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POND BIODIVERSITY AND FUNCTIONS

The role of pondscapes in supporting identities

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Abstract This study investigates how pondscapes, networks of ponds, and their surrounding environments contribute to supporting identities across diverse cultural contexts. Supporting identities is a non-material Nature's Contribution to People referring to people's sense of place, belonging and connection to nature. We draw on data on landscape features from 17 pondscapes across eight countries in Europe and South America, along with over 700 questionnaire responses. We assessed whether certain landscape features are associated with the perceived delivery of supporting identities and examined how personal characteristics, individual perspectives, and engagement in different activities shape people's perceptions. Our findings indicate that the perceived delivery of supporting identities emerges from a combination of social and ecological factors rather than from landscape features alone. Although pondscape characteristics showed weak direct effects, pondscapes in warmer climates and with a higher proportion of natural land cover might be associated with a stronger sense of identity. In addition, a strong personal connection to nature and engagement in nature-based activities (wildlife watching, picnicking,

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hunting), were key pathways shaping perceptions, highlighting that identity-related benefits are context dependent and socially mediated. By integrating ecological and social dimensions, our study highlights the importance of incorporating non-material values into conservation and landscape management strategies.

Keywords Sense of place · Place attachment · Nature's contributions to people · Cultural ecosystem services

Introduction

Ponds are small, shallow, standing water bodies, typically ranging from a few square meters to a few hectares that can be either natural or artificial (Hill et al., 2018; Richardson et al., 2022; Cuenca-Cambronero et al., 2023). They are characterized by dynamic ecological conditions and strong interactions with surrounding terrestrial environments (Richardson et al., 2022). Lakes, in contrast, are natural water bodies with typically larger area, depth, and volume and hence form distinct aquatic ecosystems with less strongly expressed connectivity to land. The term pondscape refers to a network of ponds embedded within their terrestrial matrix, together with the ecological, hydrological, and social interactions that connect them (Boothby, 1997). Despite their limited size, ponds and pondscapes make a disproportionate contribution to regional biodiversity by providing habitats for numerous aquatic and semi-aquatic species, including many of conservation concern (Oertli et al., 2024; López-de Sancha et al., 2025a, 2025b). Moreover, pondscapes can play a significant role in climate adaptation and mitigation by regulating hydrological processes, such as water storage that alleviates droughts and floods, as well as supporting carbon dynamics, while also offering opportunities for recreation, education, and community engagement (Holgerson & Raymond, 2016; Cuenca-Cambronero et al., 2023; Bartrons et al., 2024; Oertli et al., 2024; Ryfisch et al., 2024). Nevertheless,

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ponds and pondscapes remain largely overlooked in environmental management and policy frameworks compared with larger water bodies, despite their abundance and multifunctionality (Ryfisch et al., 2024). Taken together, these multiple ecological and social roles highlight the need for integrative conceptual frameworks to systematically assess how nature contributes to people.

In the last two decades, there has been an increasing academic interest in assessing the contributions of ecosystems and their biodiversity to human well-being (Maki Sy et al., 2021). The concept of ecosystem services has gained considerable traction since the Millennium Ecosystem Assessment, which classified them into four categories: provisioning, regulating, habitat (or supporting), and cultural services (MEA, 2005). In recent years, the framework of Nature's Contributions to People (NCP) was proposed to inclusively engage more diverse sources of knowledge, including those from the social sciences, and to incorporate different worldviews regarding ecosystem values (Díaz et al., 2018; Kadykalo et al., 2019). In particular, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines 18 categories of NCP, grouped into regulating, material, and non-material contributions (IPBES, 2019). The non-material group refers to the intangible benefits people derive from nature, which influence culture, identity, spirituality, inspiration, and overall well-being. Within the IPBES framework, these non-material NCP include three main categories: Supporting Identities, Learning and Inspiration, and Physical and Psychological Experiences. These contributions are not directly linked to material goods or ecosystem regulation, but are essential for shaping human experiences, values, and social cohesion (Díaz et al., 2018). Although non-material contributions are often less tangible and reflect more relational values, such as the relevance of people's attachment to a particular place, they are fundamental to understanding people–nature relationships and sustaining biocultural diversity (McElwee, 2021). Their recognition highlights how cultural practices, traditions, and symbolic connections to landscapes underpin local identities and community resilience (Dean et al., 2021; González Ramil, 2023; Gaglio et al., 2024). However, despite their growing visibility in global assessments, non-material contributions remain less represented in environmental decision-making and policy frameworks compared with material and regulating ones (IPBES, 2019; Dajka et al., 2025). Among these non-material contributions, the NCP "Supporting Identities" is particularly relevant for understanding how people develop emotional and cultural bonds with nature. NCP Supporting Identities is defined as the "provisioning of opportunities for people to develop a sense of place, belonging, rootedness or connectedness, associated with different entities of the living world; basis for narratives, rituals and celebrations; and source of satisfaction derived from knowing that a particular landscape, seascape, habitat or species exists" (IPBES, 2019).

The new notion of NCP Supporting Identities is related to previous concepts such as identity, sense of place, place attachment, or landscape identity. Landscapes have a central function in developing collective and individual identities in response to the human need to belong (Egoz, 2013). Identity emerges from lived experiences, reflections upon these experiences, and consequent actions, providing a sense of belonging and shaping a rhetoric that legitimizes practices and relationships (Dixon & Durrheim, 2000). In this sense, identity has been framed as a relational value that links people and the environment through meanings and responsibilities, beyond purely intrinsic or instrumental views (Klain et al., 2017). Similar to a sense of place, the source of a person's self-identity lies in the meanings that inform their sense of self (Tadaki et al., 2017; Rajala et al., 2020). Here, sense of place refers to the meanings and emotions attached to a setting, whereas place attachment refers to the affective bond that forms between individuals and their environment. The emotional bond and meanings people attribute to a place define the sense of place, encompassing the diverse connections that develop through attachment and personal experiences in a particular setting (Brown & Raymond, 2007; Trentelman, 2009; Lewicka, 2011). Importantly, these meanings are not purely social constructions; physical landscape attributes can also shape a sense of place. Furthermore, place attachment is commonly conceptualized as a positive emotional bond that develops between people and their environment, integrating the social and physical setting with one's self-identity (Stedman, 2003). To facilitate conceptual clarity, the main definitions and relationships among these terms are summarized in Table 1.

Table 1 Conceptual definitions and relationships among key terms used in this study

Concept	Brief definition	Key references
Identity	The way individuals or communities understand themselves in relation to their environment and social context. It emerges from lived experiences, reflection, and shared practices, providing a sense of belonging and continuity. Considered a relational value that links people to the land through meanings and responsibilities	Dixon and Durrheim (2000), Klain et al. (2017)
Sense of place	The set of meanings, emotions, and symbolic associations that people attach to a specific setting, shaped by personal experiences and social interactions. It integrates both cognitive and affective dimensions of the human–environment relationship	Brown and Raymond (2007), Lewicka (2011) and Rajala et al. (2020)
Place attachment	A positive emotional bond between people and a place, grounded in both the physical and social attributes of the environment and intertwined with one's self-identity. Often viewed as a component of, or contributor to, sense of place	Stedman (2003), Trentelman (2009), and Lewicka (2011)
NCP supporting identities	Opportunities provided by nature for individuals and groups to develop a sense of belonging, connectedness, rootedness, or cultural identity associated with particular landscapes, habitats, or species. Encompasses emotional and symbolic dimensions of people–nature relationships	IPBES (2019) and Díaz et al. (2018)

The table summarizes how the concepts of identity, sense of place, and place attachment relate to the NCP Supporting Identities, highlighting their shared relational and experiential dimensions

The NCP Supporting Identities reflects both the satisfaction people derive from knowing that particular landscapes or species exist and the opportunities nature provides to develop a sense of belonging, connectedness, or sacredness (Christie et al., 2019). These identities are shaped by interactions between people and the physical and social characteristics of landscapes, as certain environmental features can reinforce attachment and satisfaction (Shumaker & Taylor, 1983; Kemmis, 1990; Stedman, 2003). However, meanings and attachments vary among individuals, even within the same setting, depending on personal attributes, such as age, gender, education, or origin (Raymond et al., 2017; Schirpke et al., 2022; Gaglio et al., 2024). Moreover, activities practiced in a landscape (such as work, recreation, or traditional uses) play a key role in strengthening people's connection to place and shaping collective landscape identities (Ness, 2011; Butler et al., 2018, 2019). Age-old activities, maintained in specific areas and landscapes and perceived as traditions, play a key role in reinforcing identities through their contribution to non-material values. This is particularly the case for pastoralism (Dean et al., 2021), fish pond farming (Delpero and Volpato, 2022), or salt production (Gaglio et al., 2024), for example. Other aspects should also be considered when explaining the value of supporting identities in these areas, as this type of spatial identity involves a sense of belonging rooted in regional history, literature, language or dialect, livelihoods, folklore, or gastronomy (Pohl, 2001; Häkli and Paasi, 2003; Gearey et al., 2020). Therefore, landscape features, personal attributes, and activities synergistically play a crucial role in shaping and supporting identities at both individual and collective levels.

