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Essays and Perspectives

Nature-based activities improve human-nature connectedness: A systematic review and meta-analysis

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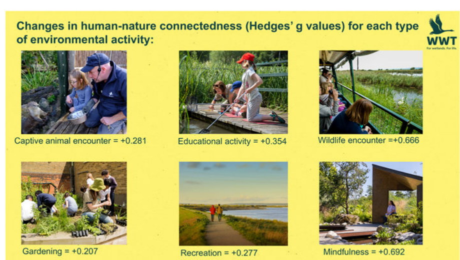
HIGHLIGHTS

- We reviewed changes in human-nature connectedness linked to 6 environmental activities.
- Human-nature connectedness increased most after mindfulness and wildlife encounters.
- Human-nature connectedness increased most after activities carried out over 2–7 days.
- Changes in human-nature connectedness did not vary between adults and children.
- Activities facilitated by conservation organisations foster human-nature connectedness.

GRAPHICAL ABSTRACT



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ABSTRACT

Conservationists recognize the importance of human-nature connectedness, which refers to a person's subjective perception of their relationship with the natural world. People with higher human-nature connectedness have greater support for pro-environmental and pro-nature conservation behaviours, as well as higher wellbeing. Fostering greater human-nature connectedness through activities that environmental organisations facilitate can therefore help to inspire people to support conservation efforts. However, we currently have a limited understanding of which activities increase human-nature connectedness. In this study, we address this knowledge gap by conducting a systematic review and meta-analysis, to assess the changes in human-nature connectedness associated with participating in environmental activities conducted in green and blue spaces including zoos, aquariums, parks, gardens, nature reserves, and similar places. Our initial searches found 356 studies, which through detailed screening were reduced to 43 studies that contained relevant information. These 43 studies yielded 123 estimates of changes in human-nature connectedness in response to participants undertaking one of six environmental activities: encounters with captive or wild animals, educational activities, opportunities for nature-based recreation, gardening and habitat management activities, and mindfulness activities. Our modelling showed that all six activity types were associated with increases in human-nature connectedness. Changes in human-nature connectedness were highest for mindfulness and wildlife encounters, whilst being lowest for gardening. Among the six activity types, mindfulness and wildlife encounter activities both led to a statistically significantly greater increase in human-nature connectedness than either captive animal encounters or

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recreation. Medium duration activities (i.e. those carried out over 2–7 days) led to greater increases in human-nature connectedness compared with activities conducted over long durations (>7 days), but not short durations (≤1 day). Changes in human-nature connectedness did not vary between adults and children. Our meta-analysis provides evidence that the types of activities facilitated by conservation organisations help to foster increased human-nature connectedness.

Introduction

In recent years, conservation organisations have begun to recognize the importance of human-nature connectedness, a multi-dimensional concept linked to a person's perception of their relationship with the natural world (Martin et al., 2020); such connections can be material, experiential, cognitive, emotional, and philosophical (Ives et al., 2018). This concept is also known by a range of other terms, including nature connection, nature connectedness, and nature relatedness (e.g. Nisbet et al., 2009; Lumber et al., 2017; Brambilla et al., 2024). No single formal definition of human-nature connectedness is accepted by all researchers, and so a plurality of ideas and definitions exist in the literature. As an example, Zylstra et al. (2014, p.126) offer a multi-dimensional definition of human-nature connectedness as "a stable state of consciousness comprising symbiotic cognitive, affective, and experiential traits that reflect, through consistent attitudes and behaviors, a sustained awareness of the interrelatedness between one's self and the rest of nature". Alternatively, Salazar et al. (2021, p.2) define human-nature connectedness as "the way people identify with these landscapes and the relationships they form with the elements in those environments". It is clear that human-nature connectedness can encompass a range of linked concepts, such as emotional affinity toward nature (including experiences of awe and concern for nature), inclusion of nature in self (i.e. a person's perception of the distinction between nature and self), and connectedness with nature (i.e. the extent to which a person feels a part of nature) (Tam, 2013; Salazar et al., 2021).

A rapidly growing body of research has demonstrated that higher levels of human-nature connectedness among people are associated with greater pro-environmental and pro-nature conservation behaviours, as well as improved physical and mental health and wellbeing (Arendt and Matthes, 2016; Martin et al., 2020; Whitburn et al., 2020; Barragan-Jason et al., 2022, 2023). Connecting people with nature and people acting to protect nature can be mutually reinforcing (Chawla, 2020). Fostering greater human-nature connectedness through activities that conservation organisations facilitate can therefore play a role in helping to inspire people to support conservation efforts (Barragan-Jason et al., 2023).

Conservation organisations have opportunities to influence the human-nature connectedness of their supporters, which could benefit conservation work by increasing the pro-environmental and pro-nature conservation attitudes of their supporters (Restall and Conrad, 2015; Mackay and Schmitt, 2019). Research has shown that contact with nature is an important mediator of the link between human-nature connectedness and the resulting benefits to wellbeing and pro-environmental and conservation attitudes and behaviours (Lumber et al., 2017; Richardson et al., 2020; Liu et al., 2022; Barragan-Jason et al., 2022, 2023). Zoos, aquaria, nature reserves and other green and blue spaces provide opportunities to foster a connection to nature, through activities which facilitate contact with nature, including encounters with captive or wild animals, educational activities, opportunities for nature-based recreation, gardening and habitat management activities, and mindfulness activities (Miller et al., 2004; Wyles et al., 2019; Reeves et al., 2021; Rose and Riley, 2023). Many such activities are specifically offered to children (Barrable and Booth, 2020; Keith et al., 2022), as human-nature connectedness is a strong predictor of pro-environmental behaviours among children (Otto and Pensini, 2017).

Experimental studies have found that engaging in certain environmental activities can increase participant's connection with nature (Lumber et al., 2017; Pennisi et al., 2017; Hatty et al., 2022; Kleespies et al., 2022; Low et al., 2024), whilst other experimental studies have either not detected such changes or reported mixed results (e.g. Kleespies et al., 2020; Henson et al., 2023; Whitburn et al., 2023). Given these mixed results, previous work has called for research to examine the effectiveness of a wider range of nature engagement activities in fostering human-nature connectedness (e.g. Sheffield et al., 2022). Numerous variables could influence the capacity of environmental activities to foster a change in human-nature connectedness among participants; for example, previous evidence has suggested that different environmental activities may vary in their capacity to foster a change in a person's connection with nature (Martin et al., 2020; Barragan-Jason et al., 2022; Hatty et al., 2022). For example, a recent meta-analysis by Barragan-Jason et al. (2022) found that nature-based mindfulness and direct contact with nature were more effective than outdoor environmental education, virtual nature, or indoor environmental education, in increasing human-nature connectedness. Similarly, the age of the participants may modulate any change in human-nature connectedness (e.g. Braun and Dierkes, 2017; Hughes et al., 2019), as shown in two developmental cross-sectional studies by Richardson et al. (2019) and Barragan-Jason et al. (2025), as well as a longitudinal study assessing children by Otto et al. (2019). For example, Hammond (2020) reported that feeding wild birds resulted in an increase in human-nature connectedness among parents but not their children. To date, therefore, we have a limited understanding about the extent to which different activities might affect human-nature connectedness. To further our understanding of the conditions under which human-nature connectedness can be increased through different environmental activities, there is a need to synthesise the currently available evidence through systematic review and meta-analysis.

