

The Relationship between Connectedness to Nature in Childhood and Pro-Environmental  
Behaviour: A Systematic Review and Meta-Analysis

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Author Note

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### **Abstract**

Children are not only the most vulnerable to the current degradation of the natural environment but are the ones left to restore the natural world. Yet, children are progressively having less direct contact with nature, potentially creating disconnection with the natural world and reduction in commitment to protecting it. The purpose of this systematic review and meta-analysis is to synthesise the literature on childhood nature connection to better determine its influence on pro-environmental behaviours. Twenty-four studies with a pooled sample of 8,564 children and youth were identified from seven databases. Quantitative, qualitative, and mixed methods approaches were included and quality assessed. The included studies consistently reported a positive relationship between childhood nature connection and pro-environmental behaviour, but incorporated a wide range of assessment methods, as well as covered a broad age and geographical range. Effect sizes were calculated for the relationship between connection to nature and pro-environmental behaviour amongst the sixteen eligible quantitative studies. Using random-effects modelling, connection to nature in childhood was found to have a large effect in influencing pro-environmental behaviour. However, significant heterogeneity suggests limitations in drawing conclusions from the results and reinforces the need for better standardisation of measures. Subgroup analyses show the effect was present across the entire age range, despite being stronger in younger children. Also, the effect appears to be universal, although not all global regions were represented in the meta-analysis. Overall, the findings suggest that the development of pro-environmental behaviour is strongly related to the connection one feels with nature during childhood.

*Keywords:* Connection to nature, pro-environmental behaviour, children, systematic review, meta-analysis

**Declaration**

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

Mikaela Todd

24<sup>th</sup> October 2021



### **Contribution Statement**

In writing this thesis, my supervisor and I collaborated to generate research questions of interest. My supervisor guided me on the systematic review and meta-analysis methodology. I developed the eligibility & screening criteria, and then created the logic grids for each database with the assistance of the University of Adelaide Liaison Librarian. I conducted the literature search and study screening with guidance from my supervisor. A psychology PhD student, Madison Bellchambers, independently screened all 130 full text articles as a second independent reviewer for screening reliability. I pre-registered the project and uploaded all relevant information and materials onto the PROSPERO database, created a data extraction sheet and extracted all data, completed the risk of bias assessment, and undertook all statistical analyses with the support of my supervisor. My supervisor independently quality assessed all 24 included articles to account for reliability. I was responsible for all aspects of the thesis write up.

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Firstly, I wish to express my deepest gratitude to my thesis supervisor, Mark Kohler. I am indebted to you for the utmost support and guidance for what I could say was one of the hardest years so far. Your kind and compassionate words, patience with my constant anxiety and endless number of questions, alongside your striking attention to detail, and openness to always have a chat and feel like a friend, has made this year a truly enjoyable experience. I couldn't have asked or received a more suited supervisor for myself, and I feel blessed to have been able to work with you this year and cannot find the words to thank you enough.

Secondly, I would like to kindly thank Madison Bellchambers for taking the time out of your PhD to screen 130 full text articles to assist with the reliability of my research.

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The Relationship between Connectedness to Nature in Childhood and Pro-Environmental  
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## Chapter 1

### 1.1 Environmental Problems

In the twenty-first century, climate change is one of the greatest environmental and societal challenges facing humanity. It has been widely agreed that the “earth’s climate is now changing faster than at any point in the history of modern civilization, primarily as a result of human activities” (Dietz, Shwom, & Whitley, 2020, p. 136). Findings from the International Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC) report that since the mid 20<sup>th</sup> century anthropogenic change exceeds any other point in history, causing a surge in greenhouse gas emissions, leading to a rise in global surface temperature (IPBES, 2019; IPCC, 2021). Therefore, it is imperative to investigate, understand and ultimately promote pro-environmental behaviour (PEB) to all populations, for the health and longevity of civilisation and the natural world (Otto & Pensini, 2017).

These climate changes introduce several interrelated problems including but not limited to, increases in extreme weather events, and more gradual changes such as rising sea levels, prolonged droughts, and changes in growing seasons. These impacts of climate change are likely to lead to higher disease prevalence, lower food and water availability, a reduction in habitable areas and overall increased economic hardship for humanity (Burke, Sanson, & Van Hoorn, 2018; NASA: Climate Change and Global Warming, 2021; National Oceanic and Atmospheric Administration, 2019). Current research suggests such environmental changes are associated with increasingly negative physical and psychological impacts on people. Such effects include symptoms of depression, anxiety, pre-traumatic stress disorder, attachment

disorders and substance abuse which in turn cause problems with learning, cognition, academic performance, emotion regulation, behaviour, and language development (Burke et al., 2018; Doherty & Clayton, 2011; Van Susteren & Al-Delaimy, 2020). Children are blameless victims of climate change who are subject to contend with the cascading effects of human actions as well as being more susceptible to these impacts of environmental change (Burke et al., 2018; Hahn, 2021).

Due to the detrimental effect climate change could have on the health of our planet and on current and future generations it is imperative that these negative consequences be mitigated. Based on the current predictions, a dramatic but increasingly likely suggestion is that the current generation of young people may be the world's last chance to implement the necessary environmental actions to sustain a liveable world for future generations (Burke et al., 2018). Evidence suggests that these consequences can be mitigated by promoting what is termed pro-environmental behaviour (PEB).

## **1.2 Pro-Environmental Behaviour**

PEB can be defined as deliberate and effective behaviours that reduce harm to the environment, and in some cases benefit the environment, to protect the planet and its future inhabitants (Barrera-Hernández, Sotelo-Castillo, Echeverría-Castro, & Tapia-Fonllem, 2020; Duron-Ramos, Collado, García-Vázquez, & Bello-Echeverria, 2020; Steg & Vlek, 2009). Despite increased awareness that human actions are often the cause of increased environmental degradation, research has shown that individuals are choosing not to reduce their impact on the environment by living more sustainably (Halpenny, 2010). This disconnection between environmental awareness and PEB has been investigated mostly in adult populations, however as the environmental stewards of the future it is also important to understand these processes during childhood (Halpenny, 2010).