Research on the non-material contributions of aquatic ecosystems has traditionally focused on large and iconic environments, such as rivers, coastal zones, and mountain lakes, whereas small waterbodies have received far less attention (Koschorreck et al., 2019; Gottwald et al., 2022; Schirpke et al., 2022; Kelly et al., 2023). Studies addressing identity, sense of place, or other cultural dimensions in

pondscapes remain extremely limited and mostly descriptive, often restricted to local case studies or qualitative approaches based on interviews and participatory assessments (e.g., Pueyo-Ros et al., 2019; González Ramil, 2023). Consequently, our understanding of how people relate emotionally and symbolically to these landscapes is still fragmentary, and cross-site comparisons are rare. At the same time, the institutional and policy recognition of ponds and pondscapes remains weak, as they are frequently overlooked in water and biodiversity frameworks despite their high ecological and social value (Ryfisch et al., 2024). In contrast, seminal works in other landscape types have provided solid conceptual and empirical foundations for studying the links between physical settings and human identity; for instance, Stedman (2003) demonstrated for lake systems that physical attributes of the landscape can shape the sense of place, bridging ecological and social perspectives. These perceptions are highly contextual, emerging from the interactions between people, their activities and the characteristics of the surrounding landscape. Therefore, it is necessary to conduct dedicated research on pondscapes, as they have so far received very little attention despite their high abundance in most landscapes worldwide. Freshwater biodiversity and ecosystems play a key role in supporting people's livelihoods, quality of life, and also identities through spiritual and social cohesion experiences, enriching their lives by providing meaning, inspiration, and also a sense of belonging (He et al., 2021; Lynch et al., 2023). In some cases, this profound emotional connection is established with specific species. For example, the crustacean *Triops cancriformis* has become a local symbol in a temporary pond located at northeastern Iberia, where its reappearance after each flooding event generates widespread attention, including TV news, and reinforces community identity around the pond ecosystem (Boix et al., 2002). In other cases, the attachment extends to entire landscapes, where ecological processes and seasonal dynamics shape collective identities, as observed in riverine systems across different regions (Anderson et al., 2019). Similarly, González Ramil (2023) showed that the pondscape is a fundamental element in shaping the sense of place and regional identity of Upper Lusatia (Germany), highlighting its close links with local natural and cultural heritage.

Despite the growing recognition of the non-material contributions of nature, research explicitly linking pondscapes to identity and sense of place remains scarce. Existing studies have mostly focused on local or qualitative assessments, providing valuable insights but lacking the comparative and integrative approaches needed to identify broader patterns across regions and cultures. Furthermore, the limited acknowledgment of ponds and their cultural relevance in management and policy contexts highlights the need for interdisciplinary studies that can inform both science and practice. Addressing these gaps requires combining ecological and social perspectives to understand how the characteristics of pondscapes and the attributes of people interacting with them shape the perception of identity-related benefits. Building on these premises, this study was designed to empirically explore these relationships across contrasting cultural and ecological contexts.

This study aims to explore the role of pondscapes in the NCP Supporting Identities across diverse cultural and territorial contexts in Europe and South America. To achieve this, we draw upon a database of 17 pondscapes across eight countries, complemented by over 700 stakeholder and public questionnaire responses. First, we assessed whether certain ecological or landscape features of pondscapes may influence the perceived delivery of the NCP Supporting Identities. However, as previously mentioned, the same location can provide different meanings and foster varying degrees of attachment for different individuals, depending on personal characteristics, perspectives, and the activities they engage in within that landscape. Given these considerations, we explored how personal attributes may shape people's perceptions of pondscapes. Specifically, we assessed whether a personal connection to nature, personal characteristics (e.g., age, gender) or the types of activities practiced in pondscapes may influence the perceived delivery of NCP Supporting Identities. By integrating ecological and social perspectives, our study contributes to a better understanding of how pondscapes may influence human identity and, consequently, contribute to human well-being.

Materials and methods

Study sites and data collection

As part of the PONDERFUL project (https://ponderful.eu), we studied 17 pondscapes across multiple countries and bioclimatic regions. These included sites in Belgium (Grote Gete Vallei, Pikhakendonk, Tommelen), Denmark (Fyn, Lystrup), England (Pinkhill, Water Friendly Farming), Germany (Schöneiche), Spain (Albera, La Pletera), Switzerland (Bois de Jussy, Rhône Genevois), Turkey (Imrahor, Dikkuyruk, Golbasi), and Uruguay (La Pedrera, Sierra de los Caracoles) (Fig. 1). These pondscapes encompass a broad range of bioclimatic zones, from Atlantic to Mediterranean, Continental and Subtropical regions, and show marked contrasts in size, degree of urbanization, and surrounding land use (Table 2). Most sites are located in rural or peri-urban settings, with ponds embedded in agricultural, pasture, or semi-natural landscapes, whereas others are situated near large urban areas or within protected reserves. Additional visual and contextual information for each pondscapes, including photographs and detailed descriptions of their ecological and management characteristics, is available in the official PONDERFUL leaflets (Oertli et al., 2024).

To characterize each pondscape, we compiled data through a bibliographic review carried out within the framework of the PONDERFUL project (Table 3; Oertli et al., 2024). When literature or previous data were unavailable, field data were collected using a standardized protocol (Bartrons et al., 2025; López-de Sancha et al., 2025a, b; López-de Sancha et al., 2025b). The collected information included general background data (e.g., pondscape surface area, number of ponds) and physical, chemical, and biological characteristics of the ponds and their waters. Biodiversity aspects were also considered, including, for example, aquatic plant species richness or the number

