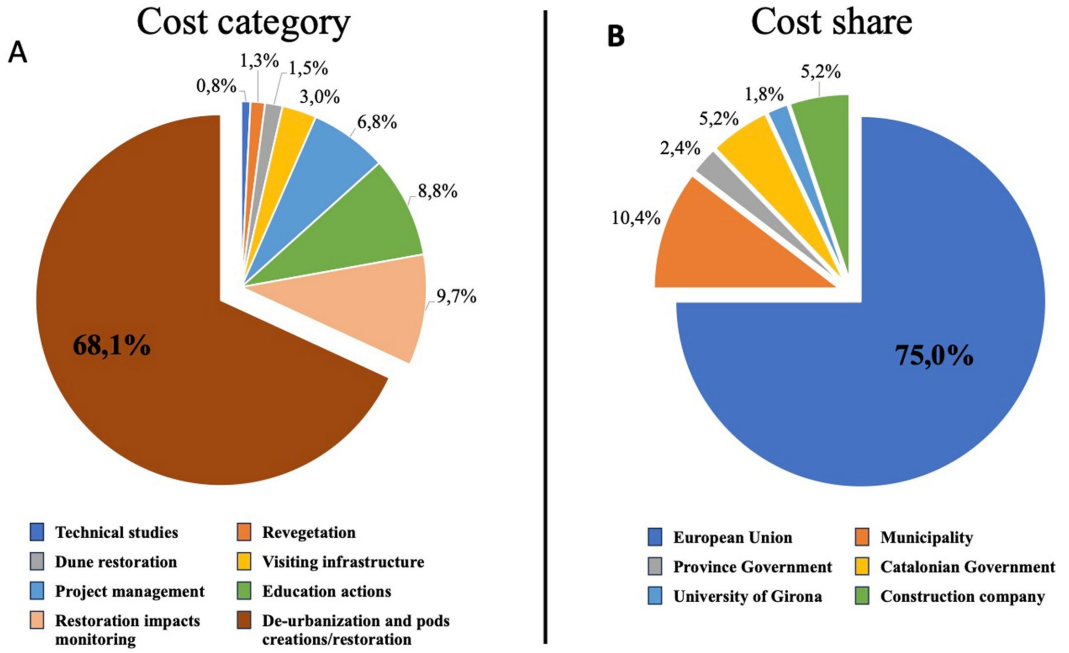

FIGURE 2
Investment made in the urbanization and ecological restoration project of La Pletera marshland by cost category **(A)** and by cost share according to funding institutions **(B)**. Source: elaborated by authors based on Life Pletera (2018a,b).

3.6 The scale issue

The scale of the intervention is another important aspect in both characterizing an NbS and assessing its effectiveness (IUCN, 2020). An ecosystem-inspired solution must be large enough to be relevant (Nesshöver et al., 2017; Frantzeskaki, 2019). Scale issues is also important when analyzing impacts and benefits, which can span from local to global (Raymond, 2017).

The restoration of La Pletera salt marsh covered an area of 63 hectares. Although small compared to the original wetland landscape, the extent of the intervention restored a functional ecosystem providing many ecosystem services, particularly those associated with regulating the water cycle and providing cultural services. The climate adaptive value is local-relevant, benefiting the surrounding urban and rural areas (Figure 3). Positive impacts on human physical and psychological well-being are mainly local and regional (municipality's residents and visitors from surrounding municipalities). However, in summer, tourists from various parts of Catalonia, Spain, and Northen Europe also visit La Pletera (Pueyo-Ros et al., 2018a). In what concerns climate mitigation, the carbon removal and stock in the salt marsh soil has a global impact (although quantitatively modest).

From a biodiversity perspective, the restoration brought a noticeable gain within the salt marsh limits, expanding the area of priority habitats and creating refuges for the endangered *A. iberus*. However, from a conservation standpoint, there is still a lack of evidence to draw definitive conclusions. Genetically viable populations need to be connected with other populations. Small areas are ineffective in this regard. For certain populations, such as plants, birds, and terrestrial vertebrates, La Pletera salt marsh serves as an ecological corridor between neighboring wetlands and within the remnants of the extensive wetland landscape that once dominated the coastal plain of the lower Ter river. However, for the *A. iberus* the nearest populations are in lagoons 20 km north, in the Aiguamolls de l'Empordà Natural Park, and 130 km south, in the lagoons of the Llobregat river Delta, near Barcelona. In practice, these populations are practically isolated and vulnerable to medium and long-term genetic problems due to inbreeding (Quintana et al., 2024). Future measures at landscape level should be considered to promote population connection and genetic exchange.

4 Final considerations

The analysis of La Pletera's case reveals the complexity, potentials and challenges in the implementation of NbS. Restoring the ecosystem and ensuring the continuity of its functionality as a source of different ecosystem services involved the combination of a set of interventions, at a high cost funded mainly by the Life program. Adjustments in the legal framework regarding land use were also paramount enabling factors. The socioeconomic and ecological benefits were plenty, covering gains for biodiversity, and improved quality of cultural and regulation services. From the point of view of climate adaptation, the de-urbanization and restoration has reduced the exposure of neighboring rural and urban areas to flooding from sea storms and extreme rain.