Barrera-Hernández et al., (2020) stress that it is important that future research focuses on a younger population when looking at climate action as they do not yet have deeply entrenched attitudes and behaviours grounded in social and political norms. Children are cognitively more open to new experiences and more able to change their environmental behaviours than adult populations (Hahn, 2021). Childhood is also likely to be the optimal time to teach about PEB given early awareness is shown to produce longer-lasting environmental attitudes, beliefs, and behaviours (Barrera-Hernández et al., 2020). Hahn (2021) elaborates that between the ages of 14 and 18 concern for the environment diminishes if these attitudes have not already been established. This developmental pattern is likely exacerbated by adolescence being a time of identity formation and more egocentric values emphasizing the ‘self’, and when the importance of establishing peer relations peak, as opposed to developing greater awareness of the external environment and place attachment (Bahar & Sahin, 2017; Chawla & Gould, 2020). The practical repercussions of this change in adolescents is reflected in the fact that electricity consumption has been shown to increase by the number of adolescents living in a family household compared to other age groups, suggesting higher energy consumption by teens (Krettenauer, Wang, Jia, & Yao, 2020). Following adolescence, PEB and environmental concern have been shown to increase again (Hahn, 2021; Krettenauer et al., 2020). Studies with adults have indicated those who engage in more PEB also show higher levels of nature connection (Chawla & Gould, 2020). The most frequent finding is that adults who report taking part in regular PEB, report regularly engaging in natural play in childhood which increases their connection with the natural world (Chawla & Gould, 2020). For example, Evans, Otto, and Kaiser (2018) in their longitudinal study of rural upstate New York adolescents found that participants at the age of 18 who reported engaging in more PEB spent more time playing outdoors at age 6.

### 1.3 Connectedness to Nature

Connectedness to nature (CN) is a relatively new research interest that has been defined as an individual trait or psychological construct that allows a person to feel as one with the natural world (Barrera-Hernández et al., 2020; Capaldi, Dopko, & Zelenski, 2014; Pritchard, Richardson, Sheffield, & McEwan, 2020). People with higher CN have developed a set of beliefs that place themselves at the same value and worth as nature, promoting an appreciation for all living organisms. This self-schema acts as a motivational component for individuals to learn about and understand nature (Barrera-Hernández et al., 2020; Bruni, Winter, Schultz, Omoto, & Tabanico, 2017; Otto & Pensini, 2017). Research on CN has shown that adults with higher CN experience greater wellbeing and trait mindfulness, and are also more likely to engage in more environmental behaviours and appreciative outdoor activities (Fletcher, 2017; Freeman, Waters, Buttery, & Van Heezik, 2019; Ives et al., 2017; Richardson, Passmore, Lumber, Thomas, & Hunt, 2021; Whitburn, Linklater, & Abrahamse, 2020; Wolsko & Lindberg, 2013). It has been hypothesised that children need to engage and feel safe in the natural environment to connect with nature and cultivate a positive sense of self. If children can connect with the environment, they are more likely to develop curiosity, interest, attraction to natural areas, empathy and care for other things, and a sense of kinship and oneness with the world (Chawla & Gould, 2020; Hahn, 2021). More recently in children this CN has been shown to have health and well-being benefits such as increased happiness, pro-social behaviours, self-regulation, and cognitive performance (Chawla & Gould, 2020; Hahn, 2021; Tillmann, Tobin, Avison, & Gilliland, 2018).

As the world is becoming more urbanised, it is clear that both adults and children are experiencing amplified feelings of human-nature dissociation or what is now being called 'nature-deficit disorder' where an 'extinction of experience' is underway due to distance from other ecological life and lack of connectedness people feel to the natural world (Barrera-

Hernández et al., 2020; Chawla & Gould, 2020; Rosa, Profice, & Collado, 2018). As individuals are living in more densely developed and populated locations, more time is being spent indoors using digital media, reducing opportunities to connect with nature (Bruni et al., 2017; Chawla & Gould, 2020). This disconnection is troubling as interest in the natural world is also likely to lessen as a consequence, leading to a reduction in PEB. This disengagement and disinterest may be passed onto future generations, which if not addressed has the potential for a generational shift causing less appreciation for the natural world and less investment in its protection. As implicated from previous research, this disconnection is not limited to affecting PEB but also likely to impact physical and psychological health and carry over from childhood into adulthood (Chawla & Gould, 2020).

In response, there are a variety of programs that have been developed to cultivate CN in children (Chawla & Gould, 2020). Such programs typical aim is to expose children to the outdoors, promote CN directly, increase environmental education, or a combination of these (Bruni et al., 2017; Otto & Pensini, 2017). Overall, such programs typically report an improvement in children's environmental knowledge as well as confidence and feelings of safety in nature, which sequentially increases children's enjoyment in nature and willingness to participate in future nature activities. In turn, such effects have the ability to build on children's prosocial behaviours and empathetic relationship with nature, therefore, increasing CN (Otto & Pensini, 2017). Conversely, these programs can reduce an individual's CN if placing constraints on one's abilities to experience nature freely, stifling independence and promoting dullness, leading to reduction in environmental interest and CN (Duerden & Witt, 2010; Rosa & Collado, 2019). Additionally, circumstantial factors such as experiencing poor weather conditions while participating in a program has been shown to negatively affect CN (Rosa & Collado, 2019). Therefore, it is important to develop a systematic approach to such

programs that accounts for potential negative experiences and cultivates, rather than reduces, CN.

#### **1.4 Connectedness to Nature and Pro-Environmental Behaviour**

Research on adult populations has shown that self-reported CN is one of the strongest predictors of PEB (Hahn, 2021; Martin et al., 2020). This finding is supported by Wilson's (1984) biophilia hypothesis, which suggests humans innately seek connections with the natural environment. Similarly, the value-belief-norm model proposed by Stern, Dietz, Abel, Guagnano and Kalof (1999), suggests values activate cognitions that create a positive environmental personal norm to engage in PEB (Pereira & Forster, 2015). Put more simply, as an individual becomes more connected with nature, possibly driven by an innate tendency, their 'relational values' are expected to increase and are likely to experience satisfaction when caring for nature, therefore, increasing engagement in PEB (Chawla & Gould, 2020). Research on child populations show this is a relationship that starts before adulthood, however as for much of the literature in this field, there are a limited number of studies conducted on children to date (Chawla & Gould, 2020; Hahn, 2021).