In this study we conducted a systematic review and meta-analysis to assess the changes in human-nature connectedness associated with participating in environmental activities conducted in green and blue spaces including zoos, aquariums, parks, gardens, nature reserves, and similar places. Building on previous research that has shown that engaging in environmental activities can increase human-nature connectedness (Barragan-Jason et al., 2022; Sheffield et al., 2022), we addressed the following two key questions:

(i) What is the relative effectiveness of different types of environmental activities in increasing human-nature connectedness?
(ii) What covariates (e.g. participant age, activity duration) influence the magnitude of the change in human-nature connectedness associated with participating in an environmental activity?

Methods

Literature searches

To provide a transparency and repeatable methodology for our study, we followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA; Page et al., 2021) flow diagram (Fig. 1) and checklist (Supplementary information 1).

Previous research has highlighted that the literature on human-nature connectedness spans multiple research fields, including environmental psychology, nature conservation, and sustainability (Zylstra et al., 2014; Ives et al., 2017). To find relevant articles across these different disciplines, we conducted our literature searches in Web of Science Core Collection (http://webofknowledge.com/WOS) and Scopus (https://www.scopus.com/), both of which are multidisciplinary in terms of the articles that they index (Gusenbauer and Haddaway, 2020). We then supplemented our initial searches with a 'snowballing' approach (described below). In this way, we attempted to achieve good coverage in our searches whilst keeping the study tractable (i.e. avoiding generating large numbers of irrelevant results that would have been time consuming to screen). Our searches were conducted on 1st October 2024. We used the following search string:

> “nature connection” OR “nature connectedness” OR “connection to nature” OR “connectedness to nature” OR “connection with nature” OR “connectedness with nature” AND "zoo*" OR "aquari*" OR "park" OR "reserve" OR "arboret*" OR "garden"

In addition to our searches in Scopus and Web of Science, we also checked reference lists of all studies that were found to include relevant information (a process known as 'snowballing' or 'citation chaining'), to increase our likelihood of locating any relevant articles that may not have been included in our initial search results (Côté et al., 2013). Any

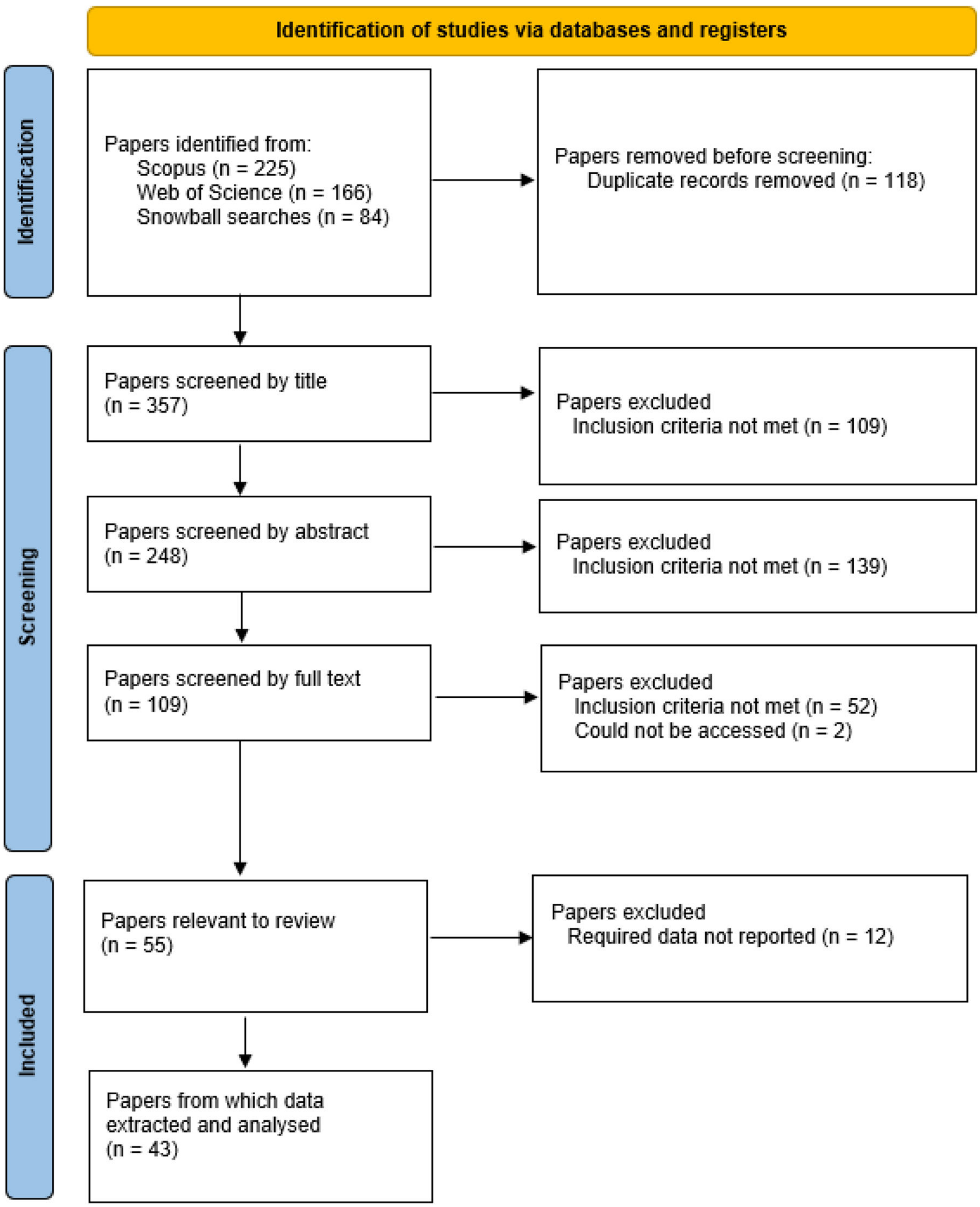

Fig. 1. A summary of our literature search results and subsequent screening process, indicating the numbers of papers processed at each stage.

article listed in a reference list, which appeared to potentially meet our relevance criteria, was added to our search results and was processed with the results from the two online search tools. Finally, we combined our search results from Scopus, Web of Science, and the snowballing exercise, and removed any duplicate articles.