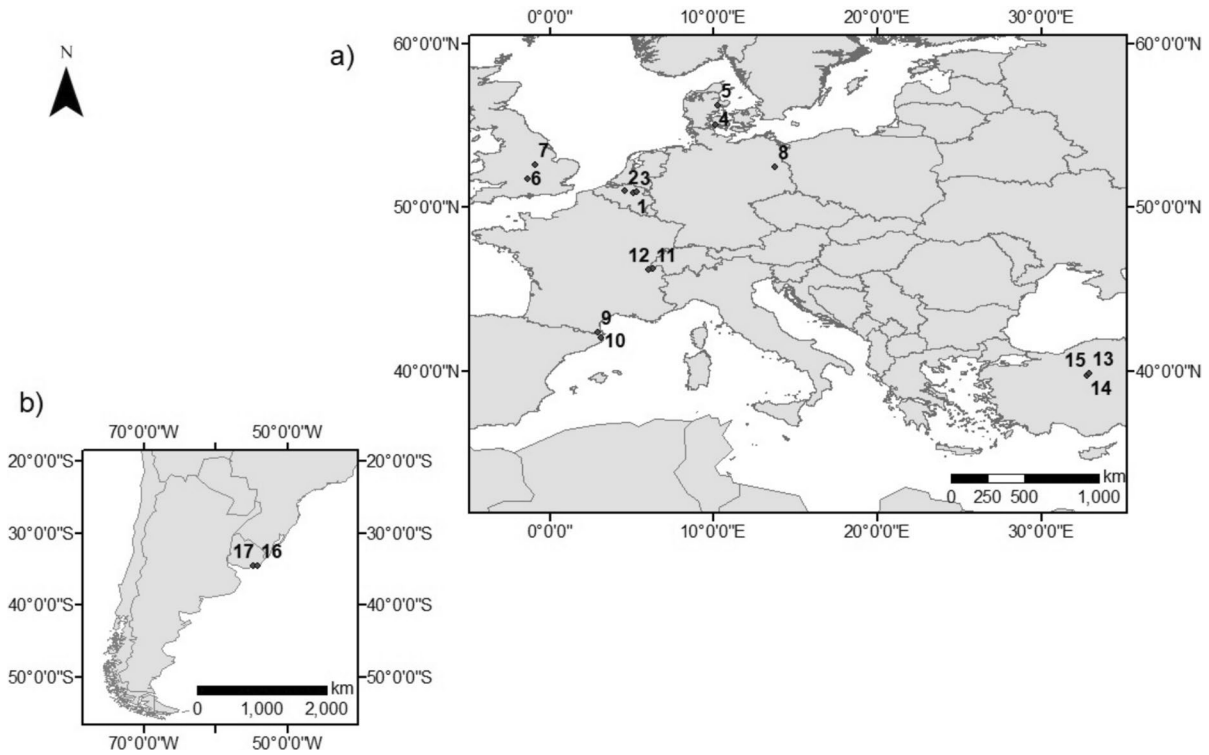

Fig. 1 Geographic location of the 17 pondscapes included in the study across Europe (**a**) and South America (**b**). The maps show the broad spatial distribution and biogeographical diversity of the study sites. Codes correspond to Belgium (1–Grote Gete Vallei, 2–Pikhakendonk, 3–Tommelen), Denmark (4–Fyn, 5–Lystrup), England (6–Pinkhill, 7–Water Friendly Farming), Germany (8–Schöneiche), Spain (9–Albera, 10–La Pletera), Switzerland (11–Bois de Jussy, 12–Rhône Genevois), Turkey (13–Imrahor, 14–Dikkuyruk, 15–Golbasi), and Uruguay (16–La Pedrera, 17–Sierra de los Caracoles)

Table 2 Main characteristics of the 17 pondscapes included in the study

Country	Name of the pondscape	Bioclimatic zone	Landscape and surrounding land use	Neighboring large town (habitants)	Land tenure	Public amenities	Area of the pondscape (km^2)	Number of ponds in the pondscape	Pond sizes (m^2)
Belgium	Grote Gete Vallei	Atlantic	Rural, grassland/arable land	Tienen (36,000)	Mostly private	Footpaths, cycling routes, picnic areas, hides	>10	41	100 to 150
	Pikhakendonk		Rural with grassland	Mechelen (87,000)	Mostly private	Footpaths, picnic areas, gravel roads	0.1	62	100 to 150
	Tommelen		Nature reserve near urban area	Hasselt (80,000)	Public	Several footpaths, picnic areas, information panels	0.12	144	100 to 150
Catalonia/Spain	Albera	Mediterranean	Rural with agriculture	Figueres (45,000)	Mostly private	Several footpaths	25	23	450 to 62,000
	La Pletera		Suburban and coastal marshes	Torroella de Montgrí (12,000)	Public	Several footpaths, some hides	0.6	20	100 to 3600
Denmark	Fyn	Continental	Rural with pasture/arable	Faaborg/Marstal (6898/2119)	Mostly private	Several footpaths, cycling routes, camping areas	8–250	30+	100 to 1500
	Lystrup		Suburban	Aarhus (290,500)	Mostly public	Extensive footpaths, some hides	8–30	14+	100 to 1500
England/United Kingdom	Pinkhill Meadows	Atlantic	Rural and floodplain	Oxford (160,000)	Private	Footpaths, hides, viewing points, boardwalks	0.1	50–60	2 to 3000
	Water F. Farming		Rural with farmland	Leicester (369,000)	Mostly private	A network of footpaths	30	120	100 to 5000
Germany	Schöneiche	Continental	Suburban with agriculture	Berlin (3,850,000)	Mostly private	Several footpaths	16	12	100 to 20,000

Table 2 (continued)

Country	Name of the pondscape	Bioclimatic zone	Landscape and surrounding land use	Neighboring large town (habitants)	Land tenure	Public amenities	Area of the pondscape (km^2)	Number of ponds in the pondscape	Pond sizes (m^2)
Switzerland	Bois de Jussy	Continental	Rural with woodland and agriculture	Geneva (600,000)	Mostly public	Several footpaths, some hides	7	25	100 to 4000
	Rhône Genevois		Suburban agro-forest mosaic	Geneva (600,000)	/	Footpaths, picnic areas, hides, swimming beach	16	40	50 to 20,000
Türkiye	Dikkuyruk	Central-Anatolian arid-cold steppe climate	Peri-urban (wheat field, landfill, ornamental garden with water pumping system, near a lake)	Bala, Haymana, Mamak, Çankaya and Gölbaşı (1,826,672)	Mostly private	Several footpaths, picnic areas	0.58	4	4,000 to 80,000
	Gölbasi				Mostly public	Several footpaths, cycling routes	0.26	23	100 to 10,000
	Imrahor				Private	/	2.51	12	225 to 57,000
Uruguay	Sierra de los Caracoles	Subtropical/temperate humid	Rural with pastures and grasslands for grazing cattle	San Carlos (30,290)	Private	Footpaths, hides, panoramic views	> 10	25	400 to 5000
	La Pedrera			Rocha (26,780)		Footpaths, bird-watching	> 10	18	

Additional descriptive details can be found in the official PONDERFUL leaflets (Oertli et al., 2024)

Table 3 Pondscape variables compiled for the analysis of their influence on NCP Supporting Identities values

Variable	Definition
Pondscape_Area	Pondscape surface area (km^2)
Ponds_Surface	Surface area of all ponds in the pondscape (m^2)
Ponds_Number	Number of ponds in the pondscape (ponds sized between 10 m^2 and 5 ha)
Ponds_Density	Pond density (number/km^2)
Area_Protected	Area protected (e.g., nature reserve) (%)
Inhabitants	Number of inhabitants in nearest city (or cities) in a radius of about 25 km
Chlorophyll	Concentration of water chlorophyll *a*: median value (µg/L)
Water_Surface	Total water surface area (ha)
Water_Depth	Water depth: median value (m)
Water_Volume	Total water volume (m^3)
Water_Volum_Max	Volume of water potentially stored during a severe flooding (m^3)
Plant_Sp	Aquatic plant species richness (submerged, floating, helophytes), including Charophytes
Bird_Sp	Water bird species richness (nesting, mating, overwintering)
Amphibian_Sp	Amphibian species richness
Inv_Fam	Number of families of macroinvertebrates (aquatic stages)
Inv_Sp	Number of species of macroinvertebrates (aquatic stages)
Priority_Sp	Number of conservation priority species on National Red Lists
Conse_Score_Total	Conservation score: total value for the pondscape
Connectivity	Structural connectivity: pond density (number/km^2) (ponds sized between 10 m^2 and 5 ha)
Sp_HD	Number of freshwater species listed on HD Annex II and Annex IV
Land_use_urban	Human-made structures such as buildings, roads, and other artificial surfaces
Land_use_crop	Agriculture, including fields of various crops
Land_use_pasture	Managed grassland used for grazing livestock
Land_use_natural	Shrublands, grasslands, natural forests, sparsely vegetated regions, and bare areas
Temp	Annual mean of the monthly mean temperature at 2 m above the surface
Precip	Annual mean of the monthly mean precipitation rate (both liquid and solid phases)
Arid	Monthly potential evaporation divided by the monthly mean precipitation, averaged over the year

Eleven variables ultimately selected, highlighted in bold, were chosen based on data availability, lack of cross-correlation with other variables, and ecological relevance

of conservation priority species listed in National Red Lists, defined at the country level and reflecting region-specific conservation priorities. Furthermore, each pondscape was characterized using seven quantitative variables related to climate and land use. Climatic variables included mean annual temperature, mean annual precipitation, and an aridity index derived from the Copernicus Climate Change Service (C3S), whereas land-use variables represented the proportion of the main land-use categories (urban, crop, pasture, and natural areas) derived from downscaled land-use maps based on the CORINE Land Cover 2018 dataset (see Table 3 for further details).

Additionally, a total of 705 questionnaires were completed between 2021 and 2022 to explore the relationship between the general public and stakeholders with pondscapes, as well as their preferences and expectations (see Appendix for the questionnaire; for further details, see Perrin et al., under revision). The questionnaire was administered in each local language (Catalan, Danish, Dutch, English, French, German, Spanish, and Turkish). The translation was standardized across countries by native speakers to ensure that all questions and response options were exactly equivalent. Participation was voluntary and completely anonymous using QR codes offered on paper supports in the pondscapes or on specific websites. The questionnaires targeted both residents living within or around the pondscapes and visitors who frequented these areas with varying regularity. To reach

this audience, different dissemination methods were used. Small posters were installed in the pondscapes to inform about the study and included a QR code linking directly to the online questionnaire. These posters were placed at pond entrances, on information panels, and in visitor centers. They remained available between 2021 and 2022 and were not associated with any specific events held at the pondscapes. The questionnaire and QR code were also shared via social media (Twitter and WhatsApp) and on local websites (including those of nearby municipalities). In some pondscapes with visitor centers, the questionnaire was also offered in paper format to facilitate participation. These methods ensured consistent access to both residents and visitors across countries. Respondents provided information on parameters that helped characterize their profile, such as gender, age, level of education, frequency of visits, and distance from their home to the pondscapes. The survey covered topics such as how they heard about the pondscape and the types of activities they engaged in within the area. Respondents were also asked to evaluate the contributions (i.e., NCP of IPBES) provided by the pondscape, on a five-point scale (1 = not important at all, 2 = slightly important, 3 = moderately important, 4 = important, 5 = very important). They were specifically asked how the pondscape contributed to supporting identities, including cultural heritage and local identity (i.e., related to NCP Supporting Identities). Finally, the survey also examined respondents' relationship with nature and pondscapes, as well as the perceived importance of pondscapes for their quality of life.