When combining all of the elements discussed so far, a stronger sense of CN is likely to be cultivated in children who engage in more environmental activities which in turn facilitates commitment to nature friendly behaviours (Hahn, 2021; Martin et al., 2020; Otto & Pensini, 2017). In fact, findings have suggested that natural learning environments are attractive to children which in turn positively influences their attitude towards the natural world, and future behaviours (Duerden & Witt, 2010; Otto & Pensini, 2017). More broadly, CN has shown to be one of the strongest predictors of PEB, sharing up to 60% of the common variance across a selection of studies utilising different measures (Otto & Pensini, 2017; Ramkissoon, Weiler, & Smith, 2012). By consequence, factors, or programs, that most



effectively promote CN are also those with the strongest likelihood of promoting PEB (Otto & Pensini, 2017).

Although majority of the research on CN has reflected a variety of positive outcomes with greater connectedness, in the context of increasing environmental degradation it is important to also note where CN may promote a sense of helplessness due to feelings of ‘ecological grief’ in children (Cunsolo & Ellis, 2018; Hahn, 2021). As our natural world is currently under increasing stress, incomparable to any time in human history, children are subject to constant news about environmental degradation and species loss which are embedded within their everyday experiences of environmental change (Chawla & Gould, 2020; Cunsolo & Ellis, 2018). In the situation, due to high CN and high exposure to environmental degradation, young people fall into hopelessness regarding their ability and willingness to act, thus reducing PEB by children falling into patterns of avoidance (Chawla & Gould, 2020). Ojala (2015) found that negative outcomes between CN and PEB are only evident when a child’s thoughts are based on denial of the seriousness of climate change or the inability to reduce impact. Whereas, if thoughts are based on positive assessment and trust in humanities’ abilities to protect the environment, increased environmental engagement is found and hopelessness is avoided. This suggests that CN includes both positive and negative facets depending on the context, and therefore has the capacity to influence engagement in PEB differently. Therefore, it is important to encourage agency or what has been defined as ‘constructive hope’ within children to promote comfort, gratification, and interest in and around nature. This can help negate negative emotions of environmental loss by increasing confidence in one’s own ability to overcome obstacles and be able to face environmental and global threats (Blanchet-Cohen, 2008; Chawla & Gould, 2020; Marlon et al., 2019).

### 1.5 Limitations in Prior Research

Although there is increasing evidence supporting the relationship between CN and PEB, there are limitations that need to be considered when reflecting on this body of knowledge, beyond just the relatively smaller number of studies on children. The concept of CN in research is relatively new, and as such no single “gold-standard” approach to measurement exists, nor does a consistent operationalisation of the concept. A broad range of self-report measurement scales have been employed to measure CN. This is problematic not only because self-reported measures are subject to ‘social desirability bias’, meaning individuals may try to exaggerate their reports of connections between the self and the natural environment to create the impression of being more pro-environmental, but also due to the variability in results as a consequence of differing definitions of CN. This is further evident by the varied use of terms to describe connection, such as: connectedness to nature, environmental attitudes, environmental concern, emotional affinity toward nature, ecological beliefs, nature relatedness, dispositional empathy with nature, and many more (Bahar & Sahin, 2017; Barrera-Hernández et al., 2020; Collado, Evans, Corraliza, & Sorrel, 2015; Huang & Yore, 2005; Kals, Schumacher, & Montada, 1999; Tam, 2013).

A further limitation is that nature-based environmental education programs often address CN and environmental knowledge simultaneously. As such, it is difficult to determine how an educational setting separately affects an individual’s environmental knowledge, CN, and PEB. Whether CN and environmental knowledge affect PEB concurrently, or whether one aspect has great influence on PEB, remains unclear (Otto & Pensini, 2017). Therefore, it would be beneficial for future research to attempt to isolate each of these factors to determine how elements of the nature-based environmental education programs uniquely influence PEB in individuals.

### **1.6 The Current Systematic Review and Meta-Analysis**

Due to the devastating impacts of climate change and continued industrialization and urbanisation, it is crucial to understand the relationship between children, the natural world, and PEB, as children represent the environmental stewards of the future (Chawla & Gould, 2020; Hahn, 2021). This is an important research area as evidence indicates that connecting with nature not only promotes PEB but also supports children's psychological wellbeing and biological health. The aim of this systematic review and meta-analysis is therefore to collate and quantify the current state of knowledge regarding whether higher CN in children promotes PEB. This information could potentially be used to optimise programs for children to increase their CN and therefore engage in more PEB, as well as to direct future research as childhood is a leading place to motivate future conservation actions and human wellbeing.

## Chapter 2

### Methods

#### 2.1 Literature Search

A systematic literature review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Page et al., 2021) in April 2021. The protocol was registered through PROSPERO an international database of prospectively registered systematic reviews (PROSPERO #CRD42021260220). Seven electronic databases were searched: Embase (a biomedical research database with coverage from 1947 to present); PsycINFO (a psychological and social sciences research database with coverage from the early 1800s to present); PubMed (a biomedical and life sciences research database with coverage from the early 1800s to present); ERIC (an education research and practice database with coverage from 1966 to present); Scopus (a core multidisciplinary database with coverage from the early 1800s to present); Education Research Complete (an education database with coverage from the early 1900s to present); and Sociological Abstracts (a sociology and related disciplines database with coverage from the mid 1900s to present).

A logic grid was constructed for each database with a list of search terms related to CN, children, and PEB. Search terms were compiled by assessing research articles on the topic question and including the different ways in which CN, children, and PEB can be described. Indexing terms were then collected from each database thesaurus and used only within the relevant database search. Each database also required different search terminology including truncation, wildcard, adjacency operations, and variations in spelling which were determined with the assistance of a Liaison Librarian from the University of Adelaide. Complete logic grids including search terms, search terminology, and boolean operators for each database search are shown in Appendix A.

## 2.2 Eligibility Criteria

To be included in the present study, articles were required to fit the following criteria:

1. Articles were peer-reviewed empirical articles, available in full text format, and in the English language. No publication date or geographical location restrictions were applied.
2. Participants were generally healthy children or adolescents, aged between 2-18 years. Studies were also included if the mean age was under 18 years. Studies involving both healthy and unhealthy cohorts were included only if data could be independently obtained from the healthy sample. Retrospective studies relating to childhood CN were also included.
3. Included studies could be quantitative, qualitative, or mixed method design, in order to comprehensively overview the research area; however, meta data was analysed only for quantitative studies (i.e., meta-analysis).
4. Included a scale measuring CN, operationalised as a psychological construct that allows an individual to feel as one with the natural world and develop relationships that promote understanding and appreciation of the human-nature relationship, including a deep love and caring for nature, enjoyment in being outdoors, feeling a sense of oneness with the natural world, appreciation of and kinship with other living organisms, having an understanding of how personal actions effect the natural world, a personal responsibility to protect nature from harm, awareness of environmental issues, and a clear recognition of nature's intrinsic value (Barrera-Hernández et al., 2020; Bruni et al., 2017; Mayer & Frantz, 2004; Nisbet, Zelenski, & Murphy, 2009; Otto & Pensini, 2017).