Screening and inclusion criteria

One coauthor screened all articles to assess their suitability for inclusion in our meta-analysis. To meet our inclusion criteria we required studies to have used an experimental approach to measure how human-nature connectedness changed in response to an environmental activity. By experimental, we mean for example, studies which compared peoples' connection with nature before and after they had encountered captive animals at a zoo, or compared human-nature connectedness between one group which had undertaken an activity and a second group that had not; such experimental approaches are commonly used to assess changes in human-nature connectedness (Camacho-Guzmán et al., 2023). To increase the robustness of our findings, we further required that studies had measured human-nature connectedness on a defined scale, such as the Connectedness to Nature Scale (CNS; Mayer and Frantz, 2004), Inclusion of Nature in Self scale (INS; Schultz, 2001), Nature Relatedness Scale (NRS; Nisbet et al., 2009), and the Connection to Nature Index (CNI; Cheng and Monroe, 2012). However, similar to Ives et al. (2017) we did not select studies based on a strict fixed definition of human-nature connectedness or its measurement, but instead we were guided by whether a study addressed human-nature connectedness, regardless of the specific conceptual basis or measurement scale that was used. We included studies conducted in a green or blue space including zoos, aquariums, parks, gardens, nature reserves, and similar places. However, studies conducted in virtual spaces (e.g. Leung et al., 2022; Calogiuri et al., 2023) were considered to be outside of the scope of our study, especially given that the role of virtual environments in fostering human-nature connectedness has already been assessed by two recent systematic reviews and meta-analyses (Barragan-Jason et al., 2022; Brambilla et al., 2024). Studies that were restricted to indoor activities only (Lankenau, 2018) were also outside of the scope of our study. Any studies that met these inclusion criteria were deemed to be relevant and were included in our review. Whilst we searched using keywords in English, we screened results regardless of language, using Google Translate to translate articles written in languages other than English. Article screening was conducted in three stages (Fig. 1). In stage one, articles were screened by title only. At stage two, articles were screened by their abstract only. Finally, in stage three articles were screened based on their full text. At each stage, any article that was assessed to not meet our inclusion criteria was excluded from our list of articles and was not considered further.

Data extraction

From each relevant study, the mean, standard deviation (SD), and sample size (n) associated with each estimate of human-nature connectedness were extracted. In addition, information on the following variables was collected, which we predicted could influence the change in human-nature connectedness (as per our first key question):

a) Activity type: the type of activity (e.g. captive animal encounter) associated with the change in human-nature connectedness. Activities were assigned to one of six major types: (i) Encounters with captive animals, which comprised observational or physical interactions with captive animals during visits to zoos, aquariums or similar institutes. (ii) Encounters with wildlife, which comprised observational or physical interactions with free-living animals in any blue or green space, for example bird watching or feeding; (iii) Educational activities, which represent formal learning opportunities associated with nature, such as taught courses in natural history; (iv) Gardening, which comprised activities related to tending and cultivating green spaces, such as involvement in community garden projects; (v) Mindfulness activities, which involve a focus on awareness of our thoughts, feelings, and surrounding environment, centred in the present, for example forest bathing or meditation activities; (vi) Recreation, which comprised leisure activities such as walking or camping in any green or blue area. We drew on the information provided by the original studies on the primary purpose of each activity to determine which category it should be assigned to. As our work focused on experimental studies, we encountered no 'edge cases', as the original authors had designed their interventions to test the effectiveness of specific types of activity. We expected that not all activities would provide the same change in human-nature connectedness, as per our second key question (Martin et al., 2020).
b) Age group: were the people undertaking the activity adults or children (i.e. < 18 years old)? We wanted to test the idea that adults and children might respond differently in terms of their change in human-nature connectedness, as some earlier research has suggested (e.g. Hughes et al., 2019; Hammond, 2020).
c) Activity duration: the period over which the activity associated with the change in human-nature connectedness occurred; we classified this as either "short" (≤ 1 day), "medium" (2–7 days), or "long" (>7 days). This allowed us to test whether longer or shorter activities were associated with a greater/lesser change in human-nature connectedness.

All data were extracted by the same coauthor to minimise bias (i.e., due to differences in data extraction procedures amongst multiple individuals; Curtis et al., 2013). Studies were not included unless all required data was reported and could be extracted. We calculated the standardized mean difference between each pair of mean nature connection values reported in each study (i.e. before and after values, control and intervention values). As our measure of standardized mean difference, we used Hedges' g, which is not sensitive to unequal sampling variances and is effective even for small sample sizes (Hedges, 1981; Rosenberg and Rothstein, 2013). We calculated Hedges' g, along with its 95% confidence interval, and a weighting factor based on the inverse of the variance, using the *esc* package in R version 4.4.0 (Lüdecke, 2022; R Core Team, 2024); further details of the formulae used in these calculations is given by Wilson (2017).

Data analysis

To address our key questions, we fitted linear mixed effects models with Gaussian error structures, using the *glmmTMB* and *MuMIn* packages (Bartoń, 2012; Brooks et al., 2017) in R, with model assumptions checked using the *performance* package (Lüdecke et al., 2021). The changes in human-nature connectedness reported by each study (i.e. the values of Hedges' g) were modelled as the response variable. We tested additive effects of environmental activity type, age group, and activity duration as our three covariates, as well as a two-way interaction between activity type and age group. It was not possible to fit any other interactions between the other variables due to high collinearity (Variance Inflation Factor >10; Dormann et al., 2013).

We compared the performance among our candidate models using second-order Akaike's Information Criteria (AIC_c) associated with each model. All models with an AIC_c value within 2.0 of the lowest value were considered to be competitive (Burnham et al., 2011). However, models were not considered competitive if they contained an 'uninformative variable', i.e., a variable which increased the AIC_c value of a model relative to an otherwise identical model which lacked that covariate (Arnold, 2010). The marginal R^2 and conditional R^2 values for each model represented the proportion of variance explained by the fixed effects alone, and by both the fixed and random effects, respectively. Tukey's HSD post-hoc differences among different levels of each categorical variable were determined using the *emmeans* package (Lenth et al., 2019).

Across many scientific fields there is a well-known issue of preferential publication of positive findings (Wood, 2020). To examine how such publication bias may have affected our dataset, we assessed the relationship between the Hedges' g and standard error values from each study, using a visual assessment (via a funnel plot; Sterne et al., 2011) and a regression test, using the *metafor* package (Viechtbauer, 2010). More specifically, the regression test examined whether the relationship between changes in human-nature connectedness and standard error differed significantly from a random pattern (Sterne et al., 2011).