Statistical analysis

We first evaluated whether specific ecological or landscape features may influence the perceived delivery of the NCP Supporting Identities using the scoring values for the NCP Supporting Identities from questionnaires, alongside pondscape features data collected. Although we compiled numerous variables describing pondscape features (Table 3) ultimately, we had only a limited number of variables with complete data across pondscapes. Additionally, many of these variables were highly correlated (e.g., Pondscape area, Pond surface, and Pond number). Therefore, we selected 11 variables taking into account data availability, lack of cross-correlation with other variables, and ecological relevance (Table 3). We performed Spearman correlation analyses to detect potential correlations between the 11 pondscape feature variables and the perceived delivery of the NCP Supporting Identities because data for several variables were not normally distributed. We also included the other two non-material NCP (Learning and Inspiration and Physical and Psychological Experiences) to additionally evaluate their correlations with pondscape features, as well as the relationships among the three non-material NCP.

Secondly we evaluated whether some personal attributes may influence the perceived delivery of NCP Supporting Identities using the individual data from the 705 questionnaires. These analyses were conducted for three sets of predictors: i) personal relationships with nature: relation with nature, relation with pondscapes, and importance of pondscapes for quality of life; ii) personal characteristics: gender, age, education, distance to home, and frequency of visit; and iii) Activities in the pondscape: professional use, art, camping, cycling, diving, educational purpose, fishing, hiking, hunting, ice sport, relaxation, picnic, running, sailing, swimming, and wildlife watching (see Appendix for more details of the questionnaire). We performed Generalized Linear Mixed Model (GLMM) analyses, with a multinomial distribution, using NCP Supporting Identities as the dependent variable and pondscape as a random factor to account for the geographic distribution of the data, implemented with the *lme4* package in R (Bates et al., 2015). This approach was selected because the response variable (i.e., NCP Supporting Identities) was measured on a five-point Likert scale, which does not meet the assumptions of normality, and because responses collected within the same pondscape may not be statistically independent. Including pondscape as a random effect accounts for this potential clustering and allows partitioning the variance between, and within, pondscapes, thus avoiding pseudoreplication. We used a logit link function and fitted models by maximum likelihood estimation. An automatic stepwise backward selection using the regsubsets function of the *leaps* R package (Lumley, 2020) was used to identify the most significant predictor variables of the GLMM models, iteratively recalculating each model until the best-fitting predictors were determined based on the Akaike Information Criterion (AIC). This procedure starts with the full set of predictors and

sequentially removes the least influential ones, aiming to obtain the most parsimonious model while avoiding overfitting. The AIC is an information-theoretic index that balances model fit and complexity by penalizing the inclusion of unnecessary parameters, where lower AIC values indicate better model performance. All statistical analyses and plots were performed in R (v.2023.12.1, R Core Team 2023).

Results

While our results revealed considerable differences in the perceived delivery of NCP Supporting Identities across the studied pondscapes, the ecological and landscape characteristics appeared to have limited direct influence. In contrast, specific personal attributes, such as an individual's connection to nature, and the type of activities carried out in the pondscapes, appeared to be more strongly associated with the perceived delivery of NCP Supporting Identities.

Variation of NCP supporting identities among pondscapes

The differences in the perceived delivery of NCP Supporting Identities among the 17 studied pondscapes on a scale with a maximum value of 5 (very important) were shown using a boxplot (Fig. 2). It should be noted that the number of survey responses varied among pondscapes, with relatively small sample sizes for some sites, which may limit the strength of cross-site comparisons and calls for cautious interpretation of the observed patterns. Nine pondscapes showed median values equal to or greater than 4 (important), six pondscapes had median values ranging between 3 and 4, and only two had median values below 3 (moderately important). The four pondscapes with the

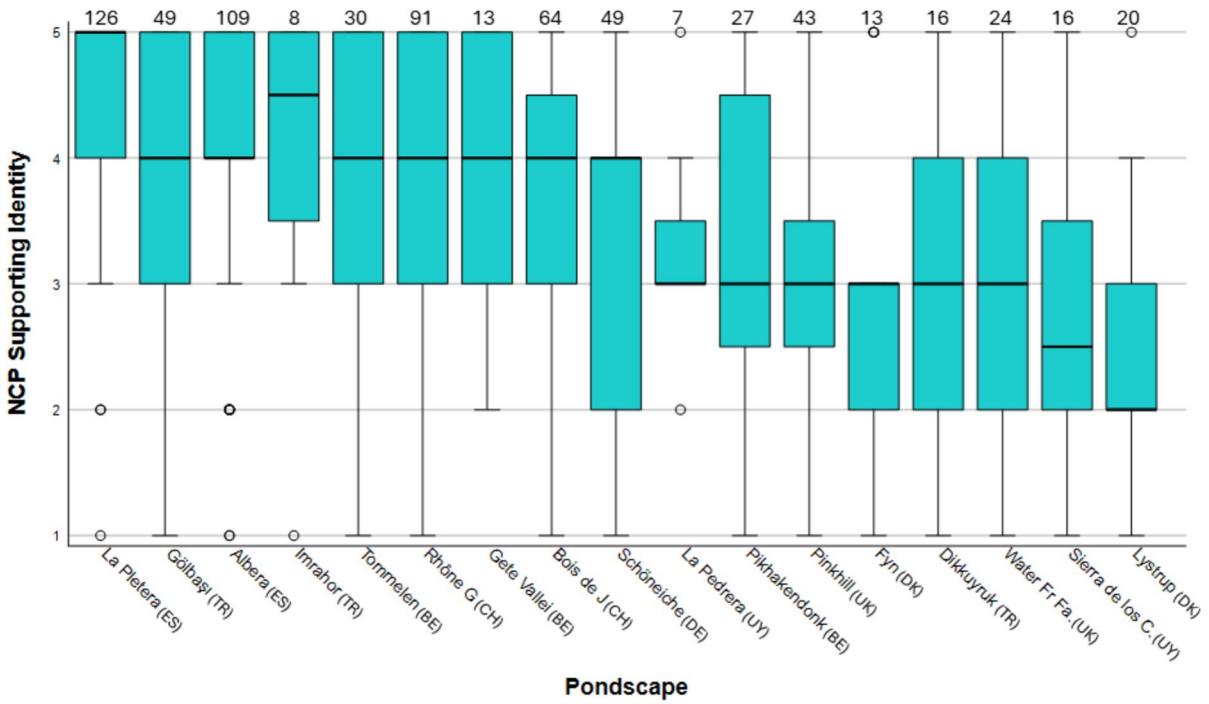

Fig. 2 Boxplots of NCP Supporting Identities across the studied pondscapes. The *Y*-axis represents the scale (1–5) used in the questionnaires to evaluate the importance of Supporting Identities NCP, ranging from 1 ("not important at all") to 5 ("very important"). The values above each box are the number of questionnaires completed. Each boxplot shows the median (horizontal line inside the box), the interquartile range (box), and the data range excluding outliers (whiskers). Country codes are BE – Belgium; DK – Denmark; UK – England (UK); DE – Germany; ES – Spain; CH – Switzerland; TR – Turkey; and UY – Uruguay

highest scores were in lower-latitude countries in Europe (Spain and Turkey).

Pondscapes features

The Spearman's correlation analyses revealed only two ecological or landscape features of pondscapes showing some influence on values for NCP Supporting Identities (Fig. 3). Specifically, annual mean temperature ($r=0.68$) and the percentage of natural land cover ($r=0.56$) were positively correlated with the perceived delivery of NCP Supporting Identities. Moreover, NCP Supporting Identities also exhibited positive correlations with the other two non-material NCP. In particular, its relationship with NCP Learning and Inspiration was notably strong ($r=0.82$).