As well as a scale that measures PEB, operationalised as a series of deliberate actions aimed at the preservation and conservation of natural resources which include,

recycling, waste avoidance/reduction, reusing i.e., reusing gift wrapping paper, house/energy/water conservation i.e., turning off the light when leaving a room, purchasing behaviour, animal protection/empathy for living creatures, protection and conservation remediation of local natural environs, and political/global environmental actions and behaviours (Barrera-Hernández et al., 2020; Duron-Ramos et al., 2020; Steg & Vlek, 2009; Tapia-Fonllem, Corral-Verdugo, Fraijo-Sing, & Durón-Ramos, 2013).

5. PEB was reported as an outcome

Articles were excluded if they met any of the following criteria:

1. Full text was not available.
2. Full text was not available in English.
3. Participants mean age were not under 18 years.
4. Participants were reported as having any medical or psychiatric condition that would impact on CN or the ability to perform PEB.
5. Data for healthy children and/or adolescents were not provided separately.
6. CN or PEB were not assessed directly through a defined measure.
7. The study design was a review, opinion piece, editorial, case study, or empirical study where the relationship between CN and PEB was discussed but not directly investigated.

### **2.3 Study Selection**

The screening protocol is depicted in Figure 1. The search strategy identified 1,343 articles from the chosen electronic databases. After importing all 1,343 articles to Covidence, a primary screening and data extraction tool used for conducting standard intervention reviews (Veritas Health Innovation, 2021), 177 duplicates were removed, resulting in 1166 articles to be screened through titles and abstracts. After screening titles and abstracts, 130

articles were assessed to be potentially relevant. The remaining articles were then screened by reading the full text, where a further 106 articles were removed, resulting in 24 included articles relevant to the topic question. Majority of the articles removed from the full-text screening process were studies involving the wrong phenomenon under investigation or the wrong type of study used to report the data. To reduce any bias in the study selection process, eligibility assessment of the 130 full-text articles were performed independently by a second reviewer (a psychology PhD student), with an acceptable moderate inter-rater reliability (85%,  $\kappa = 0.52$ ). Where disagreement occurred, discussion between the two reviewers was undertaken and studies were re-evaluated to reach consensus. If consensus could not be agreed upon input from a third reviewer was sought (Honours supervisor).

While completing the full-text screening nine authors were contacted to gain the full age details to determine if the article fit within the inclusion criteria. Four articles were excluded due to the age of childhood CN not being defined (Clayton et al., 2019; Dewey, 2021; Molinario et al., 2020; Rosa et al., 2018), and five articles were included as the authors were able to provide the childhood age of CN (Buttigieg & Pace, 2013; Collado & Evans, 2019; Gould, Krymkowski, & Ardoin, 2018; Huang & Yore, 2005; Otto & Pensini, 2017).

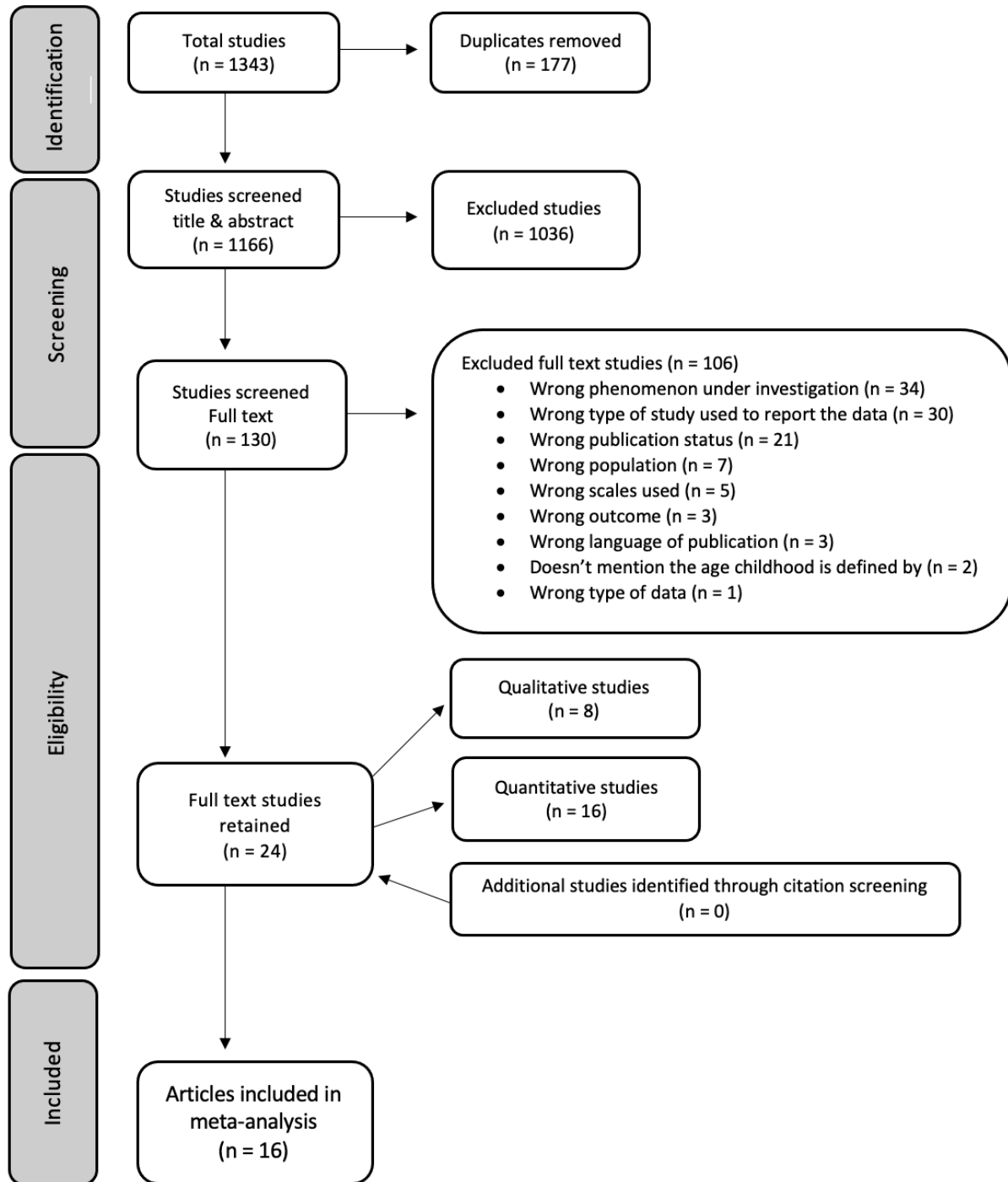


Figure 1. Screening protocol.