Results

Literature searches, screening, and data extraction

Our initial searches found a total of 357 studies (Fig. 1). Following our screening process, we identified a total of 43 relevant studies, which yielded 123 estimates of changes in human-nature connectedness (Fig. 1). Of the 43 studies, only 4 reported follow up estimates of the change in human-nature connectedness. These studies were published between 2008 and 2024 (Fig. 2). Most studies were conducted in Europe and North America, with the UK and USA each accounting for 11 studies (Fig. 3). However, smaller numbers of studies were found for other continents, including Asia (Singapore, South Korea, and Taiwan), Africa (Uganda), and Oceania (Australia and New Zealand) (Fig. 3). Among the 43 relevant studies, a total of 11 different scales were used to measure human-nature connectedness (Supplementary information 2). We found that the most frequently used scales to measure human-nature connectedness among the studies included in our meta-analysis were the Connectedness to Nature Scale (CNS; 13 studies), Inclusion of Nature in Self scale (INS; 12 studies), Nature Relatedness Scale (NRS; 8 studies), and Connection to Nature Index (CNI; 4 studies); no other scale was used in more than 2 studies (Supplementary information 2). Short, medium, and long activities accounted for 58, 14, and 51 data points, respectively.

Models of human-nature connectedness

Of the 10 candidate models that we compared, the model with the lowest AIC_c was the one in which the variation in changes in human-nature connectedness were explained by the activity type and activity duration (Table 1). Based on the estimated R^2 values, this model accounted for 83% of the variance in the changes in human-nature connectedness, with the fixed effects (activity type and activity duration) accounting for 29% of the variance (Table 1). Only one other model had an AIC_c value within 2.0 of the lowest AIC_c model, a model comprised of additive effects of all three variables: activity type, age group, and activity duration (Table 1). However, as the inclusion of the age group variable made this a more complex version of the first model, but resulted in an increase in the AIC_c value, we consider age group to be an uninformative variable in this case, and so we did not consider this model further. Accordingly, we based our inferences on the model with the lowest AIC_c value, in which the variation in changes in human-nature connectedness was explained by the activity type and activity duration (Table 2).

The mean estimates of the changes in human-nature connectedness associated with our best-supported model were highest for mindfulness (mean = 0.69, 95% CI = 0.55–0.84) and wildlife encounters (mean = 0.67, 95% CI = 0.51–0.82), whilst being lowest for gardening (mean = 0.21, 95% CI = −0.28–0.70) (Table 3; Fig. 4). Our post-hoc testing indicated that mindfulness activities were associated with a significantly greater increase in human-nature connectedness than either captive animal encounters or recreation (Table 4). Similarly, wildlife encounters were also associated with a significantly greater increase in human-nature connectedness than either captive animal encounters or recreation (Table 4). No other statistically significant differences between activity types were detected. Our post-hoc comparisons of different activity durations showed that medium duration activities were associated with significantly greater increases in human-nature connectedness than long duration activities (Table 4). However, there were no statistically significant differences in the changes in human-nature connectedness between long and short duration activities, or between medium and short duration activities (Table 4).

Funnel plot asymmetry

A regression test for funnel plot asymmetry indicated a significant relationship between Hedges' g and standard error values ($z = 3.33$, $P < 0.001$), such that lower Hedges' g values were more likely to be associated with lower standard error values. Visual inspection of the funnel plot (Fig. 5) also suggested asymmetry, with a strong clustering of data points with low Hedges' g and SE values, but few corresponding data points at higher Hedges' g values (Fig. 5).

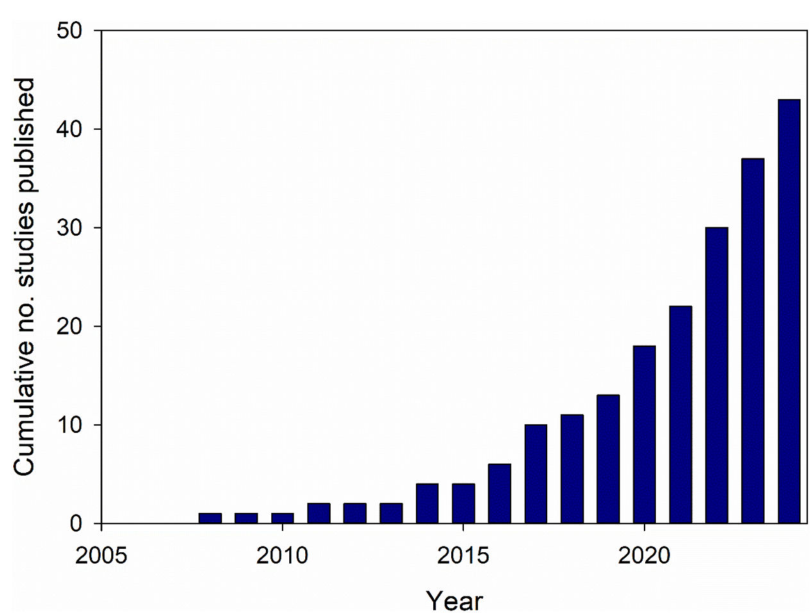

Fig. 2. The temporal trend in the cumulative number of relevant studies identified in our review.

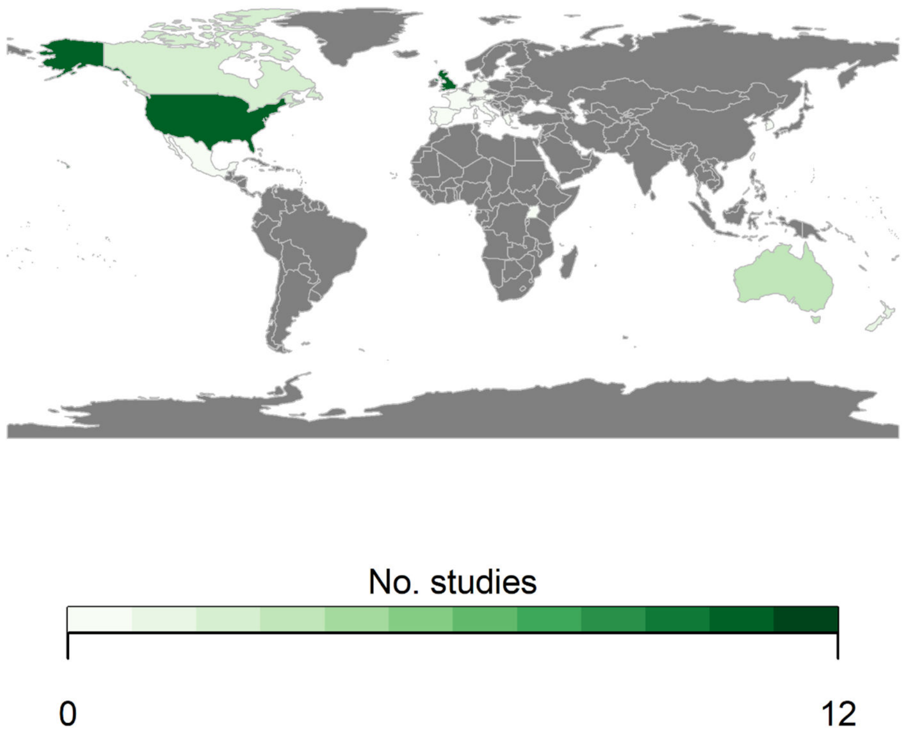

Fig. 3. A global map showing the numbers of studies conducted in each country. Grey colouration indicates no studies available.

