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Environmental self-identity partially mediates the effects of exposure and connection to nature on urban children's conservation behaviours

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ABSTRACT

As crises of biodiversity loss and climate change have intensified, so too have efforts to promote human behaviours that ameliorate these global stressors. Leveraging people's connectedness with nature is proposed as a means of inspiring pro-nature behaviours at a personal and societal scale. However, it is only recently that studies have begun to characterise the specific mechanistic drivers of connectedness and its behavioural outcomes. A separate body of research shows that self-identities motivate pro-environmental behaviours. Here, we simultaneously investigate the effects of affective connection to nature and environmental self-identity on urban children's conservation behaviours. We also evaluate passive exposure, active learning, and nature-focused activities as predictors of connectedness. Using confirmatory composite analysis and path analysis in tandem, we analyse survey responses from 1037 children and adolescents attending 16 schools throughout Sydney, Australia. In this dataset, connection to nature had a large effect on commitment to conservation behaviours, half of which was mediated by environmental self-identity. Time spent in green and blue spaces had a weak direct effect on connection to nature. Most of its impact was mediated by regular engagement with nature-focused activities (e.g., looking for wild animals), which were the strongest predictors of connectedness alongside frequency of outdoor learning and reading about nature. Greenness of school catchment areas was negatively associated with connectedness, likely because children connect with nature at a finer scale and even indoors, as suggested by the moderate positive effect of household biodiversity on connectedness. Overall, we demonstrate that not all forms of contact with nature are equal when it comes to strengthening the kinds of affective bonds that lead urban children to identify with and act for nature.

1. Introduction

Interconnected global crises of depleting biodiversity and accelerating climate change pose an unprecedented existential threat to humanity (Steffen et al., 2015). As these phenomena are anthropogenic in kind—resulting from consumptive, reproductive, and democratic choices in addition to directly destructive activities—it is ultimately a crisis of human behaviour that we are facing (Milner-Gulland, 2012; Schultz, 2011; Swim et al., 2011). There is an urgent need to identify leverage points that promote beneficial behaviours variously labelled as pro-environmental, pro-nature, and pro-conservation (Manfredo et al., 2017; Richardson, Dobson, et al., 2020; Riechers et al., 2021). An overarching aim of research in this area is to "improve" a "failing" relationship between people and the ecosystems in which we live (Richardson et al., 2020a, p. 387). If this does not occur, it is today's youth and future generations who will suffer most in the long term, as there is an inherent intergenerational inequity in the impacts of ecological crises (Hayward et al., 2022; Rios et al., 2021).

At the same time, we live on an "urban planet" (Wigginton et al., 2016, p. 905) where most people inhabit cities. Yet city living enables only certain human-nature interactions, while constraining others (McDonnell and MacGregor-Fors, 2016). Children in cities report fewer everyday interactions with nature than their rural counterparts (Collado et al., 2015), and this likely results—in part—from 'mundane' elements of urban nature going unnoticed (Newman and Dale, 2013). Indeed, a minority of urban children and adolescents feel that nature is irrelevant to their lives (Keith et al., 2022; Pointon, 2014). Fortunately, most are able to establish meaningful relationships with urban nature and vocalise this, thereby providing opportunities for us to learn from their successes (Keith et al., 2022, 2021). The fact that many conservation movements originate in cities indicates that urban living is not necessarily associated with apathy toward nature (Wang, 2010), and

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that global conservation might benefit from interactions between urban residents and nearby nature (Dunn et al., 2006).

1.1. Drivers of conservation behaviours

In seeking to understand what drives adult environmentalists to act in nature's benefit, research initially focused on childhood exposure to nature via "significant life experiences" (e.g., Hsu, 2009). Today, a large body of evidence attests to the value of contact with nature, through a variety of experiences and activities, in promoting environmental action (reviewed in Chawla, 2020; D'Amore and Chawla, 2020). Exposure to nature is not homogeneous (see Lengieza and Swim, 2021): it can be incidental or purposive (e.g., transiting through a green space by chance vs. searching for urban wildlife); it can also be vicarious or direct (e.g., reading about nature vs. visiting a national park). Opportunities for spending time in nature are influenced by where people live and work/study (e.g., in relatively green vs. grey urban neighbourhoods), including their ability or inability to travel (as evidenced during the COVID-19 pandemic). These variables are, in turn, constrained by demographic traits such as socioeconomic disadvantage (Astell-Burt et al., 2014; Gallegos-Riofrío et al., 2022). All of these factors interact in such a way that they create countless modalities of human-nature interaction, with frequency of contact adding further complexity to this milieu (Lengieza and Swim, 2021). However, very few studies have simultaneously tested the predictive power of different frequencies and modalities of nature exposure to determine which ones are most impactful (Chawla, 2020).

Attention has recently shifted to nature connectedness as a driver of commitment to conservation (Hughes et al., 2018; Richardson et al., 2020b). One of the motivators of this transition was the emerging consensus that contact alone does not necessarily inspire people to act pro-environmentally; rather, it is essential to care about nature (Lumber et al., 2017). For this reason among others, enhancing nature connectedness is now considered the most promising target for promoting beneficial behaviours (see Richardson et al., 2020a). Nature connectedness can be defined as "a psychological joining of nature and the self which manifests as a sense of oneness with nature" (Lengieza and Swim, 2021, p. 2). People connect with nature not only through sensory contact, but also emotion, beauty, meaning, and compassion (see Lumber et al., 2017). In other words, the strongest connections to nature are cognitive, affective, and experiential in character (Zylstra et al., 2014).

Children and adolescents who connect strongly with nature are likely to undertake conservation behaviours (Hughes et al., 2018; Keith et al., 2021). Understanding exactly how this association arises is key to developing interventions that have the potential to mitigate the global ecological crisis and boost human health (Richardson et al., 2020a), yet we are only beginning to identify the specific mechanistic drivers of nature connectedness, especially in children (Lengieza and Swim, 2021). There is also uncertainty surrounding how connectedness interacts (and potentially overlaps) with closely aligned psychological constructs such as environmental identity (Vesely et al., 2021).

Environmental self-identity, i.e., "the extent to which you see yourself as a type of person who acts environmentally-friendly" (Van der Werff et al., 2013, p. 56), is a particular form of environmental identity related to nature connectedness (Tam, 2013). Indeed, some scholars argue that the two constructs could be categorised under the same rubric (Vesely et al., 2021). Despite this assertion, some initial evidence suggests that nature connectedness is a causal factor implicated in the formation of environmental identity via biospheric values (Martin and Czellar, 2017; Van der Werff et al., 2013). Thus, it is useful to treat environmental identity and connection to nature as very closely related yet distinct phenomena (e.g., Mackay et al., 2021), both of which promote pro-environmental behaviours (see Barragan-Jason et al., 2022; Mackay and Schmitt, 2019; Udall et al., 2021; Vesely et al., 2021; and Whitburn et al., 2020 for meta-analyses).

There is a dearth of knowledge regarding how nature connectedness and environmental self-identity interact as behavioural predictors. In the absence of studies where these constructs have been explored together, we generated research hypotheses from findings originating in two separate bodies of research: a large collection of studies on nature connectedness, and a smaller group of papers on the relatively neglected environmental self-identity. Through this process, we developed a theoretical framework linking these constructs in a predictive chain to conservation behaviours, with exposure to nature included as an antecedent (Fig. 1). This framework includes logical alternatives for each hypothesis, which we test in this study using path analysis. These specific hypotheses follow.

1.2. Hypotheses

H1. Effects of exposure to nature on conservation behaviours are mediated by connection to nature. For this to occur,
a) exposure to nature must directly predict connection to nature, and
b) connection to nature must directly predict conservation behaviours.

H2. Exposure to nature directly predicts conservation behaviours. This is an alternative hypothesis to H1.

H3. Effects of connection to nature on conservation behaviours are mediated by environmental self-identity. For this to occur,
a) connection to nature must directly predict environmental self-identity, and
b) environmental self-identity must directly predict conservation behaviours.

H4. Exposure to nature directly predicts environmental self-identity. This would allow for a mediated effect of exposure to nature on conservation behaviours in the case that H1 and H2 were refuted but H3 was supported.

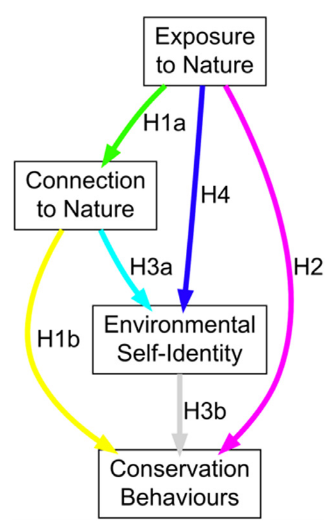

Fig. 1. Hypothesised predictive paths between key theoretical constructs. Paths are labelled according to the nomenclature above.