## 2.4 Data Collection

In accordance with the PRISMA statement (Page et al., 2021), a data extraction sheet was created to obtain required information from the included studies (see Appendix B). For the systematic review, extracted data included study characteristics (i.e., location, setting, study design, number of participants); participant characteristics (i.e., age mean and standard deviation at the time of the study, age range childhood CN was related to, gender, and race); outcome measures (i.e., CN measure and PEB measure); intervention details (i.e., type of nature engagement, intensity, duration, and frequency); and the main behavioural findings. For the meta-analysis the relevant data to allow calculation of effect size (i.e., pearson's correlations, standardised and unstandardised coefficients, p-values, standard errors, and sample sizes) were extracted.

## 2.5 Risk of Bias in Individual Studies

To determine the extent to which errors and biases were minimised in the included studies, study quality was assessed using a modified appraisal checklist comprising the QualSyst tool (Kmet, Cook, & Lee, 2004) and the McGill Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018) (See Appendix C). The QualSyst tool was chosen as it is suitable for use with a variety of study designs amongst quantitative and qualitative research. The MMAT was chosen as it also includes a mixed methods component of quality assessment which was required for the type of studies retained from the literature search.

Each quantitative study was assessed on 14 criteria taken from the QualSyst tool (Kmet et al., 2004), each qualitative study was assessed on 10 criteria also taken from the QualSyst tool (Kmet et al., 2004), and each mixed methods study were assessed on both the quantitative and qualitative criteria as well as 5 mixed methods criteria taken from the MMAT (Hong et al., 2018) (see Appendix C). Articles were given a score of two (completely meeting criteria), one (partially meeting criteria), zero (not meeting criteria), or n/a (not

applicable to the study design and excluded from the summary score). A summary score was then calculated by summing the total score (i.e., (number of “yes” (2)) + (number of “partials” (1))) and dividing by the total possible score (i.e.,  $28 - (\text{number of n/a} \times 2)$ ) (Kmet et al., 2004). For a mixed methods study to be considered of a high quality, both the qualitative and quantitative components of the study also needed to be appraised at a high quality, to ensure that no important threats to trustworthiness were present (Hong et al., 2018). This process was then ascertained by a second independent reviewer (Honours supervisor), with results demonstrating substantial agreement and strong interrater reliability (91%,  $\kappa = 0.94$ ) (McHugh, 2012). Where disagreement occurred, discussion between the two reviewers was undertaken and studies were re-evaluated to reach consensus.

## 2.6 Meta-Analysis

The primary effect sizes for level of engagement in PEB in association to level of CN in childhood were entered into Comprehensive Meta-Analysis (CMA) software (Borenstein, Hedges, Higgins, & Rothstein, 2013) for all relevant studies. Effect sizes were calculated by obtaining study sample sizes and using correlation coefficients for the relationship between CN and PEB. Where correlation coefficients were not provided, estimation of correlations from standardised ( $\beta$ ) and unstandardized (B) coefficients were conducted by the authors (Peterson & Brown, 2005). As Collado, Staats, and Corraliza (2013) did not provide this data, the authors were contacted to gain the sample size information of each experimental group, where group means and SD were used to determine the effect size.

As the research around childhood CN and PEB is a relatively new interest, no gold-standard measure has been developed. Consequently, a wide range of scales were employed within and across the included studies (Barrera-Hernández et al., 2020; Halpenny, 2010). Studies conducted by Collado et al. (2015), Collado et al. (2013), Gould et al. (2018), and Hoover (2021) employed multiple scales that fit into this paper’s operationalisation of CN.

Studies conducted by Bahar and Sahin (2017) and Clayton et al. (2019) broke down a single scale into separate factors, and studies conducted by Huang and Yore (2005) and Krettenauer et al. (2020) were conducted on two separate populations. To simplify the meta-analysis, multiple effect sizes from within a single study were pooled, and the unique coefficient and relevant sample were used for the respective effect. The direction of the measurement scale did not differ between studies (all were positive), except for Gould et al. (2018) where a single item PEB measurement was negative, and this was accounted for when calculating the effect size for this study. Hedges' *g* and standard errors (SEs) were used to measure effect sizes. Hedges' *g*, also known as the corrected effect size, reflects an unbiased effect size by expressing the average intervention effect in units of the pooled standard deviation and therefore was employed over Cohen's *d* (Enzmann, 2015; Lakens, 2013). Based on guidelines suggested by Cohen (1988; 1992), an effect of 0.20 was considered small, an effect of 0.50 medium, and an effect of 0.80 large. A random effects model was chosen for the analysis, as the measurements used for CN and PEB between studies were vastly different, meaning the studies were assumed to be heterogeneous in nature.

## **2.7 Evaluation of Heterogeneity**

Although the included studies were assumed to be heterogeneous due to the different measures of CN and PEB used in each, they were sufficiently homogenous in terms of participant demographics, interventions, and outcomes for the meta-analysis to be undertaken (Deeks, Higgins, & Altman, 2008). Heterogeneity between studies was first examined by visually inspecting the forest plot for varying CIs. Secondly, a chi-squared test (Cochrane's *Q*) assuming the null hypothesis (that all study effects are equal) and its corresponding *p*-value were used to quantify heterogeneity (West et al., 2010). Lastly, the impact of any heterogeneity was then examined using  $I^2$ . This statistic determines the total variation in estimated effect size that is due to real differences rather than chance (Deeks et al., 2008;

West et al., 2010). Interpretation of  $I^2$  was based on guidelines provided by West et al. (2010) while also taking into consideration the significance value from the chi-squared test.