Table 1
A comparison of our 10 candidate models of the changes in human-nature connectedness. AIC_c = second order Akaike's Information Criteria, RL = relative likelihood, df = degrees of freedom. R^2_m and R^2_c refer to the marginal and conditional R^2 values, respectively.

Model	df	AIC_c	ΔAIC_c	RL	Akaike weights	Evidence ratio	R^2_m	R^2_c
Activity type + Activity duration	10	−2450.00	0.00	1.00	0.63	1.00	0.289	0.827
Activity type + Age group + Activity duration	11	−2448.64	1.36	0.51	0.32	1.98	0.278	0.825
Activity type + Age group + Activity duration + (Activity type: Age group)	14	−2445.01	5.00	0.08	0.05	12.15	0.326	0.826
Activity duration	5	−2378.15	71.85	0.00	0.00	$4.00 \cdot 10^{15}$	0.152	0.764
Age group + Activity duration	6	−2376.75	73.25	0.00	0.00	$8.07 \cdot 10^{15}$	0.141	0.763
Activity type	8	−2351.74	98.26	0.00	0.00	$2.17 \cdot 10^{21}$	0.164	0.807
Activity type + Age group	9	−2350.09	99.91	0.00	0.00	$4.95 \cdot 10^{21}$	0.162	0.808
Activity type + Age group + (Activity type: Age group)	12	−2347.85	102.15	0.00	0.00	$1.52 \cdot 10^{22}$	0.198	0.800
null	3	−2284.94	165.06	0.00	0.00	$6.94 \cdot 10^{35}$	0.000	0.720
Age group	4	−2283.39	166.61	0.00	0.00	$1.51 \cdot 10^{36}$	0.006	0.723

Table 2
The estimated values of each of the variables included in our best-supported model of the changes in human-nature connectedness.

Effect type	Variable	Level	Estimate	SE	Variance	SD
Fixed	Intercept		0.041	0.101	–	–
	Activity type	Mindfulness	0.411	0.048	–	–
		Wildlife	0.385	0.064		
		Gardening	−0.074	0.264	–	–
		Education	0.073	0.158	–	–
		Recreation	−0.004	0.009	–	–
	Activity duration	Medium	0.483	0.048	–	–
		Short	0.236	0.118	–	–
Random	Study.ID		–	–	0.119	0.345
	Residual		–	–	0.038	0.196

Table 3
The estimated mean values for each level of the categorical variables included in our best-supported model of the changes in human-nature connectedness.

Variable	Level	Mean	SE	df	lower. CL	upper. CL
Activity type	Mindfulness	0.692	0.072	113	0.549	0.835
	Wildlife encounter	0.666	0.078	113	0.512	0.820
	Educational	0.354	0.133	113	0.091	0.617
	Captive animal encounter	0.281	0.075	113	0.132	0.430
	Recreation	0.277	0.075	113	0.129	0.425
	Gardening	0.207	0.248	113	−0.284	0.698
Activity duration	Medium	0.656	0.085	113	0.487	0.825
	Short	0.409	0.090	113	0.231	0.587
	Long	0.173	0.081	113	0.012	0.334

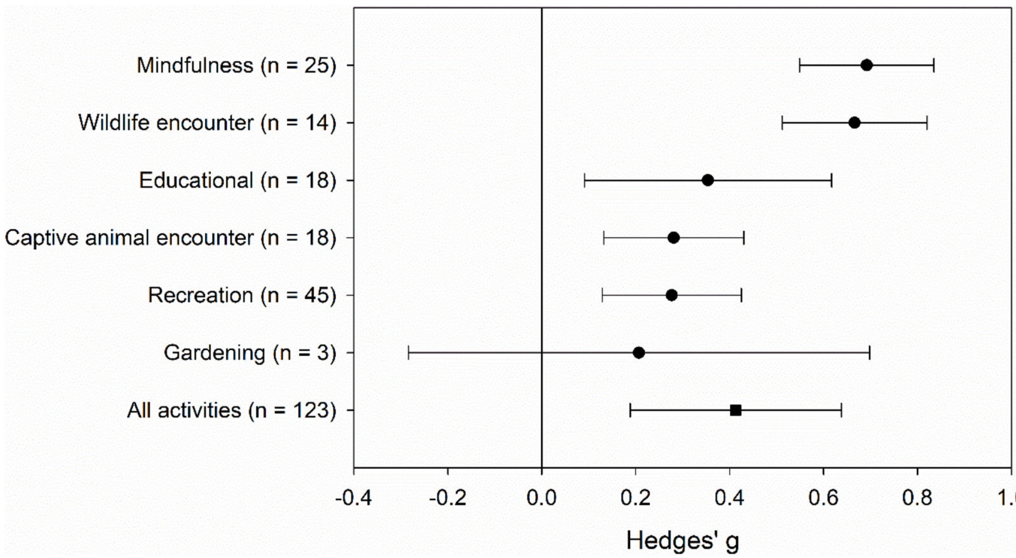

Fig. 4. The mean and 95% CI estimates of the changes in human-nature connectedness associated with different environmental activities (as well as the overall mean for all activities), based on our best-supported model. The values of *n* indicate the number of data points that each estimate is based on. The solid vertical reference line indicates no effect.

Table 4
A summary of the statistical comparisons between different activity types and between different activity durations. Statistically significant differences are shown in bold.