2. Methods

2.1. Participants and procedure

To collect survey data for this study, we distributed an online questionnaire to 16 public (i.e., government) schools located throughout the urban centre of Sydney, Australia (Fig. 2). Eight of these were primary schools with classes from kindergarten through grade 6 (student ages ~5–11); eight were secondary schools with students in grades 7–12 (ages

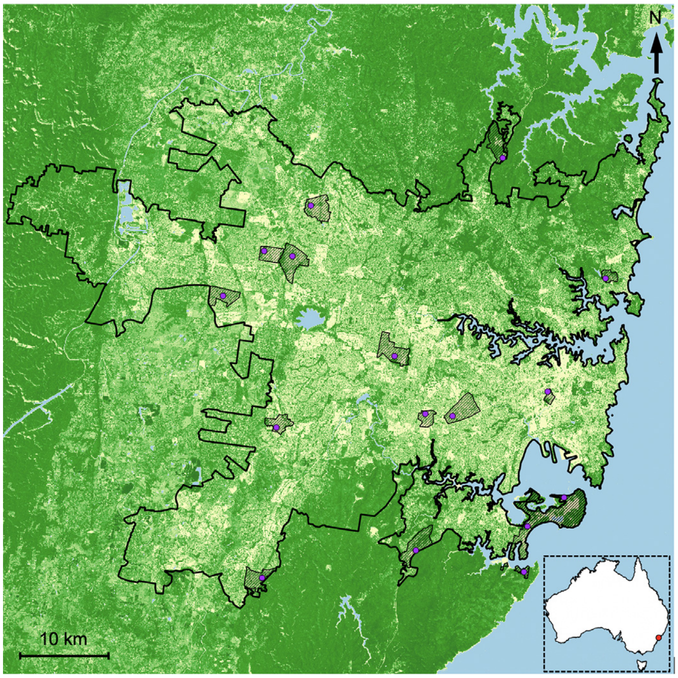

Fig. 2. Pseudocolour map of Sydney based on Normalized Difference Vegetation Index (NDVI) values, showing the location of participating schools (purple points) and their catchments (black shaded areas). The area enclosed by the thick black line is Sydney's urban centre as defined by the Australian Bureau of Statistics (UCL #101001). Water appears blue and vegetated areas dark green, with impervious surfaces in pale yellow. Spatial resolution = 10 m. Inset is an outline map of Australia, with Sydney's location marked in red.

~12–18). All but one of the schools was co-educational; an all-girls' secondary school was also included in our sample.

Participating schools were representative of those across the state of New South Wales in terms of socioeconomic status and linguistic diversity within student cohorts (Keith et al., 2021). To attend a particular public school in Sydney, students must reside within the school's intake zone or "catchment area". The distribution of tree canopy cover among the catchments of participating schools accorded well with canopy cover data collected across Sydney's Local Government Areas (Keith et al., 2021), indicating they are representative of schools throughout the city in this regard.

At each school, we recruited respondents opportunistically across grades 3-8 (ages ~8–14), with a goal of at least 50 students per year group in total. This initially involved asking each school principal to endorse our research and nominate a teacher to coordinate the project onsite. We then liaised with coordinating teachers, who in turn engaged classroom teachers to distribute participant information statements and consent forms to their students. As only some teachers volunteered to take part, recruitment of class cohorts within each year group was typically incomplete. Participants in secondary school provided informed consent to take part in this study, whereas primary schoolers assented with additional written consent from a parent or carer. Ethical protocols were approved by both the University of Sydney's Human Research Ethics Committee (#2016/961) and the New South Wales Government's State Education Research Applications Process (#2016467).

Teachers administered our questionnaire in class during March of 2017, under controlled conditions such that students did not research their answers. A total of 1269 questionnaires were returned, including 1157 that were more than 90% complete. Of these, 1037 were from respondents who specified both their age and gender, forming the dataset analysed here. This included 569 girls and 468 boys. Sample sizes of age groups from 8 to 14 years were as follows: 64, 96, 43, 71, 314, 330, 119. The over-representation of older participants reflects the fact that year group cohorts were much larger in secondary schools, where recruitment was further boosted by heads of department.

2.2. Measures

2.2.1. Exposure to nature

2.2.1.1. Frequency of visits to green / blue spaces. For this study, we constructed a composite measure of ambient nature exposure using the frequencies at which students visited different green and blue spaces. We chose six location types based on prior research into places that urban Australian adolescents value (Widdop Quinton, 2015): parks, sports fields, "bush" (i.e., forest/scrub), front and backyards (i.e., domestic gardens), the ocean, and waterways. Respondents indicated how often they visited each place by choosing one of six options on a frequency scale: never, yearly (1-2 times per year), occasionally (3-4 times per year), monthly (1-2 times per month), weekly (1-3 times per week), or daily (every day). Where participants struggled to choose between adjacent options, they were instructed to select the lesser of the two. Prior to analysis, responses were each assigned a decimal value between 0 (never = 0/365) and 1 (daily = 365/365). As they reflect an underlying count of visits with a true zero, these values were treated as numeric data in our analyses. Any discontinuities between response options were blurred on aggregate by the process of extracting and transforming composite scores derived from a combination of weighted items (see Section 2.3).

2.2.1.2. Frequency of nature-focused activities. We surveyed the frequency with which students undertook nature-focused activities (cf. "simple nature activities" in Richardson et al., 2020b) by asking them how often they gardened, played with pets outside, went for long walks outside, and looked for wild animals (e.g., birdwatching). The first three of these activities were previously mentioned by adolescents in Melbourne, Australia, when discussing their connections to nature (Widdop Quinton, 2015), and the final indicator was adapted from a survey of children's nature connectedness in Tokyo, Japan (Soga et al., 2016). Students responded on the same frequency scale we used for visits to green / blue spaces, and we treated their responses in an identical manner.

2.2.1.3. Participation in outdoor recreation. We measured participation in outdoor recreation by asking respondents how often they went camping, surfing, and fishing. We featured these three pastimes because they are popular among Australian residents and have been implicated in prior studies as potentially important predictors of connectedness to nature in children and adolescents (Hignett et al., 2018; Szczytko et al., 2020). Prior to analysis, we assigned a value of 0 to *never* responses and a value of 1 to all other categories, thereby creating binary numeric variables.

2.2.1.4. Learning about nature. Considering the diversity in sources of information about nature available to children, we designed a broad composite measure of learning. We asked respondents how often they learnt about nature from television, the internet, print media ("books, magazines, [and] newspapers"), school classes, talking with family, talking with friends, and going outdoors. Five of these items were adapted from a measure of vicarious nature experiences designed for use with Japanese schoolchildren (Soga et al., 2016). To these, we added the item referencing school classes as a source of formal learning, plus the final item as an indicator of experiential nature-based learning (sensu Chawla, 2021). Students responded to items using a 4-point frequency scale: never, rarely, sometimes, often. Frequency categories were assigned integers from 0 to 3, with the resulting data treated as ordinal.

2.2.1.5. Household biodiversity. To measure a proxy for organismal biodiversity in students' immediate home environment, we asked participants how many outdoor plants ("trees, bushes, flowers etc."), indoor plants, pets, "bugs", and other wild animals ("birds, lizards, frogs etc.") they had at home. Respondents answered these five items using a simple 3-point scale of relative abundance: none, some, or lots (i.e., many). These response categories were assigned values from 0 to 2 and data were treated as ordinal.

2.2.1.6. Local greenness. To generate an objective (vs. self-reported) measure of greenness in students' local areas, we calculated the mean NDVI value within each school catchment boundary using QGIS version 3.14.0 (QGIS Development Team, 2020). First, it was necessary to produce NDVI values. We downloaded Sentinel-2 multispectral data from the Copernicus Open Access Hub for the two 100 km x 100 km image tiles (T56HKH & T56HLH) covering Sydney's urban centre. These data were sensed in the early morning of August 8th and 28th, 2016. They included red and near-infrared (NIR) spectral bands, allowing us to calculate NDVI for each 10×10 m pixel using the standard formula: NDVI = (NIR – red) / (NIR + red). We generated a new layer from NDVI data and intersected this with the shapefiles bounding our 16 school catchments, which we imported from the 'School intake zones (catchment areas) for New South Wales government schools' online dataset (Centre for Education Statistics and Evaluation, 2017). With this complete, we calculated the mean NDVI within each catchment using the Zonal Statistics plugin.