## 2.8 Subgroup Analysis

Based on the results of the meta-analysis, subgroup analysis was conducted using a random effects model assuming a common between study variance, to examine the potential moderating effect of age and location on the relationship between CN and PEB. The studies were grouped according to the age of participants: childhood (6 – 12 years) and adolescence (>13 years). The studies were also grouped according to location. Grouping by continent was thought to be the most appropriate way to conduct a location-based analysis, which included: Europe, Asia, and North America, being the only continents present within the included studies. Main findings for studies conducted by Huang and Yore (2005) and Krettenauer et al. (2020) were separated according to location and effect sizes estimated for each, as two separate cultures were explored within each study. It was considered not appropriate to conduct a subgroup analysis on the scales used across studies due to the extreme level of variability. Significant differences between subgroups were determined using Cochran's Q (Borenstein, Hedges, Higgins, & Rothstein, 2013).

## 2.9 Risk of Bias Across Studies

When drawing conclusions from the results of a meta-analysis, issues such as publication bias and selective reporting in individual studies can affect the pooled outcome (Liberati et al., 2009). To assess the possibility of bias, a funnel plot of standard error by Hedges'  $g$  was created. The funnel plot was visually assessed to check resemblance of a symmetrical inverted funnel shape, where larger studies were represented at the top of the plot close to the pooled effect size, and smaller studies were represented closer to the bottom of the plot with a wider spread, assuming an absence of bias (Sterne et al., 2011). Rosenthal's Fail-safe N test was also used to assess risk of bias, which indicates the number of null effects

needed to be incorporated within the meta-analysis before the p-value becomes non-significant. A small fail-safe N value indicates a greater risk of bias (Borenstein, Hedges, Higgins, & Rothstein, 2021).

## Chapter 3

### Results

#### 3.1 Study Characteristics

Twenty-four studies were included for review, representing a total of 8,564 children and youth. Of these included studies, 70.8% were based in a school setting, 17% in an out-of-school program, and 4.2% each in a college setting, at a conference, or from an environmental organisation. The median sample size was 356.8 (range = 3-1774). Majority of the included studies came from Spain ( $N_{studies} = 5$ , 18.5%;  $n = 1,846$ , 21.6%), with studies from the United States ( $N_{studies} = 4$ , 14.8%;  $n = 366$ , 4.3%), China ( $N_{studies} = 3$ , 11.1%;  $n = 1004$ , 11.7%), Canada ( $N_{studies} = 3$ , 11.1%;  $n = 1003$ , 11.7%), Mexico ( $N_{studies} = 3$ , 11.1%;  $n = 726$ , 8.5%), Germany ( $N_{studies} = 2$ , 7.4%;  $n = 369$ , 4.3%), Turkey ( $N_{studies} = 1$ , 3.7%;  $n = 1,774$ , 20.7%), Brazil ( $N_{studies} = 1$ , 3.7%;  $n = 484$ , 5.7%), Taiwan ( $N_{studies} = 1$ , 3.7%;  $n = 483$ , 5.6%), Japan ( $N_{studies} = 1$ , 3.7%;  $n = 397$ , 4.6%), South Korea ( $N_{studies} = 1$ , 3.7%;  $n = 79$ , 0.9%), New Zealand ( $N_{studies} = 1$ , 3.7%;  $n = 30$ , 0.4%), and Malta ( $N_{studies} = 1$ , 3.7%;  $n = 3$ , 0.04%) comprising the remainder (see Table 1). Sixteen (66.7%) studies employed exclusively quantitative methodology, five (20.8%) qualitative, and three (12.5%) mixed methods. Of these, nineteen (79.2%) were cross-sectional and five (20.8%) were longitudinal, covering follow-up periods of 1 week to 1 year 9 months (see Table 1 & 2).

Table 1

*Included Studies Details*

Article (First author & year)	Country	Setting	Study Design		n	Age at study (M ± SD; years)	Age of childhood CN (range; years)	Gender (% M)	Race
			Longitudinal / Cross-sectional	Methodology					
Aguirre- Bielschowsky 2012	New Zealand & Mexico	School	Cross-sectional	Qualitative	60	10 ± 1	9-11	NR	50% New Zealand 50% Mexican
Bahar 2017	Turkey	School	Cross-sectional	Correlational	1774	13.4 ± 0.7	12-15	46.4%	NR
Barrera- Hernandez 2020	Mexico	School	Cross-sectional	Correlational	296	10.4 ± 1	9-12	40.9%	NR
Barros 2020	Brazil	School	Cross-sectional	Correlational / Mixed methods	484	15.5 ± 1.4	11-19 <sup>2</sup>	48%	NR
Blanchet-Cohen 2008	Canada	Conference	Longitudinal	Qualitative	400	10-13	10-13	46%	North America 49% Latin America 18% Africa 13% Other 20% <sup>6</sup>
Buttigieg 2013	Malta	Enviro Company	Cross-sectional	Qualitative	3	20-30	5-12	33.3%	NR
Clayton 2019	China	Kindy & Primary School	Cross-sectional	Correlational	Kindy 281 Primary 326	Kindy 4-6 <sup>3</sup> Primary 7-12 <sup>3</sup>	Kindy 4-6 <sup>3</sup> Primary 7-12 <sup>3</sup>	NR	NR
Collado & Corraliza 2015	Spain	School	Cross-sectional	Correlational	832	10 ± 1.3	6-12	49%	Spanish 86% Other 14%

Table 1 continued

Collado 2019	Spain	School	Cross-sectional	Correlational	413	10 ± 1.8	9-12 <sup>3</sup>	46.8%	NR
Collado & Evans 2015	Spain	Summer camp	Cross-sectional	Correlational	107	9.4 ± 1.5	6-12	54.9%	NR
Collado 2013	Spain	Summer camp	Longitudinal	Quasi-experimental	397	10.9 ± 2.2	4-17 <sup>2</sup>	53.9%	NR
Douglas 2009 <sup>1</sup>	US	Zoo trip	Longitudinal	Qualitative	20	10-12	10-12	NR	African & Latino
Duerden 2010	US	Enviro program	Longitudinal	Quasi-experimental / Mixed methods	108	14.5 ± 1.7	9.5-19.5	52.8%	82% white
Duron-Ramos 2020	Mexico	School	Cross-sectional	Correlational	200 Rural 200 Urban	10 ± 0.7	9-12	46%	Mexican
Ebersbach 2019	Germany	School	Cross-sectional	Experimental	114	8.7 ± 1.1	6-11	47.4%	95.6% German 4.4% Other
Gould 2018	US	School	Cross-sectional	Correlational	98	13-14 <sup>3</sup>	13-14 <sup>3</sup>	46.5%	Native Hawaiian 44.9% Chinese 25.5% Filipino 37.8% Japanese 29.6% White 36.7% <sup>5</sup>
Hoover 2020	US	School	Cross-sectional	Correlational	140	17.2 ± 0.8 <sup>4</sup>	16-19	49.3%	NR