Variable	Contrast	estimate	SE	df	t ratio	p value
Activity type	Gardening - Mindfulness	−0.486	0.263	113	−1.845	0.441
	Gardening - Wildlife encounter	−0.459	0.265	113	−1.736	0.511
	Mindfulness - Recreation	**0.416**	**0.047**	**113**	**8.801**	**<0.001**
	Captive animal encounter - Mindfulness	**−0.411**	**0.048**	**113**	**−8.550**	**<0.001**
	Recreation - Wildlife encounter	**−0.389**	**0.063**	**113**	**−6.137**	**<0.001**
	Captive animal encounter - Wildlife encounter	**−0.385**	**0.064**	**113**	**−6.007**	**<0.001**
	Educational - Mindfulness	−0.338	0.156	113	−2.174	0.258
	Educational - Wildlife encounter	−0.312	0.158	113	−1.974	0.364
	Educational - Gardening	0.147	0.278	113	0.529	0.995
	Educational - Recreation	0.077	0.157	113	0.491	0.996
	Captive animal encounter - Gardening	0.074	0.264	113	0.281	1.000
	Captive animal encounter - Educational	−0.073	0.158	113	−0.463	0.997
	Gardening - Recreation	−0.070	0.264	113	−0.265	1.000
	Mindfulness - Wildlife encounter	0.026	0.043	113	0.611	0.990
	Captive animal encounter - Recreation	0.004	0.009	113	0.447	0.998
Activity duration	**Long - Medium**	**−0.483**	**0.048**	**113**	**−10.149**	**<0.001**
	Medium - Short	0.247	0.121	113	2.041	0.107
	Long - Short	−0.236	0.118	113	−2.002	0.116

Discussion

Environmental activities and human-nature connectedness

We carried out a systematic review and meta-analysis to estimate the changes in human-nature connectedness associated with the types of environmental activities that are frequently facilitated by conservation organisations. All six of the activity types considered in our study had mean positive changes in human-nature connectedness. Notably, the mean increases for all activity types, which ranged between 0.21 for gardening and 0.69 for mindfulness, were typically larger than the increases documented previously for virtual activities associated with nature, such as 0.12 by Barragan-Jason et al. (2022) and 0.26 by Brambilla et al. (2024), suggesting that in-person experiences of nature provide an important boost to increases in human-nature connectedness. Our work has built on previous reviews and meta-analyses (e.g. Sheffield et al., 2022) by providing evidence of the effectiveness of a wider range of environmental activities for both adults and children, whilst improving our understanding of factors that lead to increases in human-nature connectedness.

As expected, we found that different activity types varied in their effectiveness in increasing levels of human-nature connectedness. Mindfulness and encounters with wildlife provided the greatest increases in human-nature connectedness, with mean increases of 0.69 and 0.67 respectively, corresponding to medium-to-large effects, based on the thresholds for the interpretation of standardized mean differences such as Hedges' g (0.0 for no effect, 0.2 for a small effect, 0.5 for a medium effect, and 0.8 for a large effect; Rosenberg and Rothstein, 2013). As such, our results support previous research that has documented a strong link between mindfulness and human-nature connectedness (Howell et al., 2011; Schutte and Malouff, 2018; Barragan-Jason et al., 2022). As an example, the increase of 0.69 for mindfulness was larger than the 0.34 reported previously for mindfulness activities in nature (Barragan-Jason et al., 2022). Human-nature connectedness was increased more by encounters with wildlife than with captive animals. Whilst zoos and aquaria design exhibits carefully to provide encounters

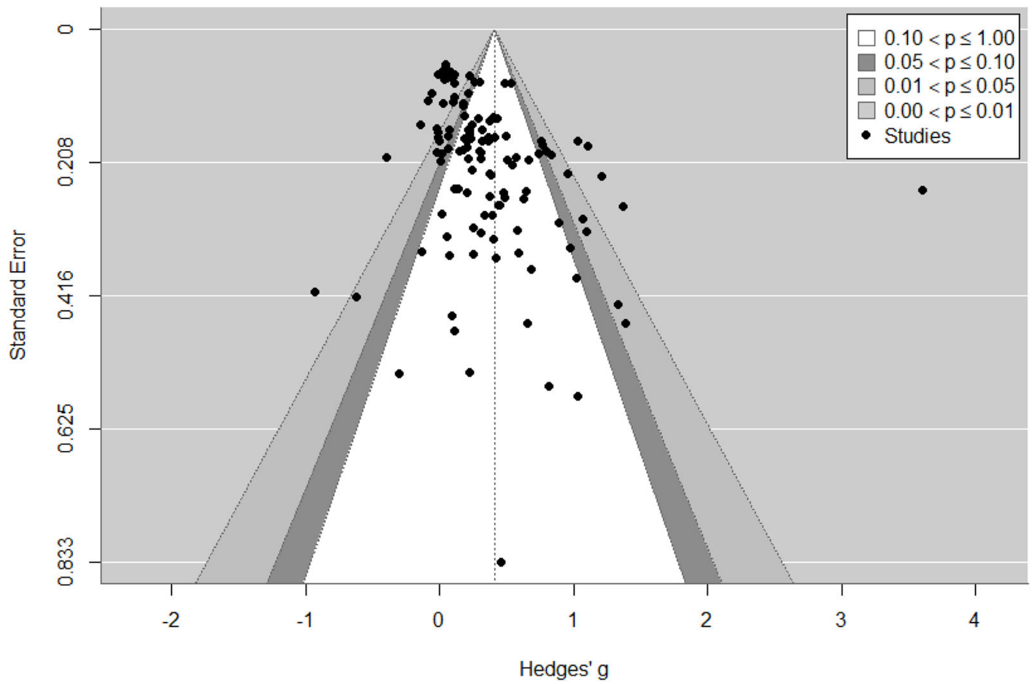

Fig. 5. A funnel plot indicating the relationship between values of Hedges' g and standard error from each study. Contour lines corresponding to thresholds of statistical significance have been included to aid visual interpretation (Sterne et al., 2011).

with captive animals, encounters with wildlife are more spontaneous and unpredictable, which may account for the greater increases in nature connectedness associated with wildlife encounters. Indeed, previous research has linked encounters with wildlife with feelings of awe and wonder, which may boost human-nature connectedness (Cameron et al., 2020; Hicks and Stewart, 2020; White et al., 2023). Moreover, mindfulness and wildlife encounters might be particularly effective at increasing human-nature connectedness because both activities involve the participant being among nature, rather than dominant over it. Hence, these activities may promote feelings of interconnectedness and of being a part of a shared community with nature (Barragan-Jason et al., 2022). As such, these activities are likely to enhance feelings that accord with the 'land ethic' of Leopold (1949) of "land as a community to which we belong". It might be possible to further enhance the increases in human-nature connectedness of other activity types by incorporating some of the elements of mindfulness and wildlife encounters. For example, by encouraging wildlife into gardens through habitat creation, it could be possible to facilitate unexpected encounters with wildlife during gardening activities, resulting in moments of awe and wonder that enhance human-nature connectedness.

Education and recreation activities were also associated with small-to-medium increases in human-nature connectedness, with mean increases of 0.35 and 0.28, respectively. Our values for educational activities were higher than the 0.10 reported for environmental activities in nature by an earlier systematic review and meta-analysis by Barragan-Jason et al. (2022).