2.2.1.7. Population density. We used the Zonal Statistics plugin once more to calculate population density within each school catchment. This involved intersecting their shapefiles with a layer comprising the 'Australian Population Grid 2016' dataset (Australian Bureau of Statistics, 2017).

2.2.1.8. Local blueness. We calculated a measure of local blueness in QGIS by drawing a circular buffer with a 5 km radius around each school (Fig. 3) and intersecting this with a rasterised layer of NDVI values below a ground-truthed threshold of -0.1 (as these values corresponded to water). This returned the area of blue space within each buffer. Our definition of "local" became particularly relevant to many residents of Sydney during COVID-19 lockdowns, as those in high-risk zones were not permitted to travel more than 5 km from home (Chand et al., 2021).

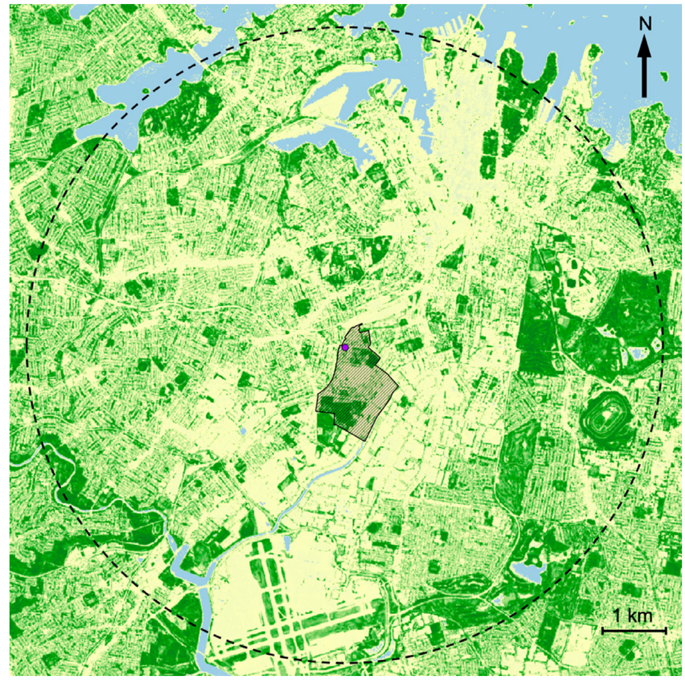

Fig. 3. Pseudocolour NDVI map showing an aerial view of one school (purple point) located within its catchment (black shaded area) and 5 km buffer (black dashed line). The rasterised layer for water is overlaid in blue. Spatial resolution of 10 m.

2.2.2. Connection to nature

We quantified nature connectedness using the Connection to Nature Index (CNI), which is a trait measure intended for use with children (Cheng and Monroe, 2012). The CNI is comprised of 16 items across four subscales: 'enjoyment of nature', 'empathy for creatures', 'sense of oneness', and 'sense of responsibility'. Students responded to each item on a 5-point Likert scale from strongly disagree to strongly agree. The CNI had a high overall internal reliability for our dataset, with a Cronbach's α of .88 (Keith et al., 2021).

A CNI score is typically calculated by taking the mean across all 16 items (Hughes et al., 2018). Following this logic, we treated the CNI as a unidimensional measure with some internal structure—i.e., subscales—by modelling it using a bifactor configuration (see Keith et al., 2021). Each CNI item loaded on the general factor 'connection to nature' in addition to one of three specific factors (cf. subscales). The bifactor model fit our dataset very well, but the presence of multidimensionality was not severe enough to preclude interpretation of the CNI as a primarily unidimensional measure (Keith et al., 2021). Thus, in this study, we exclusively analysed scores for the general factor 'connection to nature', treating them as continuous numeric data. To aid interpretation, however, regular CNI scores (sensu Hughes et al., 2018) are presented in graphs.

When validating the CNI, we detected scalar noninvariance of CNI responses across gender groups, meaning differences between boys' and girls' scores were driven—at least in part—by differential item functioning (Keith et al., 2021). To counteract this issue, we extracted the 'connection to nature' values analysed in this study from a partially invariant bifactor model in which the intercepts of four noninvariant items were freed (see Keith et al., 2021).

2.2.3. Environmental self-identity

To measure environmental self-identity (ESI), we modified three items from research instruments designed for use with adults (see Van der Werff et al., 2013): "I see myself as an environmentally friendly person.", "Protecting nature is an important part of who I am.", and "I am the type of person who cares for nature." Students responded on a 4-point scale ranging from strongly disagree to strongly agree. We assigned each response category an integer between -2 and 2 and treated those values as ordinal data in analyses.

2.2.4. Conservation behaviours

2.2.4.1. Willingness to conserve nature. We measured students' willingness to conserve nature utilising items originally developed for adults and subsequently modified for use with children (Kals et al., 1999). We selected and adjusted three items from prior research: 'I am willing to volunteer to help protect nature.' (Silvas, 2013), 'I am willing to give money to nature charities.' (cf. Müller et al., 2009), and 'I am willing to talk to friends and family about protecting nature.' (cf. Collado et al., 2013). Students responded on a 4-point scale ranging from strongly disagree to strongly agree. We assigned each response category an integer between -2 and 2 and treated those values as ordinal data when we analysed them. Given some activities such as volunteering were not necessarily accessible to all respondents even if they were willing to take part (e.g., because it required parental endorsement), we also collected a measure of everyday behaviours.

2.2.4.2. Frequency of environmentally responsible behaviours. We asked students how often they made an effort to "save" water and energy, as well as recycle rubbish. These items were adapted from a measure of 'daily conservation actions' developed for use with Spanish children

(Collado et al., 2013). Participants responded to these three items using a 5-point Likert scale of relative frequencies ranging from never to always. We assigned each category a value of 0 to 4 and treated these data as ordinal.

2.2.5. Demographic covariates

We included variables for age, gender, and socioeconomic disadvantage in our dataset to act as covariates in path models. Respondents selected their age from a dropdown list of integers and specified their gender by choosing either 'boy' or 'girl'; those who chose 'rather not say' were not included in this dataset. We assigned a value of 1 to 'girl' and 0 to 'boy', thereby creating a binary variable. We used Family Occupation and Education Index values from 2016/17, which the New South Wales Department of Education calculated to inform their Resource Allocation Model (New South Wales Department of Education, 2019), as a school-level measure of socioeconomic disadvantage.

2.3. Data analysis

All our analyses were conducted in R version 4.1.2 "Bird Hippie" (R Core Team, 2021) and RStudio version 2021.09.2 "Ghost Orchid" (RStudio Team, 2021), with data visualisation courtesy of packages 'DiagrammeR' (Iannone, 2022) and 'ggplot2' (Wickham, 2009). We used a two-step approach to model relationships between variables of interest and their indicators. The first involved estimating and assessing our measurement (i.e., outer) model using Confirmatory Composite Analysis. We then extracted construct scores for use in the second step, which entailed testing our structural (i.e., inner) model via path analysis. Two-step analysis is the predominant approach to modelling with composite variables (Henseler, 2021). Purpose-built programs such as 'cSEM'—short for Composite-Based Structural Equation Modeling (Rademaker and Schuberth, 2020)—implement routines tailored to composite analysis (vs. latent variable analysis) in keeping with best practices established via important theoretical advances. By contrast, more popular techniques such as Full Information Maximum Likelihood Structural Equation Modelling (FIML SEM) suffer from shortcomings when estimating models with endogenous composite constructs (Rigdon et al., 2014). However, using variance- and covariance-based methods in tandem can overcome such issues and capitalise on the strengths of both approaches (Benitez-Amado et al., 2018).

We began by importing our raw data and defining each indicator as either numeric or ordinal, as previously specified. We then wrote a measurement model using 'lavaan' syntax (Rosseel, 2012) wherein all endogenous variables in Fig. 4 were defined as a sum of their indicators. By including correlation terms between all variables, we specified a saturated model in which constructs could freely covary (Henseler, 2021, p. 196). This allowed us to conduct a Confirmatory Composite Analysis using the function csem() with rank-one approximation and 10000 bootstrapped resamples (Henseler, 2021). We were required to specify dominant indicators for each variable, which we chose based on face validity, i.e., theoretical relevance and likelihood of correlating positively with the construct (Benitez et al., 2020). They were, in an order corresponding to the variable list from our preceding Measures section: 'the bush', 'looking for wild animals', 'camping', 'going outdoors', 'outdoor plants', 'I see myself as an environmentally friendly person.', 'I am willing to volunteer to help protect nature.', and 'recycle rubbish'.