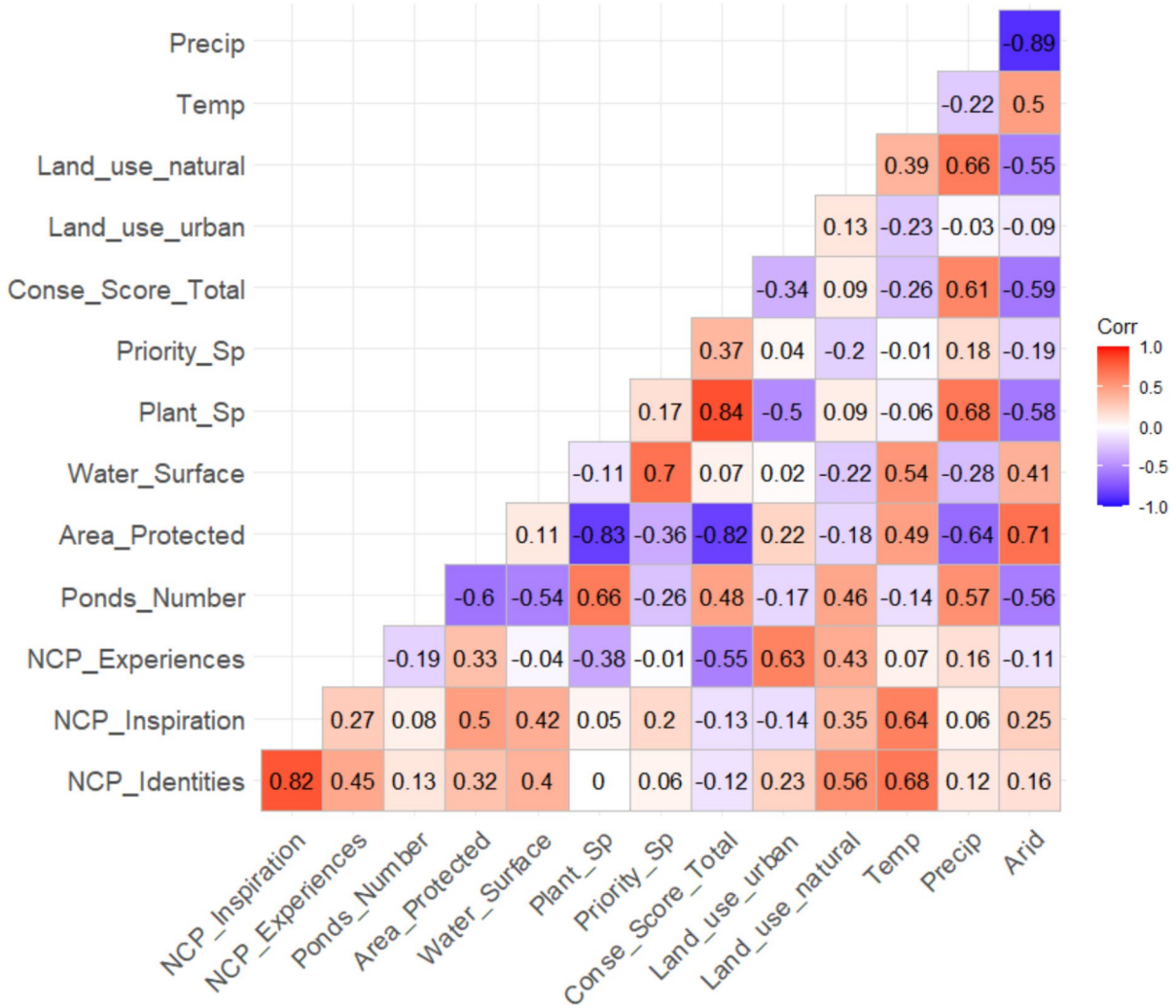

Fig. 3 Rank correlation matrix (Spearman's coefficient) among NCP Supporting Identities values and pondscapes features. Strength is shown through Spearman's *r* coefficient, represented by the value and the color of the box. Different shades of red indicate positive correlations, and blue shades represent negative correlations. Variable abbreviations correspond to Table 1: Ponds_Number (number of ponds, Area_Protected (protected area, %), Water_Surface (total water surface, ha), Plant_Sp (aquatic plant richness), Priority_Sp (priority species, National Red Lists), Conse_Score_Total (total conservation score), Land_use_urban (urban/artificial cover, %), Land_use_natural (natural cover, %), Temp (mean annual temperature, °C), Precip (mean annual precipitation, mm), and Arid (aridity index)

Personal connection to nature

Regarding how personal relationships with nature may influence the perceived delivery of NCP Supporting Identities, the GLMM analysis with stepwise model selection revealed that all combinations of predictor variables produced a significant model, indicating that the three sets of variables (i.e., relationship with nature, relationship with pondscapes, importance of pondscapes for quality of life) were highly relevant for the delivery of Supporting Identities. Figures 4, 5, and 6 show partial residual plots, which display the independent effect of each predictor variable on the response variable (i.e., perceived delivery of Supporting Identities) while accounting for the other variables in the model. Positive slopes indicate a positive association between the predictor and the perceived delivery of Supporting Identities. The best-fit model included the variables "relationship with nature" and "relationship with pondscapes" (Table 4, Fig. 4), suggesting that individuals reporting a stronger connection to nature or pondscapes perceived a higher delivery of NCP Supporting Identities. This relationship was found to be particularly strong for the "relationship with pondscapes."

Personal characteristics

The results for personal attributes (i.e., gender, age, education, distance to home, frequency of visit) were less clear. None of the variable combinations were retained through the stepwise selection. However, "age" emerged as the most likely influential variable, as it was the most consistently retained during the stepwise backward selection process. The best-fit model included both age and frequency of visits (Table 5, Fig. 5). The results seem to suggest that younger respondents (aged 18–35 years) scored the NCP "Supporting Identities" lower than respondents from other age groups (Fig. 5).

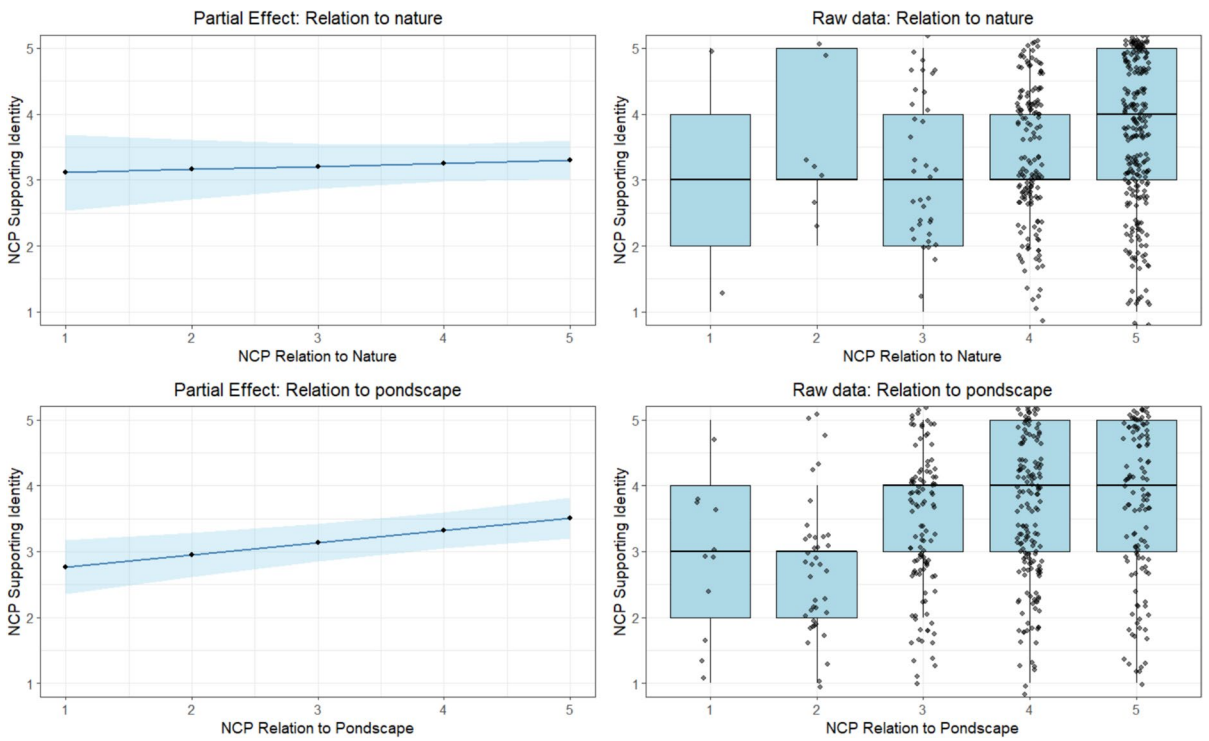

Fig. 4 Partial residual plots (left) and raw data (right) showing the relationship between the perceived delivery of NCP Supporting Identities and two predictors: relation to nature (top panels) and relation to the pondscape (bottom panels). Partial effects represent the independent contribution of each predictor while accounting for the other variables in the model; shaded areas indicate 95% confidence intervals. Raw data boxplots illustrate the distribution of responses for each category. Each boxplot shows the median (horizontal line), the interquartile range (box), and the data range excluding outliers (whiskers)