Gardening activities were associated with the smallest increase in human-nature connectedness; the mean increase of 0.21 associated with gardening only just meeting the threshold for a small effect (Rosenberg and Rothstein, 2013), although the wide confidence interval limited our ability to draw conclusions about the effectiveness of gardening in fostering human-nature connectedness. Previous research by Hatty et al. (2022) has shown that participants in environmental activities have relatively high exposure to garden-related activities, with 76% of respondents spent time in nature within a garden at least fortnightly. High levels of prior exposure might therefore limit the impact of further gardening activities on human-nature connectedness.

Explaining variations in human-nature connectedness

Our meta-analysis indicated that the duration of an environmental activity had an influence on the resulting change in human-nature connectedness. We found evidence that activities with medium duration (i.e. those carried out over 2–7 days) led to greater increases in human-nature connectedness than activities conducted over long (>7 days) durations. However, no differences could be detected between medium and short (≤1 day) duration activities, or between long and short duration activities. Our findings suggest that increasing the duration of an environmental activity does not provide a linear increase or decrease in human-nature connectedness, but rather that the relationship between activity duration and human-nature connectedness is more complex. As such, our findings accord with the "moments, not minutes" concept (Richardson et al., 2021), which highlights that engagement with nature through brief but focused experiences is more important in fostering connection and wellbeing, than the total time spent in nature. The differences in the changes in human-nature connectedness detected for the different activity durations were not an artefact of different activity types being conducted over different durations, as the collinearity between activity type and activity duration was low (Variance Inflation Factor <1.23), below the threshold of 10.00 recommended by Dormann et al. (2013), suggesting that activity type and activity duration were not correlated. The differences that we detected might be linked to the different opportunities for contact with nature over different activity durations, as greater contact with nature is known to facilitate human-nature connectedness (Liu et al., 2022). Longer duration activities might not offer the same opportunities for immersive and intensive engagement by nature as medium duration activities, because the activities that are carried out over longer durations are done intermittently rather than continuously. Hence, long duration activities could be viewed as a series of short duration activities carried out regularly, which would be consistent with our finding that long and short duration activities did not differ significantly in their increases in human-nature connectedness. Indeed, many of the long duration activities included in our study took place intermittently over periods of up to one year (e.g. Hignett et al., 2018; Tharrey et al., 2020;

Hatty et al., 2022). Activities carried out over such long periods could also induce some level of fatigue in certain participants, reducing the increase in human-nature connectedness. It should be noted that the 'long' level of our activity duration category comprised a wide range of durations, from 8 days to up to 1 year which likely increased the heterogeneity within this level, although it did not preclude us from detecting a difference in changes in human-nature connectedness between long and medium durations. We lacked sufficient data to be able to test for differences amongst a greater range of activity durations but given the rapid rise in research on human-nature connectedness, this may be possible in the future.

For the environmental activities included in our meta-analysis, we found considerable uncertainty associated with the mean changes in human-nature connectedness, as shown by the wide 95% confidence intervals. The wide confidence intervals associated with certain activities (for example, gardening) indicated high variance among the original studies included in our meta-analysis, limiting our ability to draw conclusions about the effectiveness of these activities in fostering human-nature connectedness. Given the rapid rise in the number of published studies of human-nature connectedness (Fig. 2), further synthesis in the future will likely be able to refine the estimates of increased human-nature connectedness that we report here. Our analysis showed that activity type and activity duration together explained approximately 29% of the variance in our data, and hence there must be other variables that influence the size of the change in human-nature connectedness that occurs in response to participating in an environmental activity. Some individual studies have previously reported that changes in human-nature connectedness in response to environmental activities may differ between adults and children, as well as within these age categories (e.g., Hughes et al., 2019; Hammond, 2020; Barragan-Jason et al., 2025), as shown in two developmental cross-sectional studies by Richardson et al. (2019) and Barragan-Jason et al. (2025), as well as a longitudinal study assessing children by Otto et al. (2019). For example, an earlier study by Barragan-Jason et al. (2022) suggested assessing for variation among four age groups: <18 years, 18–25 years, 26–40 years, >40 years. In our analysis we were limited to two age groups (adults and children) as the original studies typically reported changes in human-nature connectedness for these groups only and did not report sufficient information to allow a more detailed assessment of age effects. However, previous research has suggested that human-nature connectedness may vary within these two groups; for example, an analysis by Hughes et al. (2019) reported that human-nature connectedness among people aged 5–75 years declined from childhood to a low in the mid-teens, then increasing into the early twenties and plateauing thereafter, based on a cross-sectional rather than longitudinal study.

The roles of additional covariates in shaping human-nature connectedness have also been explored in previous studies, although we were not able to include them in our meta-analysis as too few of the original studies reported these variables. Participation frequency has been linked with human-nature connectedness, at least in some studies. For example, Clayton et al. (2014) found that among 7,000 zoo and aquarium visitors in the USA, individuals who visited more frequently had significantly higher reported connections with nature than individuals who visited less frequently. However, Bruni et al. (2008) reported no correlation between human-nature connectedness and the frequency of visits to zoos. Bruni et al. (2008) also found no correlations between human-nature connectedness and a person's age, gender, or whether they were a member of a zoo. Experimental research has shown that a person's pre-existing level of human-nature connectedness can influence their response to participating in an environmental activity. As an example, Kleespies et al. (2022) reported that among visitors undertaking zoo tours involving feeding animals, those with medium or high pre-existing connections with nature showed greater increases in human-nature connectedness than individuals with low initial connection to nature.

Implications for conservation organisations

Changes in human-nature connectedness are of particular interest to conservation organisations, given the links between human-nature connectedness and pro-environmental and pro-nature conservation attitudes (Restall and Conrad, 2015; Mackay and Schmitt, 2019; Barragan-Jason et al., 2022, 2023). Our work shows that many environmental activities facilitated by conservation organisations can increase the human-nature connectedness of their supporters. Hence, the work of conservation organisations will serve to increase the human-nature connectedness of large numbers of people globally. Such efforts can include facilitating on-site activities within a conservation organisation's institute, such as how zoos facilitate encounters with captive animals (Kleespies et al., 2022) or on-site learning activities (Stead, 2022), as well as off-site activities such as encouraging supporters to engage in recreation or mindfulness in a local green or blue space. Recreational activities in particular offer widespread and diverse opportunities for conservation organisations to engage their supporters. For example, a recent review found that people engage in over 60 different types of recreational activities in blue spaces such as wetlands (Wood et al., 2024).