We evaluated the measurement model according to best practices (see Benitez et al., 2020), using statistics generated by the postestimation functions from the 'cSEM' package (Rademaker and Schuberth, 2020). For composite variables, we focused on the significance of indicator weights and loadings returned by the summarize() function, as well as Variance Inflation Factors (VIFs) calculated using the vif() function from 'car' (Fox and Weisberg, 2019). For latent variables, summarize() returned Dijkstra-Henseler's rho (ρ_A), Average Variance Explained (AVE), and the Heterotrait-Monotrait criterion (HTMT), which are the

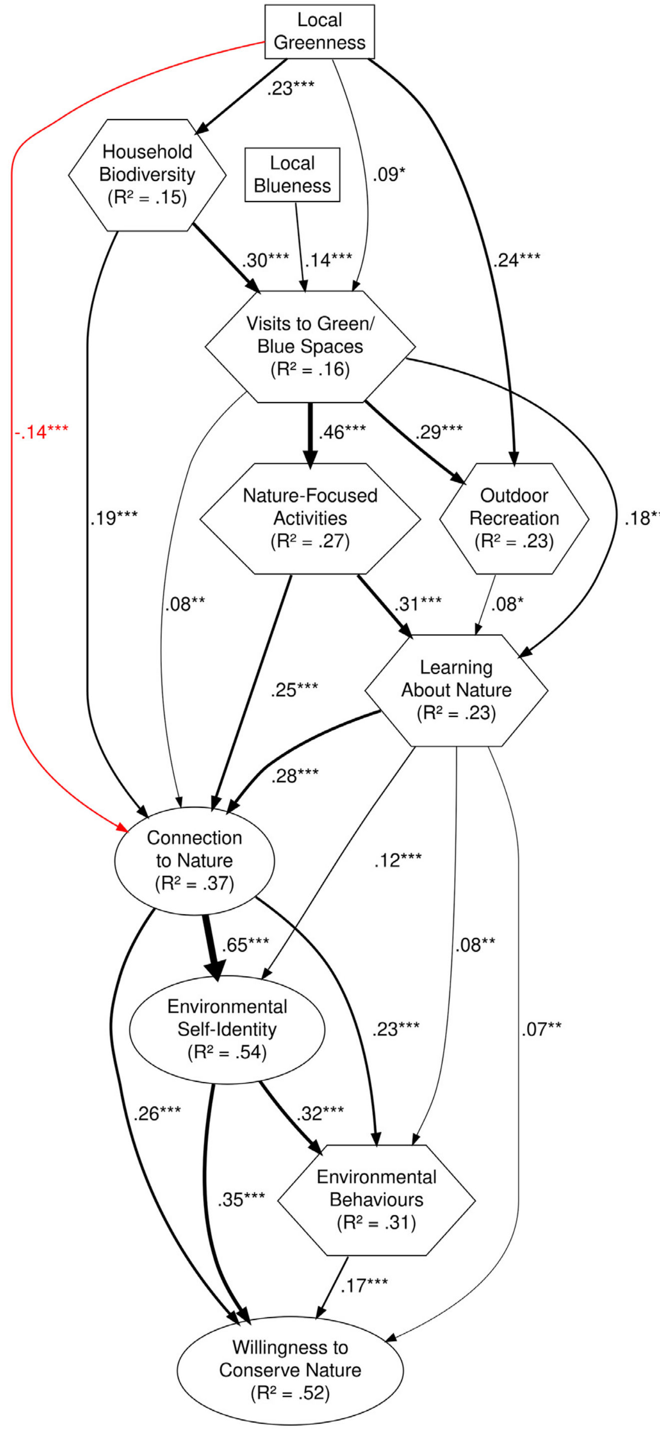

Fig. 4. Path diagram depicting significant predictive relationships between variables representing children's (N = 1037) exposure to, feelings toward, and actions for nature. Arrows are labelled with standardised regression coefficients; asterisks denote significance ($^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$). Line weights are scaled to coefficient size. Composite variables are enclosed by hexagons, latent variables by ovals, and exogenous variables by rectangles. Demographic variables (age, gender, and disadvantage) are not shown due to space constraints but were included as covariates for every endogenous variable.

preferred measures for construct reliability, convergent validity, and discriminant validity in partial least squares analyses (Benitez et al., 2020). These metrics were not generated for Connection to Nature, as it was a single-indicator construct (representing a factor score) that we exhaustively validated in a prior study using this very dataset (see Keith et al., 2021). For evaluating goodness of fit, we opted to use the Comparative Fit Index (CFI), Root Mean Squared Error of Approximation (RMSEA), and Standardized Root Mean Residual (SRMR) values returned by assess(), in addition to the chi-square result (Benitez et al., 2020). The alternative approach—i.e., assessing overall model fit using bootstrap-based tests—was not applicable to our dataset because the testOMF() function cannot, at the time of writing, handle polychoric correlations between ordinal indicators (Rademaker, 2021). We considered a CFI value above .90 to be "acceptable" (Brown, 2015, p. 75), with CFI > .95, RMSEA < 0.06, SRMR < 0.08, and χ^2/df < 5 indicating a good fit (West et al., 2012).

After evaluating the fit of our measurement model, we extracted standardised scores for every modelled variable using the getConstructScores() function in 'cSEM' (Rademaker and Schuberth, 2020). We then used the plotNormalDensity() function from the package 'rcompanion' (Mangiafico, 2016) to make a visual assessment of how each construct's scores were distributed with reference to a normal curve. Having established that the scores for all constructs except Connection to Nature deviated substantially from normality, we used the bestNormalize() function from its eponymous package (Peterson, 2021) to determine which transformation method would best normalise each of them. In all cases, the Ordered Quantile normalization transformation (Peterson and Cavanaugh, 2020) was optimal, which we implemented using the orderNorm() function in 'bestNormalize'. Connection to Nature scores were simply centred and scaled using the center_scale() function from the same package. At this point, we combined the transformed/scaled construct scores with our demographic and geographic variables to create a new dataset for the second stage of our two-step analysis.

We next built a structural model specifying our hypothesised predictive links between variables (Table A1) using 'lavaan' syntax (Rosseel, 2012). Age, gender, and socioeconomic disadvantage were included as covariates for all paths. Paths were unidirectional (as in all recursive models), and we specified directionality according to which variable in each pair was—theoretically—most likely to drive causality. We included a correlation term between Household Biodiversity and Frequency of Nature-Focused Activities because both included an indicator referring to pets. We also allowed Frequency of Nature-Focused Activities to correlate with Participation in Outdoor Recreation as they both addressed activities in nature and were originally measured on the same scale. We built mediation analyses into the model syntax by defining parameters representing direct, indirect, and total effects using a combination of variable labels and := operators.

We tested our path model using the lavaan() function's default settings, specifying that input variables should be standardised by the program prior to path analysis. We checked this test was sufficiently powerful by conducting a power analysis using the semPower.posthoc() function from the 'semPower' package (Moshagen and Erdfelder, 2016). After the model was estimated, we used the summary() function—also from the 'lavaan' package—to return standardised path coefficients (β) and their p values, R^2 values for endogenous variables, and measures of fit (including CFI, RMSEA, and SRMR). We used these outputs to evaluate the structural model. We considered an effect to be weak when $\beta < 0.2$, moderate when $0.2 \leq \beta < 0.5$, and strong when $\beta \geq 0.5$ (Acock, 2014).

Where paths between composite measures of nature exposure and Connection to Nature were statistically significant, we interrogated the indicator-level drivers of these associations. Using art() and anova() functions from the package 'ARTool', we conducted a series of non-parametric analyses of variance wherein indicators of nature exposure were the independent variables and aligned rank-transformed Connection to Nature scores formed the dependent variable (Wobbrock et al., 2011). We took this approach to testing because the 'ARTool' was specifically designed to suit the peculiarities of data derived from Likert scales (Wobbrock et al., 2011). Outputs include eta-squared (η^2) values for effect sizes, which we interpreted as being small when $0.01 \leq \eta^2 < 0.06$, medium when $0.06 \leq \eta^2 < 0.14$, and large when $\eta^2 \geq 0.14$ (Cohen, 1988). Where effects were large, we used the functions emmeans() and contrast() to conduct pairwise post-hoc tests that indicated the location and valence of differences between groups, with p values adjusted via the Tukey method for comparing families of estimates (Lenth, 2019).

3. Results

3.1. Measurement model

Our Confirmatory Composite Analysis validated the measurement model. Measures of fit all fell within the heuristic ranges for adequate fit; χ^2 (469, N = 1037) = 2025, CFI = .90, RMSEA = .057, SRMR = .046.