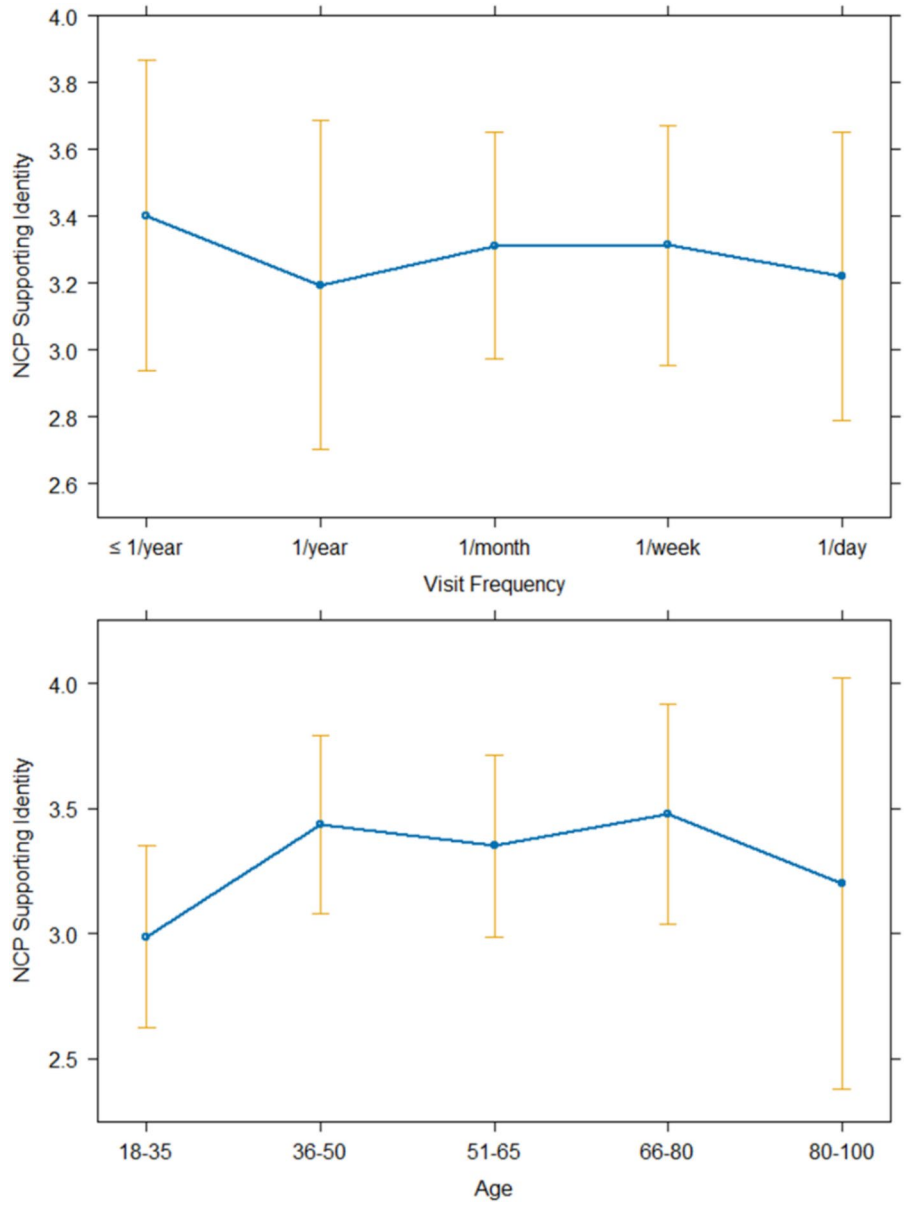

Fig. 5 Partial residual plots showing the relationship between the perceived delivery of NCP Supporting Identities and two predictors selected in the GLMM (Table 3): visit frequency (top panel) and age category (bottom panel). Points represent partial fitted values, and vertical lines indicate 95% confidence intervals, showing the independent effect of each predictor after accounting for the other variables in the model

Types of activities

Finally, we examined whether the types of activities carried out in pondscapes might influence the perceived delivery of NCP Supporting Identities. Out of the 16 activities assessed, wildlife watching, hunting, and picnicking were selected for inclusion in the best-fit model, each showing a positive relationship with the perceived delivery of NCP Supporting Identities (Table 6, Fig. 6). Among these, wildlife watching emerged as the most influential activity, suggesting that individuals engaging in this activity within the pondscape perceived higher levels of NCP Supporting Identities.

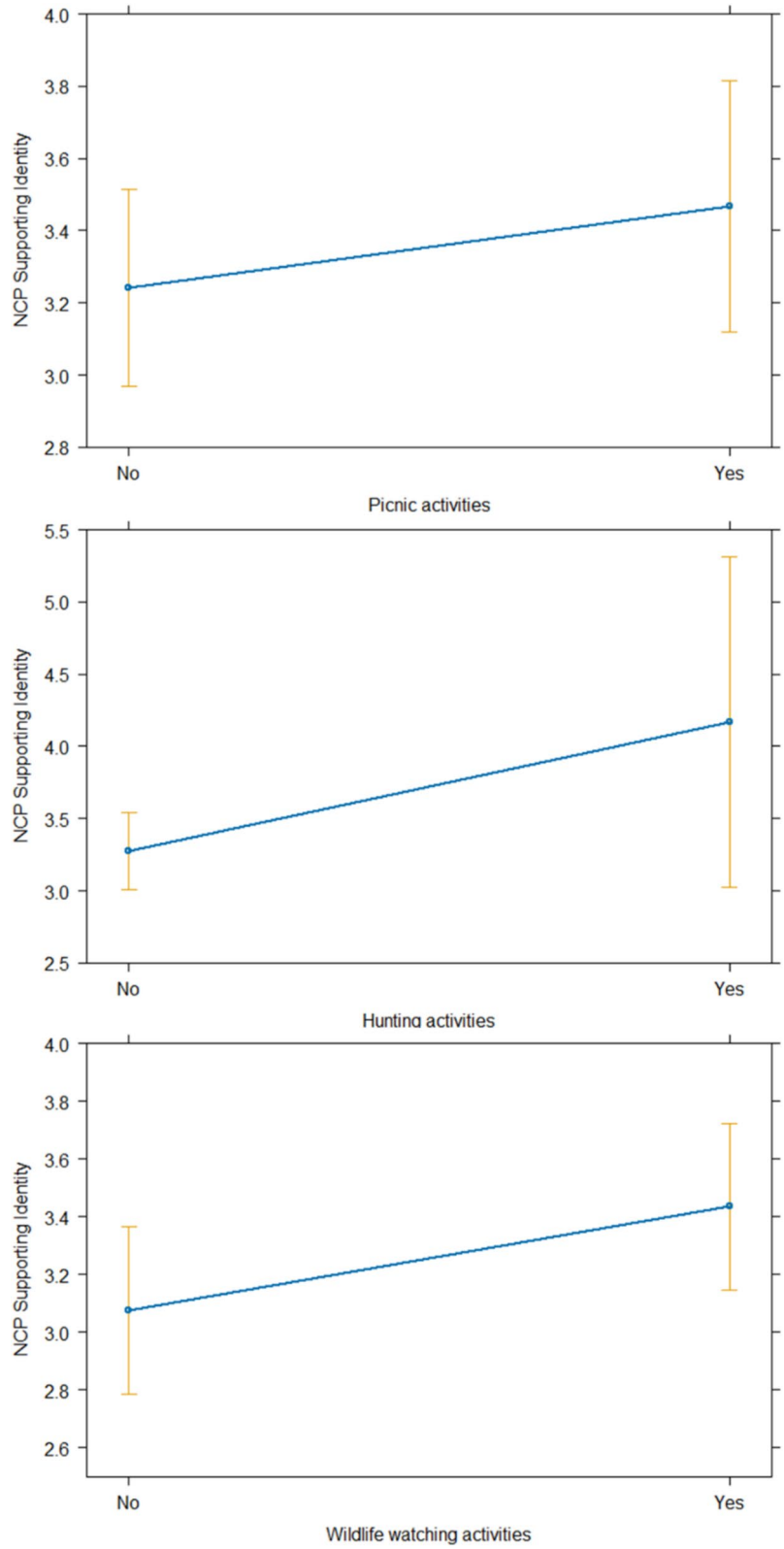

Fig. 6 Partial residual plots showing the relationship between the perceived delivery of NCP Supporting Identities and three activity-related predictors selected in the GLMM (Table 4): picnic activities (top panel), hunting (middle panel) and wildlife watching (bottom panel). Points represent partial fitted values, and vertical bars indicate 95% confidence intervals, reflecting the independent effect of each activity after accounting for the other variables in the model