Our findings also provide some insights for how conservation organisations could increase the effectiveness of activities in raising levels of human-nature connectedness. Whilst the studies in our meta-analysis tested the effectiveness of discrete activity types in isolation, in practice conservation organisations could combine elements of different activities to enhance their effectiveness. In particular, it could be possible to enhance the increases in human-nature connectedness of activity types such as recreation and education through the incorporation of elements of mindfulness and wildlife encounter activities, which showed the greatest increases in human-nature connectedness. Designing multi-faceted activities to maximise the increases in human-nature connectedness would be a valuable area of future research. For example, by providing people with information to help them encourage wildlife into their gardens, it could be possible to facilitate unexpected encounters with wildlife during gardening activities that could inspire moments of awe and wonder. Similarly, incorporating moments of mindfulness into activities such as education or recreation could deepen the connection to nature that can be gained through these activities. Another consideration for conservation organisations should be the range of activities that they offer. Our study assessed mean effect sizes among groups of participants, but we recognise that not all individuals respond to nature in the same way, and that human-nature connectedness will only be increased by activities that engage and inspire individuals (Lumber et al., 2017). Conservation organisations which offer a range of environmental activities are therefore more likely to provide experiences that successfully foster human-nature connectedness among more people.

Our work highlights the role that zoos, and other institutes that facilitate encounters with captive animals, can play in conversation, through increasing the human-nature connectedness of visitors. Such institutes have the potential to increase human-nature connectedness among large numbers of people, as those affiliated to the World Association of Zoos and Aquariums receive >700 million visitors per year (Fa et al., 2014). As such, our work builds on earlier findings such as those of McNally et al. (2025), who found evidence that encounters with captive animals within zoos and similar institutes had a positive effect on the conservation knowledge, beliefs, and behaviours of zoo visitors. Although we found five studies reporting changes in human-nature connectedness associated with zoo visitation, we found no comparable studies for visits to aquariums, in common with the earlier review of Clements et al. (2019). Hence, our conclusions regarding the human-nature connectedness benefits associated with captive animal encounters are based exclusively on zoos rather than on any other type of institution with captive collections. The zoos represented in our study facilitated encounters with a range of different animal taxa, including mammals (Miller et al., 2020; Kleespies et al., 2022) and butterflies (Pennisi et al., 2017). We recognise that outside of the experimental set-ups used in the studies included in our meta-analysis, real-world zoo visits are heterogeneous. For example, in terms of the species viewed, the level of interaction (e.g. feeding), and the level of information provided (through guides or exhibits), as well as in the environmental attitudes and pre-existing levels of environmental knowledge and human-nature connectedness of the visitors. Further research is needed to explore how these elements contribute to the ability of zoo visits to increase the human-nature connectedness of visitors.

Further considerations

Most of the studies synthesized in our study were conducted in a small number of countries in the Global North, with the UK and USA together accounting for more than half of the studies. We cannot, therefore, suggest that our current analysis provides a truly global understanding of human-nature connectedness.

The majority of studies included in our analysis measured human-nature connectedness immediately after the activity and contained no follow up measurements that could be used to assess the persistence of increased human-nature connectedness over time. However, the level of human-nature connectedness experienced by a person will not be stable over time (Furness, 2021). Only 4 of the 43 studies identified in our review reported follow up estimates of the change in human-nature connectedness. Moreover, the studies that did include follow up assessments reported divergent results. Choe et al. (2020) found that the documented increases in human-nature connectedness associated with wildlife encounters had not declined after 30 days. However, Barrable et al. (2021) found that after eight weeks, participants of a mindfulness activity no longer showed elevated human-nature connectedness. The two other studies reported mixed results of their follow up assessments. A study by Harvey et al. (2023) reported that participants of an environmental educational activity showed human-nature connectedness after 60 days that, whilst not as high as those recorded in the immediate post-activity assessment, were still higher than those recorded in the pre-activity test; the Hedges' g value for the pre-activity test and follow up test was 0.365, indicating a small-medium increase in human-nature connectedness relative to the score prior to undertaking the activity. Similarly, Butler et al. (2024) found that participants had human-nature connectedness scores 4–5 weeks after engaging in a wildlife encounter activity that were higher than the scores obtained prior to the activity, but not as high as those recorded immediately after the activity. However, in this case the Hedges' g value for the pre-activity test and follow up test was only 0.056, well below the threshold for even a small effect size. Beyond the individual studies included in our meta-analysis, we note that a recent randomized clinical trial by Leão et al. (2025) found that human-nature connectedness among participants undertaking a multicomponent nature-based intervention remained higher after 30 days, especially in peri-urban areas, when compared with individuals undertaking a single mindfulness activity (classical forest bathing); hence, the types of activities and the area in which they were undertaken may both influence the persistence of elevated human-nature connectedness. Further studies will be required to understand the circumstances under which increases in human-nature connectedness persist after engagement in an environmental activity has ceased.

We assessed the changes in human-nature connectedness for each activity in isolation, as the original studies containing the data that we used have tested the effects on different activities one at a time. However, many people participate in more than one type of environmental activity. It is unclear whether the benefit to an individual's connection with nature of undertaking multiple activities would be additive.

Our analyses showed a statistically significant relationship between the Hedges' g and the standard error values, whilst a visual assessment via a funnel plot also confirmed asymmetry, which could indicate publication bias. The funnel plot illustrated a strong clustering of data points with low Hedges' g and SE values, but few corresponding data points at higher Hedges' g values. However, publication bias is only one possible cause of funnel plot asymmetry (Sterne et al., 2011). If publication bias were the primary cause of the asymmetry, we would have expected the asymmetry to show an absence of data points with low Hedges' g, consistent with non-publication of negative results (Wood, 2020). The funnel asymmetry may instead reflect heterogeneity linked to the effects of unknown variables that we could not include in our analysis (Sterne et al., 2011), particularly as the fixed effects in our best-supported model accounted for only 29% of the variance in changes in human-nature connectedness. Such variables could include prior experience with nature and personality traits, which have been shown by earlier research to influence human-nature connectedness (Lengieza and Swim, 2021; Kleespies et al., 2022).

Conclusions

Our systematic review and meta-analysis offer new evidence from a rapidly growing literature that human-nature connectedness can be increased through a range of different environmental activities, with mindfulness and wildlife encounters found to be the most effective. The increases in human-nature connectedness that we documented for outdoor environmental activities were larger than the increases documented previously for virtual activities associated with nature (Barragan-Jason et al., 2022; Brambilla et al., 2024), suggesting that in-person experiences of nature provide an important boost to increases in human-nature connectedness. Further research could explore how elements of the most effective activities such as mindfulness and wildlife encounters could be incorporated into less effective activity types, to allow conservation organisations to maximise the effectiveness of their activities in fostering human-nature connectedness.

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Data availability

The data and analytical code used in our study are available from the following *figshare* repository: https://doi.org/10.6084/m9.figshare.28271456.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.pecon.2025.08.001.

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