None of our composite variables suffered from multicollinearity issues; indicator VIF values ranged between 1.08 and 2.23, all of which were well below the threshold of 5 (Hair et al., 2017). All indicators had statistically significant loadings ($p < .001$), meaning there were no candidates for exclusion on the basis of nonsignificant loadings and weights (see Benitez et al., 2020). Indicators with weights approaching zero (90% CIs, Table A2) were retained in the interest of construct validity (Hair et al., 2017); dropping them had no appreciable effect on downstream analyses. The indicator 'internet' was unique in having a negative weight (on the composite Learning About Nature).

The two latent constructs Environmental Self-Identity and Willingness to Conserve Nature exhibited good reliability (ρ_A = .77 for both) and convergent validity (AVE = .65 & .61 respectively). Discriminant validity was also apparent for these constructs (HTMT = .83).

3.2. Structural model

Path analyses revealed that our structural model fit the dataset very well, χ^2 (23, N = 1037) = 66.8, CFI = .99, RMSEA = .043, SRMR = .019. Our analysis was sufficiently powerful; the sample size of 1037 was associated with a power of 99.97% to reject a model with 23 degrees of freedom and an amount of misspecification corresponding to RMSEA = .05 at $\alpha = .05$.

Significance tests of path coefficients supported most of our hypotheses regarding relationships between variables (Table 1). All statistically significant paths—excluding demographic covariates—are shown in Fig. 4 and summarised in Fig. A1.

3.3. Hypothesis tests

Hypothesis 1a involved testing direct paths between measures of exposure to nature and Connection to Nature. Direct effects of Learning About Nature, Frequency of Nature-Focused Activities, and Household Biodiversity on Connection to Nature (Fig. 4) were positive, significant ($p < .001$), and moderate in size ($\beta \gtrsim .20$). The direct effect of Frequency of Visits to Green/Blue Spaces was relatively weak ($\beta = .083$, $p = .008$), but its indirect effect—mediated by Frequency of Nature-Focused Activities and Learning About Nature—was moderate in size ($\beta = .21$, $p < .001$). These results support H1a. However, contrary to our hypotheses, Local Greenness was a direct negative predictor of Connection to Nature (Fig. 4). Plus, the direct effects that Participation in Outdoor Recreation (β = -.021, $p = .46$), Local Blueness ($\beta = .028$, $p = .33$), and Population Density ($\beta = .028$, $p = .40$) had on Connection to Nature were not statistically significant. Hypothesis 1b was supported by the moderate direct effects that Connection to Nature had on Frequency of Environmentally Responsible Behaviours and Willingness to Conserve Nature (Fig. 4).

Hypothesis 2, as an alternative to Hypothesis 1, required us to test for direct effects of exposure to nature on conservation behaviours. We

Table 1
Matrix summarising tests of significance for path coefficients linking endogenous variables, as well as local greenness (LG), local blueness (LB), and population density (PD). The presence of a plus symbol indicates we hypothesised a positive relationship between the predictor and the response variable. A minus indicates a hypothesised negative relationship. If either symbol is greyed out, the relationship was not statistically significant at $\alpha = .05$. Black dots indicate significant tests of correlation terms from the structural model. Empty cells represent paths that were not modelled as they were not attached to our hypotheses. Colours follow Fig. 1, with cells representing each hypothesis shaded as follows: H1 = magenta, H2a = green, H2b = yellow, H3a = cyan, H3b = grey, H4 = blue. The first cell in row 6 is marked with an asterisk as a special case; the path was significant but had an opposite sign to what was hypothesised.

Response	Predictors										
	LG	LB	PD	1.	2.	3.	4.	5.	6.	7.	8.
1. Household biodiversity	+	+	–								
2. Visits to green / blue spaces (frequency)	+	+	–	+							
3. Nature-focused activities (frequency)	+	+	–	•	+						
4. Outdoor recreation (participation)	+	+	–		+	•					
5. Learning about nature	+	+	–		+	+	+				
6. Connection to nature	–*	+	–	+	+	+	+	+			
7. Environmental self-identity								+	+		
8. Environmental behaviours (frequency)								+	+	+	
9. Willingness to conserve nature								+	+	+	+

found that Learning About Nature was a statistically significant direct predictor of Willingness to Conserve Nature, but this effect was weak (β = .072, p = .005). So too was its effect on Frequency of Environmentally Responsible Behaviours (β = .079, p = .008). These findings provide limited support for Hypothesis 2. The indirect effects of Learning About Nature on conservation behaviours were stronger, both for Willingness to Conserve Nature (β = .14, p < .001) and Frequency of Environmentally Responsible Behaviours (β = .16, p < .001).

In testing Hypothesis 3, we found that half of Connection to Nature's effect on Willingness to Conserve Nature (β = .60, p < .001) was mediated by Environmental Self-Identity (β = .30, p < .001). Similarly, 48% of Connection to Nature's effect on Frequency of Environmentally Responsible Behaviours (β = .43, p < .001) was mediated by Environmental Self-Identity (β = .21, p < .001). These findings support Hypothesis 3. Hypothesis 3a received particularly strong support (β = .65, p < .001), and the direct effects of Connection to Nature and Environmental Self-Identity on conservation behaviours were moderate in size (Fig. 4).

The direct effect of Learning About Nature on Environmental Self-Identity was statistically significant but weak (β = .12, p < .001), providing limited support for Hypothesis 4. The indirect effect of Learning About Nature on Environmental Self-Identity—as mediated by Connection to Nature—was stronger (β = .18, p < .001).

As expected, the covariance term between Frequency of Nature-Focused Activities and Household Biodiversity was significant (β = .29, p = < .001), as was the term involving Participation in Outdoor Recreation (β = .089, p = .003). However, Local Blueness was not a significant predictor of Household Biodiversity (β = .062, p = .06), Frequency of Nature-Focused Activities (β = .015, p = .63), Participation in Outdoor Recreation (β = .006, p = .85), nor Learning About Nature (β = -.027, p = .40). Local Greenness did not predict Frequency of Nature-Focused Activities (β = -.062, p = .13) nor Learning About Nature (β = -.039, p = .36). Population Density did not predict any other variable and thus is not depicted in Fig. 4.

3.4. Demographic covariates

Demographic variables, which were included as covariates in all regressions, directly predicted several endogenous variables. Age was a negative predictor of Connection to Nature (β = -.088, p < .001), Environmental Self-Identity (β = -.089, p < .001), Frequency of Nature-Focused Activities (β = -.060, p = .041), and Household Biodiversity (β = -.064, p = .046). Female gender positively predicted Frequency of Nature-Focused Activities (β = .10, p < .001), Learning About Nature (β = .059, p = .039), and Willingness to Conserve Nature (β = .048, p = .027). Male gender positively predicted Frequency of Visits to Green / Blue Spaces (β = .082, p = .005) and Participation in Outdoor Recreation (β = .099, p < .001). Socioeconomic Disadvantage was a negative predictor of Household Biodiversity (β = -.17, p < .001), Participation in Outdoor Recreation (β = -.15, p < .001), Learning About Nature