Table 4 Results of the GLMM analyzing variables related to personal connection to nature in the pondscape, with NCP Supporting Identities as the dependent variable and pondscape as a random factor

Variable	Estimate	Std. Error	*T* value	Sig
(Intercept)	2.36501	0.34977	6.762	**< 0.0001**
Relation with nature	0.04857	0.07654	0.635	0.526052
Relation with pondscape	0.18555	0.05496	3.376	**0.000796**

Statistically significant values ($p < 0.05$) are highlighted in bold

Discussion

Pondscapes features

In line with our hypotheses, we found that some physical features of pondscapes are associated with the NCP Supporting Identities. Our results suggest that, in particular, higher annual mean temperatures and a greater proportion of natural land cover within the pondscape may be positively associated with the perceived delivery of the NCP Supporting Identities. However, these results only indicate a trend, and we do not have enough data to obtain robust conclusions. Nonetheless, these nuanced patterns contribute to the broader understanding of how landscapes support identity by suggesting that NCP Supporting Identities arise from context-dependent interactions rather than universal mechanisms. Some authors assert that the potential number of physical features that may influence the sense of place is endless, and many of the variables are difficult to quantify such as color, texture, quality of light, the feel of wind, or visual preferences for species composition or plant communities (Ryden, 1993; Gobster, 2001). For this reason, Lewicka (2011) suggested that the choice of variables either must be very selective, mostly based on common sense, or it must use very broad categories, or ideally, it must include almost all possible physical features. In this sense, we had selected 11 variables to describe pondscapes features, taking into account the lack of cross-correlation with other variables, data availability, and ecological relevance.

Pondscapes with a higher proportion of natural land cover thus seem to provide greater support for NCP Supporting Identities, which aligns with previous studies showing that land cover and its stability strongly influence the NCP Supporting Identities (IPBES, 2019; Brauman et al., 2020). Similarly, Stedman (2003) showed that the level of shoreline urban development influences the symbolic base of attachment. Consistent with this, in our dataset, pondscapes that remain less urbanized (i.e., with a high percentage of natural land cover) appear to provide stronger support for identity. Additionally, the fact that the four pondscapes with the highest NCP values are in lower-latitude countries in Europe (Spain and Turkey)

Table 6 Results of the GLMM analyzing variables related to activities in the pondscape, considering NCP Supporting Identities as the dependent variable and pondscape as a random factor

Variables	Estimate	Std. Error	*t* value	Sig
(Intercept)	3.0271	0.1511	20.036	**< 0.0001**
Hunting	0.8957	0.5780	1.550	0.1219
Picnic	0.2249	0.1420	1.584	0.1140
Wildlife watching	0.3580	0.1141	3.139	**0.0018**

Statistically significant values ($p < 0.05$) are found in bold

Table 5 Results of the GLMM analyzing variables related to personal characteristics in the pondscape, with NCP Supporting Identities as the dependent variable and pondscape as a random factor

Variable	Estimate	Std. Error	*T* value	Sig
(Intercept)	3.10965	0.23480	13.244	**< 0.0001**
Age 36–50	0.38544	0.14823	2.600	**0.00961**
Age 51–65	0.33888	0.15449	2.193	**0.02877**
Age 66–80	0.40286	0.18959	2.125	**0.03412**
Age 80–100	0.13538	0.37882	0.357	0.72099
Frequency visits a day	−0.15539	0.25122	−0.619	0.53654
Frequency visits a month	−0.06736	0.20236	−0.333	0.73940
Frequency visits a week	−0.06936	0.21269	−0.326	0.74450
Frequency visits a year	−0.21386	0.25059	−0.853	0.39387
Frequency visits a six months	−0.09876	0.21283	−0.464	0.64286

Statistically significant values ($p < 0.05$) are highlighted in bold

may contribute to explaining the observed correlation between higher annual mean temperatures and higher NCP values. One potential explanation for this observation might be the fact that ponds and pondscapes are typically less abundant in Mediterranean and arid regions, and therefore draw greater attention from people and foster stronger attachment than in places where ponds, lakes, and wetlands are more conspicuous and frequent. In this sense, Shumaker and Taylor (1983) assert that attachment to places is driven by outstanding physical features. In the context of the Mediterranean bioregion, with high evapotranspiration rates and limited precipitation, ponds are exceptionally rare, and, furthermore, many are temporary ecosystems. In contrast, the fifth pondscape providing the greatest support for identity was Tommelen (Belgium), which is at a higher latitude. This pondscape has a very small surface area (0.18 km^2) but includes 144 ponds, which were unintentionally created by bombs during the Second World War in 1944 and are known as bomb craters. The historical significance of this site may be a factor explaining the high level of identity support it provides to the population. Accordingly, Mak et al. (2024) suggest that places with historic elements may enhance the sense of place due to their distinctiveness and uniqueness, while also serving as cultural attractions that foster social interactions across diverse cultural and socio-economic groups.

In our study, the pondscape that provided the greatest support for identity was La Pletera (Spain), and it consists of some historical natural ponds and others that have been recently created through European LIFE projects (Lindoso et al., 2025). These restoration projects have involved local inhabitants and stakeholders, and such participatory processes may have strengthened both the emotional and cognitive dimensions of people's connection with the pondscape, thereby increasing their place attachment and the value they attribute to these ponds. Also, the fact that the ponds in this pondscape were created through LIFE projects may be meaningful. For example, Rooney et al. (2015) have shown that residents perceived constructed wetlands as providing better quality services than natural wetlands, which is attributed to the importance of context (i.e., specifically, juxtaposition) as the considered wetlands stand out as natural oases within a managed, often monocultured, agricultural landscape. In the case of La Pletera, the ponds are located just a few meters from a highly touristic urban area; therefore, this effect of contrast and juxtaposition is also present.

Therefore, the biogeographical and historical context may shape how pondscape features influence the perceived delivery of the NCP Supporting Identities. In this sense, McElwee (2021) assents that non-material NCPs are distinctive as they arise from interactions occurring in specific locations (i.e., they are highly contextual), in contrast to other NCPs, such as regulating services, whose processes and outcomes are more universally applicable.

Personal connection to nature

Our findings suggest that individuals expressing a strong connection to nature or pondscapes are more likely to develop an attachment aligned with what we term 'supporting identities.' Similarly, Schirpke et al. (2022), studying mountain lakes in the European Alps, found that respondents with a high affinity for lakes reported a stronger sense of belonging. This could suggest that the link to nature may represent a preliminary step in the identification of individuals with their home territory, or potentially even a co-construction between personal and collective identities mediated by elements of a given space. From a sociological perspective, the connection to nature and associated well-being can be understood through two distinct dimensions (Snyder, 1995). The first is hedonic, predominantly related to the individual's pursuit of pleasure, with ponds sometimes serving as sources of immediate relaxation and enjoyment. The second is more profoundly eudaimonic, referring to a way of life associated with deeper human fulfillment. This eudaimonic dimension, linked to well-being, often manifests more collectively and relates to notions of heritage, identity, and even spiritual well-being. Consistent with this distinction, our correlation analysis showed that NCP supporting identities was strongly associated with NCP inspiration ($r = 0.82$), whereas its relationship with NCP experiences was comparatively weaker ($r = 0.45$) (Fig. 3). This pattern suggests that participants' connections to pondscapes and their perceived importance for quality of life may be driven more by eudaimonic, identity-related values than by short-term recreational or use-based interactions. This stronger association between identity-related values and the eudaimonic dimension aligns

with broader evidence that emphasizes the central role of supporting identities in shaping social-relational well-being. In this sense, Ausseil et al. (2022) emphasize that supporting identities constitute the most significant NCP within the "social connection" domain of social-relational well-being, due to the social networks and relationships that individuals develop through their connection to specific places and ecosystems.