Table 1 continued

Huang 2005	Canada & Taiwan	School	Cross-sectional	Quasi-experimental	278 Canada 483 Taiwan	11-12 <sup>3</sup>	11-12 <sup>3</sup>	42.5% Canada 50.3% Taiwan	NR
Kim 2020	South Korea	Pre-school	Longitudinal	Quasi-experimental / Mixed methods	79	4-6	4-6	53.2%	NR
Krettenauer 2020	Canada & China	School / Uni	Cross-sectional	Correlational	325 Canada 363 China	15.4 ± 4.3	9-21	46.3% Canada 52.1% China	NR
Li 2015	China	College	Cross-sectional	Qualitative	34	26.8 ± 4.5	0-18	53%	Unspecified Chinese population
Otto 2017	Germany	School	Cross-sectional	Correlational	255	10 <sup>3</sup> ± 1.3 <sup>4</sup>	8-13 <sup>3</sup>	NR	NR
Soga 2016	Japan	School	Cross-sectional	Correlational	397	9-12	9-12	49.1%	NR
Solano-Pinto 2020	Spain	School	Cross-sectional	Correlational	87	14.2 ± 2.7	10-19	61.7%	97% Spanish

Notes. NR = Not reported; Kindy = Kindergarten; Enviro = Environmental; Uni = University; US = United States

<sup>1</sup> Mixed methods design, however, only qualitative data reported. Assessed as a qualitative study, rather than assessing as a mixed methods study at low quality.

<sup>2</sup> Range not directly reported, estimate from reported mean and SD assuming a normal distribution

<sup>3</sup> Personal communications to obtain data

<sup>4</sup> SD not directly reported, estimate from range min-max/4 assuming a normal distribution

<sup>5</sup> Ethnicity categories were not mutually exclusive

<sup>6</sup> 66 countries represented

Table 2

*Measures, Interventions, & Outcomes*

	Measure		Intervention	Intervention				Main findings	Additional findings	
	CN measure	PEB measure		Type of nature engagement	Sessions attended	Hours in each session	Frequency of sessions			Duration of intervention
Aguirre-Bielschowsky 2012	Semi-structured interview	Semi-structured interview	N	-	-	-	-	-	Education programs promote positive environmental attitudes which influence PEB.	Culture affects children's awareness of environmental problems, the perceived scale of problems, and attitudes towards solving problems.
Bahar 2017	NR-scale	CREBS	N	-	-	-	-	-	Higher concern about environmental deterioration for all life and humans other than the self, related to greater PEB.	When environmental concern was associated with egoistic motives this limited PEB.
Barrera-Hernandez 2020	CNI	GEB <sup>3</sup>	N	-	-	-	-	-	CN related to PEB, which was related to happiness.	The exception to main findings was frugality was not related to happiness.
Barros 2020	CNS Focus group	Custom	N	-	-	-	-	-	A greater perception of being connected to nature was related to greater PEB.	-
Blanchet-Cohen 2008	Open-ended interview Visual survey	Open-ended interview Visual survey	N	-	-	-	-	-	Greater CN communicated related to greater PEB.	Children express environmental attitudes differently depending on personality and the context in which they grow up.
Buttigieg 2013	Custom	Involvement in environmental activist group	N	-	-	-	-	-	Experiences in nature build CN which in turn fosters PEB.	Both positive and negative experiences can promote environmental action.

Table 2 continued

Clayton 2019	Custom <sup>2</sup>	Custom <sup>2</sup>	N	-	-	-	-	-	PEB was predicted by both CN and EK, which was related to nature contact.	-
Collado & Corraliza 2015	CEPS	Custom	N	-	-	-	-	-	CN mediate the relationship between perceived restorativeness and PEB.	-
Collado 2019	NEP <sup>5</sup>	GEB <sup>4</sup>	N	-	-	-	-	-	Relationship between nature contact and PEB is mediated by CN.	The strength of this relationship is moderated by outcome expectancy.
Collado & Evans 2015	NEP <sup>5</sup> EAN	GEB <sup>4</sup>	N	-	-	-	-	-	CN positively related to PEB, however, the relationship was stronger for older children.	CN did not mediate the relationship between age and PEB
Collado 2013	NEP <sup>6</sup> EAN	Custom	Y	Summer camps: Natural area x urban area x natural area with Environmental Education (EE)	1 camp	N/A	N/A	Natural area x 2: 1 week Natural area EE: 2 weeks Urban area: 2 weeks	PEB increased for children who attended nature camps and this effect was mediated through CN.	Compared with exposure to nature, EE was not shown to have any additional effect on PEB.
Douglas 2009 <sup>1</sup>	Custom	Open-ended interview	Y	Free walking & directed zoo visits Formal education programs Neighbourhood walks	NR	NR	NR	1 month	Acquiring knowledge about the environment promoted CN which promoted PEB.	-