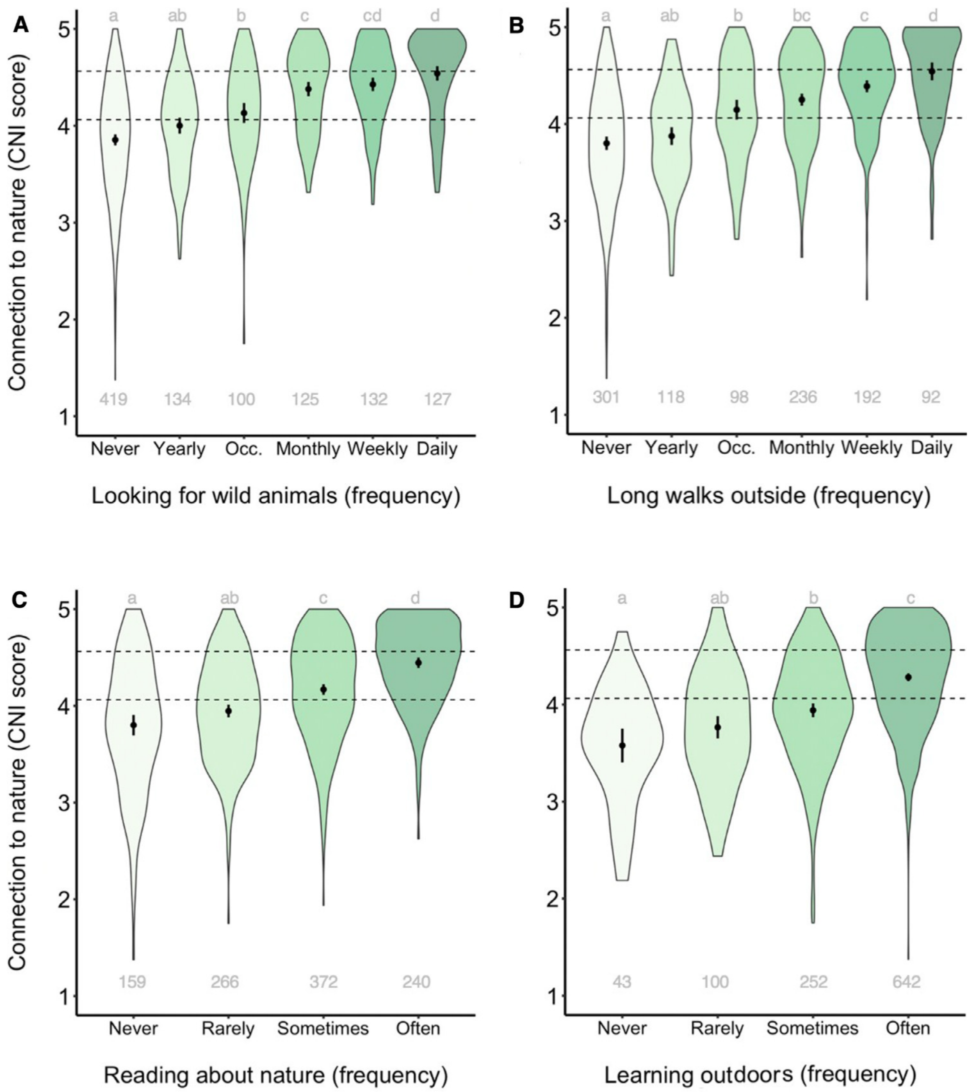

Fig. 5. Connection to nature increased in strength with the frequency at which students (A) looked for wild animals, (B) went on long walks outside, (C) read about nature in print, and (D) went outdoors to learn about nature. Violin plots surround means (black points) and 95% confidence intervals (whiskers) calculated for each frequency category. Dashed lines delineate thresholds for strong (CNI > 4.56) and weak (CNI < 4.06) connections to nature (Hughes et al., 2018). Grey numbers give n for each frequency category; grey letters denote overlap between category means at $\alpha = .05$.

(β = -.074, p = .033), and Frequency of Environmentally Responsible Behaviours (β = -.061, p = .020).

3.5. *Specific predictors of connection to nature*

Our path analysis (Fig. 4) revealed that the composite variables Frequency of Nature-Focused Activities, Frequency of Visits to Green / Blue Spaces, Learning About Nature, and Household Biodiversity were statistically significant predictors of Connection to Nature. To investigate the drivers of these relationships further, we tested the effect that every indicator from these composites had on Connection to Nature (Table A3). Four indicators had large effects ($\eta^2 \geq .14$): looking for wild animals (Fig. 5A), going for long walks outside (Fig. 5B), reading about nature in print (Fig. 5C), and learning outdoors (Fig. 5D).

4. Discussion

We found that regularly partaking in nature-focused activities, learning about nature, and living in a biodiverse home environment directly predicted the strength of respondents' connections to nature. Connectedness, in turn, predicted engagement in conservation behaviours, with half of this large effect being mediated by environmental self-identity. By contrast, contact with nature through learning was only a weak direct predictor of conservation behaviours and environmental self-identity. These key findings highlight the importance of both affective connection to nature and environmental self-identity as mediators between nature exposure and pro-nature behaviours in urban children.

4.1. *Predictors of connection to nature*

4.1.1. *Nature-focused activities*

Of all the connectedness antecedents we tested, nature-focused activities had the greatest impact. Respondents who reported making a daily effort to look for wild animals were, on average, strongly connected to nature, whereas those who claimed they never engaged with this activity were, on average, weakly connected (Fig. 5A). The same could be said for respondents' reported walking behaviours (Fig. 5B). Effect sizes were large, evidencing robust links between the strength of urban children's connections to nature and the frequency with which they reported looking for wild animals or going for long walks outdoors. Gardening and playing with pets both had moderate effects on connectedness. These results provide much-needed specificity regarding the type of nature contact needed to promote connectedness in children (Chawla, 2020; Lengieza and Swim, 2021), adding to scattered findings from a primarily adult-focused evidence base.

Looking for wildlife was the activity that most impacted connectedness with nature in our study. This aligns with a recent cross-sectional study of adult residents of the UK, which showed that, of the 11 "simple" activities investigated, watching wildlife was the best predictor of nature connectedness (Richardson et al., 2020b). Given the fact that adults' connectedness with nature can be measured, in part, by agreement with the statement 'I take notice of wildlife wherever I am' (Nisbet et al., 2009; Nisbet and Zelenski, 2013), it was not unexpected that wildlife watching played a similarly important role in this study. Clearly, urban children were able to locate and interact with urban wildlife. This was also evident when English children completed a five-day version of the 'good things in nature' writing task (Richardson et al., 2015); in that study, respondents most frequently commented on "active animals" (i.e., wildlife) they noticed nearby (C. Harvey et al., 2020). In doing so, they responded similarly to urban adults, who most often reflected with wonder on wildlife encounters in day-to-day settings (McEwan et al., 2020). When considered in conjunction with our results, these findings suggest a consistent story for children and adults alike: appreciating urban wildlife is a promising pathway to nature connectedness. By actively noticing—as opposed to merely seeing or, worse, ignoring—nonhuman species in urban landscapes, citizens nurture their connections with nature (Richardson et al., 2022). When observations of nearby nature are mindful, impacts may be stronger still (Barrable et al., 2021), potentially increasing the likelihood that connectedness will manifest in pro-nature behaviours (see Richter and Hunecke, 2022).

Importantly, our analyses indicate that behavioural commitment is an important factor when it comes to connecting with nature by watching wildlife. Respondents who reported daily involvement in looking for animals tended to have strong nature connections, but the same could not be said for less committed individuals. Assuming causality primarily flows in one direction, this suggests that constant vigilance (vs. occasional effort) affords urban wildlife watchers more opportunities to witness scenes that evoke feelings of oneness with nature. Therefore, practitioners seeking to promote urban children's connectedness with nature by tapping into their curiosity towards wildlife (C. Harvey et al., 2020) would be well served to encourage frequent observation using regular prompts (McEwan et al., 2019). For example, a recent longitudinal study wherein academics assisted English schoolchildren with regular wildlife monitoring led to improved nature connectedness over the course of one academic year for individuals who were weakly connected at the start of the program (D. J. Harvey et al., 2020).

Our findings demonstrate that behavioural commitment was important for connecting with nature through walking. Respondents who walked daily tended to have strong nature connections, but less frequent walkers had weaker connections. This is in keeping with the idea that there is a certain "dosage" of walking that promotes connectedness with nature (Chou and Hung, 2021). Although walking experiments with adults from the USA, UK, and Canada have detected short-term improvements in participants' nature connectedness following individual sessions (Lumber et al., 2017; Mayer et al., 2009; Nisbet et al., 2019; Nisbet and Zelenski, 2011), a longitudinal investigation with Taiwanese college students recently revealed that walking a forest trail each week led to an increase in nature relatedness after two months but not one month (Chou and Hung, 2021). Our dataset is the first to provide correlative evidence of a similar "dosage dependence"-type relationship in children. Though the way that people interact with nature during their walks probably matters most when it comes to boosting connectedness (Lumber et al., 2017), our analyses indicate that frequency of walking is important too, with daily commitment potentially leading to the greatest benefits. More research is needed to understand how quality and quantity of walking might interact to strengthen people's affective connections to nature.

Variation in quality of experience may partly explain why frequency of gardening and playing with pets did not have large effects on connectedness with nature. As gardening is commonly included among household chores assigned by Australian parents (Freire et al., 2022), respondents in this study may have had little control over how they gardened. When participation in an activity is externally motivated, it is associated with reduced behavioural autonomy, which can evoke negative emotions (Bidjerano and Newman, 2010; Deci and Ryan, 2000) and—we would suggest—therefore interfere with the formation of affective nature connections. This might explain why, for example, respondents who gardened on a weekly basis had CNI scores spanning 95% of this measure's range. It is certainly possible to connect with nature via gardening (Shaw et al., 2013), and respondents in this study who never gardened tended to have weak connections to nature. However, even those students who reported daily gardening habits were, on average, only moderately connected to nature (sensu Hughes et al., 2018). The same is true of respondents' interactions with pets. Students who reported playing with pets daily were more strongly connected to nature than those who claimed they never played with pets; this is consistent with prior research showing pet ownership is associated with higher nature relatedness (Nisbet et al., 2009). However, their connections to nature were, on average, not strong in absolute terms, meaning we cannot be reasonably certain they engaged in the conservation behaviours associated with strong connectedness in this sample population (e.g., willingness to volunteer in Keith et al., 2021). This finding likely reflects the variety and complexity of interactions between humans and pets, which can inspire a wide range of relationships with wider nature (Twardek et al., 2018).