Personal characteristics

Our results for personal attributes were not determinant. However, the best-fitting model for determining which personal attributes may influence the perceived delivery of NCP Supporting Identities included age and frequency of visit. Particularly, age consistently emerged as the most influential variable across the different models tested, with younger respondents (aged 18–35 years) scoring the NCP 'Supporting Identities' lower than respondents from other age groups (Fig. 4). This influence of age appears plausible, as previous studies have indicated that a sense of place develops over time through habit or custom (Jackson, 1995) and can be shaped by life stage (Elder et al., 1996). In line with this, Nicolás-Ruiz et al. (2023) found that interviewed people expressed NCP Supporting Identities through past experiences and emotions. On the other hand, we expected gender to be a relevant attribute, given that previous studies suggest that women tend to place greater value on immaterial aspects than men (Plieninger et al., 2013; Nowak-Olejnik et al., 2020). For example, Schirpke et al. (2022) found that the perceived value of the sense of place associated with mountain lakes in the European Alps was significantly higher in women than in men. However, in our studied pondscapes, gender seemed not relevant for the perceived delivery of NCP Supporting Identities.

Activities

Our results clearly indicate that some activities, particularly wildlife watching, followed to a lesser extent by hunting and picnicking, were the activities most strongly associated with the perceived delivery of NCP Supporting Identities in the set of studied pondscapes. Identity is continuously constructed through everyday practices and interactions with other individuals and the surrounding environment (Butler et al., 2019). Activities facilitate connection with the landscape and are fundamental in the formation of landscape identities (Lorimer, 2012; Butler et al., 2017). Stedman (2003) asserts that previous activities and experiences within landscapes may create lenses through which people attribute meanings to these places. Consequently, the same space may hold different meanings depending on the types of activities and experiences involved. Pondscapes provide opportunities for activities and esthetic experiences (Cuenca-Cambronero et al., 2023). Our results show that wildlife watching, in particular, reflects a strong bond with nature and may enhance individuals' sense of identity. Similarly, Wolsko and Lindberg (2013) found that individuals engaging in appreciative outdoor activities are more likely to experience a stronger connection with nature and greater psychological well-being than those participating in consumptive activities, such as hunting and fishing. However, for some individuals, activities such as hunting or fishing also represent meaningful ways of connecting with nature. This relationship is well documented, for example, in the strong association between hunting and Faroese identity, or among fishing communities in Northern Norway, where traditional practices are closely tied to values such as the maintenance of identity (Kaltenborn et al., 2017; Plieninger et al., 2025). Regarding how picnicking activity may increase the perceived delivery of NCP Supporting Identities, it could probably be related to social and family relationships that can be fostered during a picnic. In this sense, Eisenhauer et al. (2000) assert a reciprocal relationship between places in nature and social interactions, noting that these places often hold special meanings connected to family and friendship experiences. Other activities, more closely related to supporting livelihoods, such as farming and cattle raising, did not emerge to be important based on our analyses, which might be related to the relatively low number of pondscapes where such uses were dominant (e.g., Uruguay, where all ponds studies have been built to enhance agricultural production and to provide water for cattle). Also, these results can reflect the fact that such man-made ecosystems are often seen more as a means to achieve expected economic outcomes than as valuable ecosystems per se (Vo et al., 2023).

Management implications

In view of the high scores observed in our study, the NCP Supporting Identities emerges as a highly relevant contribution of nature that should not be overlooked in the planning and management of pondscapes. However, in a broad compilation of actions involving pond and pondscape creation, restoration, and management, Bartrons et al. (2024) found that most actions were primarily aimed at creating habitat for biodiversity (91%). Only two of the 183 actions evaluated in that study were primarily directed at non-material NCPs. Otherwise, non-material NCPs were included as part of an NCP mix. This highlights that these non-material contributions seldom remain a central focus in management decisions. Intangible values represent an important but overlooked dimension of nature, and their inclusion in decision-making processes requires understanding of their functioning and quantifying their value (Gaglio et al., 2024). Quantifying these values is not straightforward. This difficulty arises because they are highly context specific, and additionally, personal perspectives and characteristics influence their quantification. Nevertheless, considering these intangible values is crucial when making management decisions, since neglecting them may lead to social tension. As noted by González Ramil (2023), if people identify with their natural surroundings, this connection can foster environmentally protective attitudes. Similarly, previous research has suggested that identity-supporting NCPs are strongly influenced by the stability of land cover (IPBES, 2019; Brauman et al., 2020). Therefore, changes of land cover may have an impact on the identity of the people and the capacity of the landscape to deliver the NCP Supporting Identities. Thus, although quantifying NCP Supporting Identities is challenging, it is undoubtedly a parameter that can impact what is happening in a landscape, and as such should be considered in the management of and decision-making for natural areas.

Moreover, our findings highlight the importance of integrating local perspectives into pondscape management. While national and international stakeholders often prioritize biodiversity or regulatory objectives, local communities and local public authorities may attach particular importance to non-material values such as identity and sense of place. Recognizing and assessing these dimensions may help building trust and strengthen the social sustainability of restoration initiatives. This need is reinforced by the limited institutional attention ponds and pondscapes receive in major environmental policy frameworks (Ryfisch et al., 2024). Major international instruments also give limited attention to pondscapes and their non-material values; for instance, the EU Water Framework Directive rarely recognizes small ponds or identity-related benefits. In contrast, the Ramsar Convention has recently taken a step forward with Resolution XIV.15 (2022), which explicitly calls for enhancing the conservation and management of small wetlands, including ponds, although its operational implementation is still in early stages. Equivalent frameworks remain largely absent or inconsistent across Latin America, Africa, and Asia. In these regions, the reported rate of wetland loss has not slowed in recent decades, in contrast with trends in Europe and North America (e.g., Rhazi et al., 2012; Davidson, 2014). This highlights the need for context-specific approaches when comparing management implications across regions. In this context, involving local communities through participatory processes may enhance both the legitimacy and the long-term success of management actions.

Study limitations and prospects for future research

Despite offering novel insights into how pondscapes may contribute to NCP Supporting Identities, this study has presented several limitations that should be acknowledged and that may open avenues for future research. The survey used as the basis for our analyses was not specifically designed to address NCPs, nor did it focus on a particular NCP. A more targeted survey might have allowed a clearer examination of potential synergies, trade-offs and antagonisms among non-material NCPs. Although the dataset enabled us to explore broad patterns, future studies would benefit from survey instruments explicitly tailored to non-material NCPs, allowing a more fine-grained understanding of the mechanisms underlying identity formation. Another limitation concerns the focus on a single landscape type. While pondscapes are particularly interesting socio-ecological systems, this specificity constrains the generalization of our findings. Extending similar approaches to other landscape

contexts, such as rivers, coastal systems or forests, would help assess whether the mechanisms observed here apply more broadly. Finally, an important challenge is to develop standardized tools to assess NCP Supporting Identities across contexts. Such frameworks would be highly valuable for future research and practice. Standardised assessment tools could not only facilitate cross-site comparisons but also support the integration of non-material NCPs into planning and decision-making processes, where they remain chronically underrepresented.

Conclusion

This study is among the first to focus on pondscapes as potential contributors to identity support. Our findings suggest that the perceived delivery of the NCP Supporting Identities may result from a synergy of mutually reinforcing factors, including specific landscape features, the biogeographical and historical context, individuals' connection to nature, personal characteristics, and the types of activities carried out within the pondscape. The strong association between identity-related values and NCP Inspiration suggests that these connections are largely eudaimonic, grounded in meaning, belonging and cultural significance rather than in short-term recreational experiences. Personal engagement with pondscapes, particularly through nature-based activities, emerged as a key pathway shaping these perceptions. Taken together, these findings highlight that the delivery of identity-related NCPs is context dependent and socially mediated and should therefore be explicitly considered in pondscape management and conservation planning.

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Data availability The dataset on pondscape features is available in the Zenodo repository (https://doi.org/10.5281/zenodo.14017011). Any additional raw data used in the manuscript are available from the corresponding author upon reasonable request.

Declarations

Conflict of interests All the authors of the manuscript are part of PONDERFUL project and declare no conflict of interest.

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