Therefore, the Life projects in La Pletera were made possible by particular conditions: availability of adequate financial resources; planning oriented to goals determined *a priori* and monitored along the implementation; favorable political environment, engagement of local stakeholders and social acceptance; adequate scientific knowledge and a legal framework on land use that restricted

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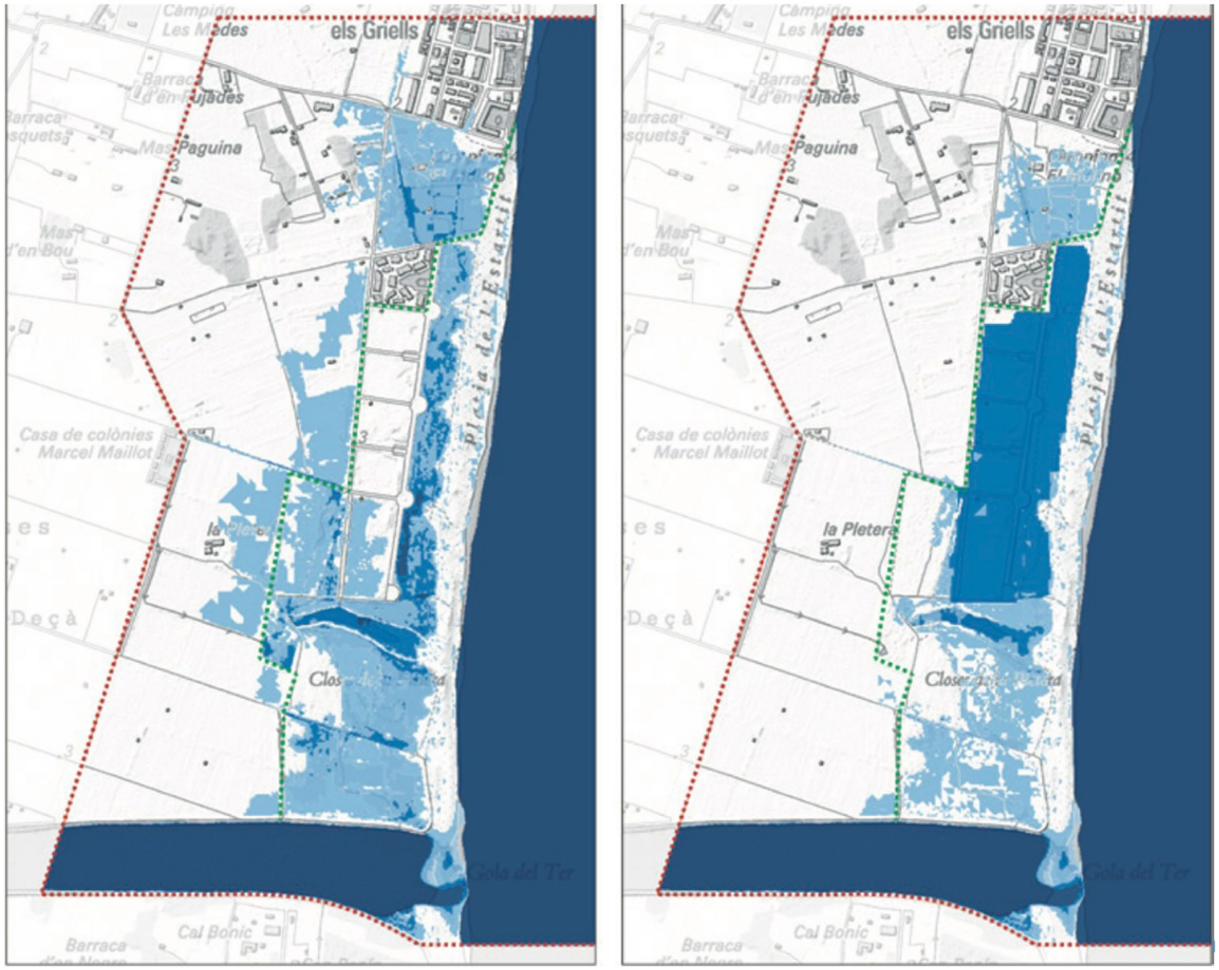

FIGURE 3
Hydrological modeling of the flooded area during a marine storm before (left) and after (right) the interventions of the Life Pletera project (2014–2018). The storm magnitude is based on the one recorded on December 26, 2008. Dashed red line: Natura 2000 Network; dashed green line: maritime-terrestrial public domain (source: Quintana et al., 2018b adapted from Geoservei, 2016).

urbanization and designated the use of the space as a natural area. This confluence of factors was decisive for the success of the project implementation. Such results corroborates the premise that NbS are not generic strategies that can be copy-and-pasted, but it requires an ex-ante context evaluation and, whenever necessary, a bottom-up process to create favorable political, social and legal conditions. The adherence of the Life restoration projects to the local economic development model based on nature and cultural tourism was another important aspect identified that explains why it was widely accepted in local community. Although nature has an immeasurable value in itself, presenting conservation from an economic point of view can be a key instrument to engage local private stakeholders, not only in the implementation of NbS phase, but also in the medium-long term maintenance.