4.1.2. Outdoor recreation

Our results indicate that urban children's interactions with domesticated nature (i.e., pets and gardens) are not as impactful as their interactions with stereotypically wild nature (i.e., urban wildlife) when it comes to inspiring committed connectedness with nature. However, we also found that participating in outdoor recreation—i.e., camping, surfing, and fishing—did not directly enhance respondents' connectedness with nature. Individually, each of the three activities had a small to null effect on connectedness (Table A4). This finding aligns with the null effect reported in an English study where surfing was evaluated as a means of connecting with nature (Hignett et al., 2018). Because surfers primarily focus on only one abiotic component of marine environments (i.e., waves), this may limit the scope of affective connections they establish with nature. Noticing abiotic natural features has been reported to have a negligible impact on connectedness with nature, in contrast to the substantive effect of noticing biotic elements such as wildlife (Richardson et al., 2022). Experimental studies are needed to determine if noticing abiotic and biotic elements of nature boost outdoor recreationists' connections to nature in different ways.

With regard to camping, our findings contradict recent research from the southeast USA wherein this activity was identified as an impactful predictor of children's connectedness with nature (Szczytko et al., 2020). This discrepancy could be due to a difference in cultural context, instrument (CNI vs. CTN), or analytic approach (path analysis vs. classification tree analysis). Alternatively, it may be that "camping" is a somewhat generic term encompassing a range of different activities with impacts that register as small effects on connectedness only after being pooled. For example, tent camping/backpacking and trailer camping are qualitatively different (Asah et al., 2018), with the latter only possible in areas accessible by road, unless off-road driving is involved. In a recent correlational study with Texan high schoolers, appreciative nature activities—including backpacking—were significant predictors of connectedness with nature, whereas environmentally abusive activities—including off-road driving—were not (Hoover, 2021). This indicates that we may have inadvertently diluted the positive effect of tent camping on connectedness with nature by including it alongside less influential modalities under the umbrella term "camping".

Like camping, the term "fishing" can encompass a broad range of modalities. This may partly explain why fishing has been identified as a significant positive predictor of nature connectedness in some youth cohorts (Szczytko et al., 2020) but not others (Hoover, 2021), including ours. In the state of New South Wales—where our research took place—adult recreational anglers can be classified as one of five distinct types, including 'hunter gatherers' who mainly fish for food and 'outdoor enthusiasts' who are primarily motivated by a desire to connect with nature, typically deriving no more satisfaction from keeping fish than they do from releasing them (Magee et al., 2018). Given the explicit focus on nature connectedness in the latter group's angling experiences, we would expect those types of contact with nature to promote connectedness in children, but measuring the impact of "fishing" in general may have diluted this effect in our dataset. Similarly, null results from other youth cohorts could have arisen as a result of pooling fishing and hunting together as consumptive activities (e.g., Hoover, 2021), which is inappropriate when anglers engage with sustainable catch-and-release practices instead of eating their catch (Raynal et al., 2020). In terms of pro-environmental behaviour, angling can—in fact—resemble appreciative activities such as hiking and birdwatching more closely than it does innately consumptive activities like hunting (Nord et al., 1998), and belief in the efficacy of catch-and-release as a conservation tool was recently highlighted as a positive predictor of pro-environmental behaviours among Canadian anglers (Jeanson et al., 2021). Treating fishers as a homogeneous group risks masking positive impacts that specific forms of engagement can have on committed connectedness with nature. Those seeking to boost children's affective nature connections and promote conservation behaviours via fishing experiences (e.g., Theimer and Ernst, 2012) should focus on activities that resonate most with 'outdoor enthusiast' anglers (Magee et al., 2018) who feel closest to nature. Evaluations of such interventions are essential, as they will ultimately confirm or refute the potential of angling to strengthen children's connections to nature (as they appear to do in adults).

4.1.3. Learning about nature

When respondents felt they were learning about nature, they reported stronger connections to nature. Students who reported they frequently read about nature or learnt outdoors were, on average, moderately connected to nature, whereas those who claimed to have never engaged in these activities tended to be weakly connected (Figs. 5C & 5D). These findings suggest that urban children can connect to nature both through nature-based learning and through indirect exposure to nature via reading (Norwood et al., 2019). Although a clear picture of the benefits children derive from nature-based learning is only just beginning to emerge (Mann et al., 2021; Miller et al., 2021), both theory and practice suggest it can promote connectedness with nature (Chawla, 2021). By demonstrating that respondents' perceived frequency of outdoor learning has a large effect on the strength of their connections with nature, in this study we contribute substantially to a modest correlative evidence base in this area (Schilhab, 2021).

Our investigation is the first to demonstrate that reading about nature has a large effect on children's connectedness with nature. Previous studies have shown that reading nature books is positively associated with adults' environmentally responsible behaviours (Mobley et al., 2010), as well as children's ecologistic attitude (Eagles and Demare, 1999) and their aspirations toward nature-focused careers (Sheldrake and Reiss, 2021). Outside the peer-reviewed literature, there is evidence of a moderate correlation between Nature Connection Index scores and "looking at books, photos, or websites about the natural world" (Hunt et al., 2017, p. 50), but a value-action gap was evident whereby the degree of connectedness associated with participation in these activities (i.e., an index score of 69) did not necessarily translate to engagement with pro-environmental behaviours (Richardson et al., 2019). We observed a similar phenomenon in our dataset, with the mean CNI score for respondents in the highest frequency category (Fig. 5C) still falling below the 'strong' connectedness threshold associated with commitment to conservation behaviours in this sample population (see Keith et al., 2021). Despite its large effect size, reading about nature—a form of indirect contact with nature—may not be equivalent to more active and embodied pastimes such as wildlife watching when it comes to inspiring committed connectedness with nature (Table A3). Nevertheless, our findings imply that urban children might be able to maintain or boost their connections with nature through reading if they are unable, for example, to go for long walks outside. By contrast, we found that screen-based learning (via television and the internet) and classroom-based learning do not show as much promise, having only small effects on urban students' nature connections. This not to say it is impossible to design screen- or classroom-based interventions for boosting nature connectedness (see C. Harvey et al., 2020; McEwan et al., 2019), but learning about nature in those contexts did not often yield such a desirable outcome for our respondents. Using the internet to learn about nature showed the weakest relationship with connectedness in our dataset, potentially reflecting a negative association between screentime and nature connectedness (see Price et al., 2022).

4.1.4. Household biodiversity

In our dataset, perceived household biodiversity was a positive predictor of respondents' connectedness with nature (Fig. 4). Considering household biodiversity was also positively correlated with the frequency at which respondents undertook nature-focused activities, including 'looking for wild animals', it may be that the positive predictive relationship between household biodiversity and nature connectedness was mediated by noticing nature. Though we did not include this path in our structural model, a *post hoc* comparison indicates that students who noticed nature (i.e., looked for wild animals daily) perceived their gardens to be more biodiverse than those who did not (Fig. A2). This provides the first piece of independent empirical evidence corroborating a new finding that visible garden biodiversity leads to an increase in noticing nature, which in turn leads to an increase in nature connectedness (Hamlin and Richardson, 2022). It is also possible that connecting with nature causes people to notice nature more; previous research in English and European cities has highlighted correlations between the strength of adults' nature connections/orientations and enhanced perception of biodiversity in urban green spaces (Fischer et al., 2018; Hoyle et al., 2019).

In any case, our results suggest that living in a noticeably biodiverse home environment is associated with enhanced nature connectedness. This is in keeping with the idea that urban children mostly encounter biodiversity in household gardens, with these locations affording valuable opportunities to connect with nature (Hand et al., 2018, 2017). However, our results demonstrate that frequenting urban gardens is not enough, as even those respondents who spent time in these green spaces every day were, on average, only moderately connected to nature. The quality of respondents' home environment, as measured by perceived biodiversity, was a better predictor of connectedness: students from the most biodiverse households were, on average, strongly connected to nature and those from the least biodiverse households were, on average, weakly connected (Fig. A3). This may be because people with stronger nature connections choose to live in more biodiverse homes, and/or because living in a biodiverse household promotes connectedness. Assuming the relationship primarily reflects a positive effect of perceived household biodiversity on connectedness and not the inverse, it suggests that parents seeking to boost their children's nature connections might be able to do so by promoting biodiversity in the home through practices such as wildlife gardening (Hamlin and Richardson, 2022; Mumaw and Bekessy, 2017; Shaw et al., 2013). Indeed, it is possible that parental connections to nature ultimately drove the positive association between household biodiversity and measures of connectedness in this study (see Passmore et al., 2021). Our results further indicate that homeowners should ideally promote biodiversity to such a degree that plants and animals are perceived as abundant both indoors and outdoors; it was only under those conditions that we could be reasonably certain young residents in this study felt strongly connected to nature.

4.1.5. Visits to green / blue spaces

Our finding that perceiving biodiversity in urban gardens was more impactful than simply spending time there is just one example of a broader result: beyond its association with learning and undertaking nature-focused activities, frequency of visiting green and blue spaces had little impact on connectedness with nature (Fig. 4). This suggests that simply "getting kids into nature" (New South Wales Department of Education, 2018, line 1) will not necessarily promote nature connectedness; the activities undertaken there are key (see Figs. A4 & A5). In this dataset, nature-focused activities—and how these were perceived—took primacy over time spent in nature. This echoes the conclusion that it is "moments, not minutes" in nature that are important for promoting adults' wellbeing (Richardson et al., 2021). It also supports and extends findings from a recent study wherein frequency of visiting nature was unrelated to connectedness across a sample of 209 English children (Passmore et al., 2021). Those authors suggested the null result may have arisen as an artefact of sample size or parental reporting methods (Passmore et al., 2021), but here we detect a weak effect across a sample population that is five times larger, using self-report measures. While this suggests the lack of a strong impact is not a "methodological fluke" and is, instead, theoretically meaningful (Lengieza and Swim, 2021, p. 7), further investigation is required to fully understand why certain interactions with nature fail to inspire connectedness.

4.1.6. Local greenness

Contrary to the common assumption that living in a green neighbourhood promotes nature connectedness, we discovered a negative association between school catchment greenness (NDVI) and student CNI scores. Prior research has linked the greenness of buffer areas around schools to improved student academic performance (e.g., Wu et al., 2014), but we did not detect a comparable positive effect on connectedness with nature; rather, the opposite pattern prevailed. To our knowledge, a significant negative relationship between neighbourhood green space and nature connectedness has been reported only once before, in English children (Passmore et al., 2021). The authors of that study suggested the unusual result arose from residual confounds between their measures of green space and neighbourhood deprivation, with the latter driving the observed pattern (Passmore et al., 2021). We had no such issue in this study, where socioeconomic disadvantage was included as a covariate in all analyses involving greenness but was not a significant predictor of connectedness.

The cause of the negative relationship between school catchment greenness and student connectedness is unclear, but it is possible that residents of the relatively grey suburbs in our sample were actively compensating for a lack of neighbourhood greenspace by promoting biodiversity at a hyper-local scale e.g., indoors, in covered outdoor spaces, or in small private gardens. Indeed, empirical data show that feature-rich grey urban areas can be more biodiverse than feature-poor green spaces (Hand et al., 2016). These pockets of urban nature are not likely to register in satellite NDVI imagery (e.g., at a spatial resolution of 10 m), but have the potential to promote children's connectedness with nature, as we have demonstrated for perceived household biodiversity. It may be that urban children respond most strongly to hyper-local nature (including greenness) on account of their highly restricted home ranges (Hand et al., 2018, 2017), so characteristics of school catchments are less important. This idea is supported by the null effects of population density and socioeconomic disadvantage—both measured at the school catchment scale—on student connectedness in this study. Therefore, living in a grey neighbourhood may not necessarily prevent children from connecting with nature, provided they are able to access and engage with natural elements in their immediate vicinity. Future studies on urban children's interactions with nature should investigate small-scale features of the physical spaces students occupy most frequently; namely, homes and schools themselves (as opposed to buffer areas surrounding them). This will produce a clearer picture of the affordances for nature connectedness that everyday settings can offer.

4.2. Predictors of conservation behaviours

4.2.1. Connection to nature

Connection to nature was a strong predictor of urban children's conservation behaviours, both in self-reported terms and in terms of willingness (Fig. 4). The effect sizes for these predictive relationships fell within or exceeded the upper ranges calculated in recent meta-analytical studies (see Barragan-Jason et al., 2022; Mackay and Schmitt, 2019; Vesely et al., 2021; Whitburn et al., 2020). Thus, our findings demonstrate that the robust link between nature connectedness and conservation behaviour is evident even from a young age (see Keith et al., 2021) and, indeed, that this relationship may be strongest in youth (see Vesely et al., 2021). One longitudinal research program has already shown that pro-environmental behaviours decline in adolescence and are not necessarily linked to positive environmental attitudes (Evans et al., 2018; Otto et al., 2019). This is supported by correlational evidence (Keith et al., 2021; Price et al., 2022), but further investigation is needed to determine whether connectedness and behaviour become decoupled with age. In the meantime, our findings and those from other child-focused studies (e.g., Hughes et al., 2018) suggest that promoting connection to nature could be a promising means of engaging children and adolescents in conservation. The malleability of nature connectedness makes it a good target for interventions designed to ultimately promote pro-environmental behaviours, with proven 'pathways' to connectedness offering a variety of starting points (Richardson et al., 2020a). Importantly, our path analysis suggests that another psychological construct offers a similarly promising intervention target.

4.2.2. Environmental self-identity

Environmental self-identity had a moderate overall effect on students' conservation behaviours in this study, consistent with results of recent meta-analyses that establish identity as an impactful behavioural motivator (Udall et al., 2021; Vesely et al., 2021). Our findings contribute substantively to the growing body of literature in this area by simultaneously addressing the roles of environmental self-identity and nature connectedness, thereby clarifying how they interact and compare. As a direct predictor of conservation behaviours, environmental self-identity (β = .32/.35) performed just as well, if not better, than connectedness (β = .23/.26); it also mediated half of the overall effect connectedness exerted on conservation behaviours (Fig. 4). This suggests environmental self-identity should receive just as much attention as connectedness when it comes to promoting conservation.

Pro-environmental identities are malleable and tend to be non-specific, so strengthening them or increasing their salience has the potential to motivate a wide range of beneficial behaviours (Fritsche et al., 2018; Van der Werff et al., 2013; Vesely et al., 2021; Whitmarsh and O'Neill, 2010). Many intervention strategies involving the use of social identities to promote pro-environmental action have been developed and implemented in corporate settings (see Fritsche et al., 2018). We suggest that extending these to pedagogical scenarios offers a promising means of fostering motivation for pro-nature behaviours in urban children and adolescents. We have already found that students, when asked to explain why nature is important to them, used phrases that reveal salient environmental identities, e.g., "Nature is … my personality … It is who I am." (Keith et al., 2022, p. 8).

4.2.3. Learning about nature

In total, learning about nature had moderate positive effects on conservation behaviours, largely mediated by connection to nature (and environmental self-identity in turn). Direct effects of learning about nature on conservation behaviours were weak. These findings are in keeping with the discovery that nature-based education of school children mainly promotes pro-ecological behaviour via increased connection to nature, with environmental knowledge playing a less important mediating role (Otto and Pensini, 2017). In short, our findings attest to the importance of affect in environmental education: participants who reported that they learnt about nature often—even from a variety of useful information sources—were not particularly likely to behave in nature-friendly ways unless they also felt connected to nature. Simply knowing about nature was typically not enough to inspire conservation; it was also necessary to care about it. The same is true for exposure to nature via routes other than learning (e.g., visiting green/blue spaces) – adding them to our structural model as direct predictors of conservation behaviours explained less than one percent additional variance compared to affective connectedness alone. This echoes the idea that committed connectedness with nature arises only when affect is present alongside cognition and experience (Zylstra et al., 2014). Having empirical evidence of this in a sample of urban children should further advance committed connectedness theory.

5. Conclusion

This study provides insights into the kinds of experiences that inspire urban children to care for nature in times of ecological crisis. Our analyses revealed that these experiential pathways promote conservation behaviours in two equally impactful ways: by strengthening affective connections with nature, and by indirectly fostering environmental self-identity. Promisingly, many of the most influential experiences are accessible regardless of students' circumstances. Even if, for example, a child is unable to regularly go for long walks outside, they can spot urban wildlife almost anywhere, and—at the very least—boost their connectedness by learning more about nature in the pages of books from a public library (see, e.g., Sadokierski et al., 2022). In dwellings surrounded by concrete jungle, children can interact with household biodiversity (via practices such as wildlife gardening; see Mumaw and Bekessy, 2017; Shaw et al., 2013). These actions may seem simple and quotidian, but here we show that, in aggregate, they can begin to change the way our youth view and interact with their surroundings and the natural world more broadly.

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.

Data Availability

The authors do not have permission to share data.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cresp.2022.100066.

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