The analysis undertaken in this work adopts a recent implemented case and uses data and evidence collected during and immediately after the execution of the Life Pletera project, which ended in 2018. Even though the results are promising, the conclusions about the effectiveness of the NbS are partial and valid for a short-term horizon only. Further analysis will be necessary to corroborate the effectiveness of the La Pletera restoration as NbS, in particular to assess how the improvements in structure and functioning of the ecosystem can be related to improvements in the quality of relevant ecosystem services in the long-term. In general, NbS projects would benefit if a socio-environmental impacts monitoring plan (covering short, medium and long term) were already foreseen in their conception and funding. The accumulation of knowledge on the evolution of the quality of ecosystem services over time is essential to support the defense of NbS as a central strategy in efforts that seek to integrate the challenges of facing the climate crisis and the conservation of biodiversity.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: http://lifepletera.com/sensibilitzacio/.

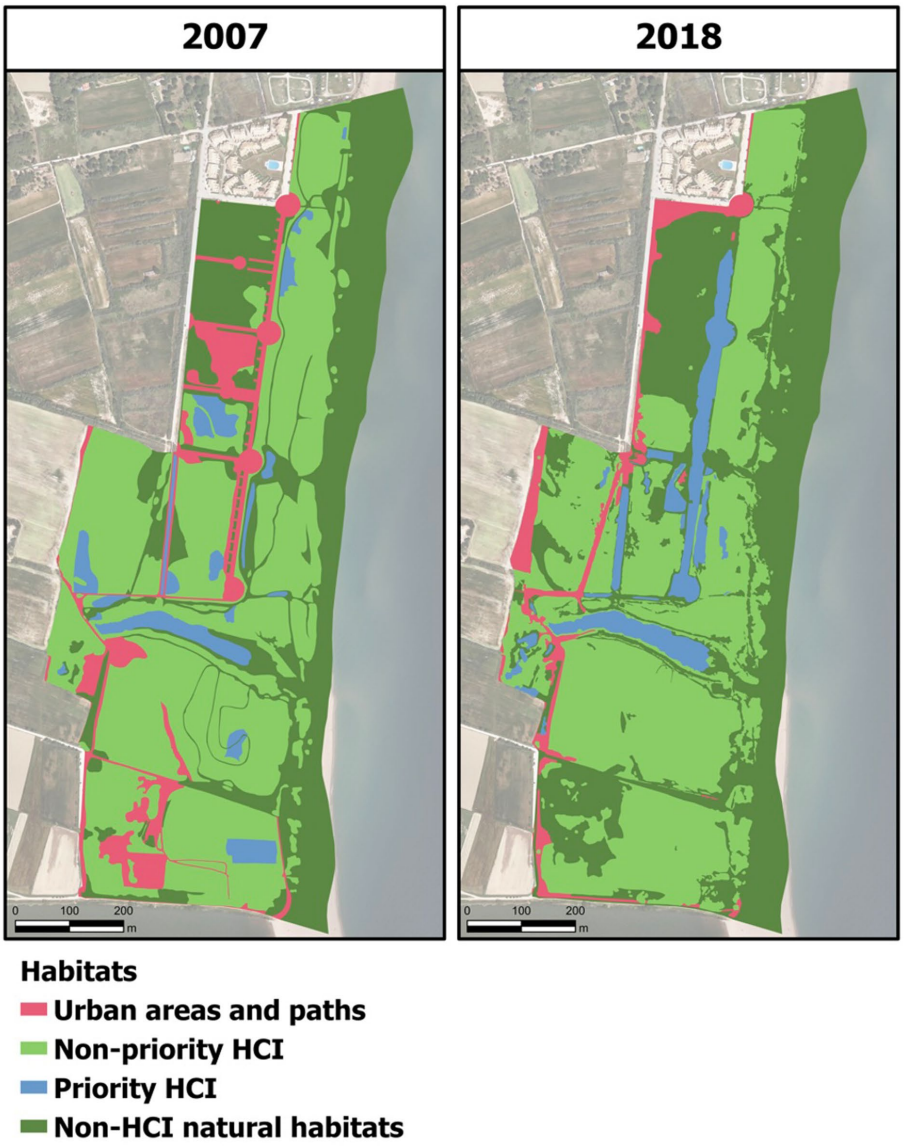

FIGURE 4
Natural habitats and urban area change before (2007) Life Pletera de-urbanizations and restoration project and just after its implementation (2018). HCI: Habitats of Community Interest under European Habitat Directive (source: elaborated by the authors based on Bou et al., 2018).

Author contributions

DP: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft. DB: Investigation, Project administration, Writing – review & editing. AR: Investigation, Project administration, Supervision, Writing – review & editing. JB: Investigation, Writing – review & editing. XQ: Investigation, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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