Table 2 continued

Duerden 2010	CHEAKS	CHEAKS	Y	Preparatory component (PC) Field workshop (FW)	PC: 9-12 sessions FW: 1 session	PC: 1-3 hours FW: N/A	PC: <sup>10</sup> FW: N/A	PC: NR FW: 7-14 days	Attitudes were more strongly associated with behaviour from the PC, and attitudes and knowledge were similarly associated with behaviour in the FW.	CN was more noticeable in programs that allowed autonomous engagement with nature compared with a more structured program.
Duron-Ramos 2020	CNI	GEB <sup>3</sup>	N	-	-	-	-	-	Stronger CN predicts PEB.	The relationship between CN and PEB was stronger for girls than for boys.
Ebersbach 2019	CNI	Custom	Y	Animal population conservation task	3 game sets of 4 rounds	NR	NR	NR	Older children behaved more sustainably than younger children, yet children's sustainable behavior was not related to CN.	Children showed ceiling effects regarding their CN.
Gould 2018	CNS <sup>7</sup>	Custom	Y	Surveying coral reefs and testing water quality	4	NR	NR	School year (August through till May)	CN, culture, and self-efficacy were all related to PEB.	Culture was also significantly related to CN and self-efficacy.
Hoover 2020	CNS R-NEP	PEBS	N	-	-	-	-	-	CN predicts PEB.	Free play during childhood, was related to CN and PEB.
Huang 2005	Custom	Custom	N	-	-	-	-	-	PEB was positively influenced by 3 aspects of CN, EK, nature experience, and gender.	Cultural disparities of development of PEB were shown between Canadian and Taiwanese cohorts.
Kim 2020	CATES - PV	CATES - PV	Y	Cotton growing project	NR	NR	NR	1 year	By viewing nature as positive and meaningful, children became more likely to be environmentally sensitive, concerned, and active.	-

Table 2 continued

Krettenauer 2020	DCN <sup>8</sup>	GEB <sup>4</sup>	N	-	-	-	-	-	CN related to PEB.	CN and PEB were negatively correlated with age in both cultural groups, with the decline in PEB being less prominent for Chinese vs Canadian adolescents.
Li 2015 (Study 1)	Open-ended interview	Open-ended interview	N	-	-	-	-	-	People reporting CN in childhood were engaged in PEB later in life	-
Otto 2017	DCN <sup>9</sup>	BBEAS	N	-	-	-	-	-	Nature-based EE related to greater PEB, mediated by increased EK and CN, with CN explaining more variance than EK.	-
Soga 2016	Custom	Custom	N	-	-	-	-	-	Both direct and vicarious experiences in nature were related to PEB, which was mediated by CN.	-
Solano-Pinto 2020	CNS	PEBS	N	-	-	-	-	-	Positive relationship between PEB and CN in a rural environment.	-

*Notes.* NR = Not reported; N/A = Not applicable; CN = Connection to nature; PEB = Pro-environmental behaviour; EK = Environmental knowledge; EE = Environmental education; NR-scale = Nature Relatedness scale (Nisbet et al., 2009); CNI = Connection to Nature index (Cheng & Monroe, 2012); CNS = Connectedness to Nature scale (Mayer & Frantz, 2004); CEPS = Children's Environmental Perceptions scale (Larson et al., 2011); EAN = Modified Emotional Affinity Toward Nature (EAN) scale adapted for use with teenagers (Müller et al. 2009); NEP = New Environmental Paradigm (Dunlap, 2008); CHEAKS = The Children's Environmental Attitude and Knowledge scale (Leeming & Dwyer, 1995); R-NEP = Revised New Ecological Paradigm (Dunlap et al., 2000); CATES - PV = The Children's Attitudes toward the Environment scale - Preschool Version (Musser & Diamond, 1999) adapted to measure a nature-friendly attitude (Soh, 2007 & Kim, 2013); DCN = Disposition to Connect to Nature scale (Brügger et al., 2011); CREBS = Children's Responsible Environmental Behavior scale (Erdoğan et al., 2012); GEB = The General Ecological Behavior scale (Kaiser, 1998; Kaiser & Wilson, 2004); PEBS = Modified Pro-Environmental Behavior scale (Markle 2013); BBEAS = Behaviour-Based Environmental Attitude scale (Kaiser et al., 2007).

<sup>1</sup> Mixed methods design, however, only qualitative data reported. Assessed as a qualitative study, rather than assessing as a mixed methods study at low quality.

<sup>2</sup> Personal communications to obtain data

<sup>3</sup> GEB scale adapted for use with children (Fraijo et al. 2012)

<sup>4</sup> GEB scale adapted for use with children (Collado, Evans, & Sorrel, 2017; Evans et al., 2007)

<sup>5</sup> NEP adapted for use with children (Evans et al., 2007)

<sup>6</sup> NEP adapted for use with children (Manoli et al., 2007)

<sup>7</sup> Subset of items from the CNS

<sup>8</sup> Modified version (Krettenauer, 2017) of the DCN

<sup>9</sup> Shortened version of the DCN

<sup>10</sup> Some implemented multiple sessions over a few weeks whereas other groups implemented one session every couple of weeks

Interviews were the most common method to assess CN and were used in five (20.8%) studies. Four (17%) studies used a custom measure to assess CN (Clayton et al., 2019; Douglas & Katz, 2009; Huang & Yore, 2005; Soga, Gaston, Yamaura, Kurisu, & Hanaki, 2016). Both the Connection to Nature Index (CNI) (Cheng & Monroe, 2012) and Connectedness to Nature scale (CNS) (Mayer & Frantz, 2004) were used in three studies (12.5% of studies for each). A wide variety of additional CN scales were used in just one or two studies. Other approaches including focus groups, pictorial based responses, and participant observation were each used to assess CN in just one or two studies (see Table 3).

For PEB, custom scales were the most commonly employed measurement method (Barros & Pinheiro, 2020; Clayton et al., 2019; S. Collado & Corraliza, 2015; Collado et al., 2013; Ebersbach, Malkus, & Ernst, 2019; Gould et al., 2018; Huang & Yore, 2005; Soga et al., 2016), used in eight (33.3%) studies. Interviews were the next most frequent and used in four (17%) studies, followed by the General Environmental Behaviour (GEB) scale adapted for use with children (Evans et al., 2007) which was used in three (12.5%) studies. Of the remaining six scales employed, each were used in just one or two studies. Other approaches including focus groups, pictorial based responses, and being a member of an environmental activist group were each used to assess PEB in a single study each (see Table 3). The scales used were not mutually exclusive, meaning some studies employed more than one scale to measure CN or PEB. All scales used for both CN and PEB, apart from some of the custom scales, were reported to have high internal consistency (see Table 3).

Table 3

Measures of CN (left) and PEB (top) including estimate of reliability and studies using each measure. Total number of studies using each are included below (for PEB) and right (for CN)

CN measure	PEB measure	CREBS	GEB <sup>2</sup>	GEB <sup>3</sup>	CHEAKS	PEBS	BBEAS	CATES -PV	Custom	Interview	Focus group	Pictorial based response	Enviro-activist group member	Total Studies
	Cronbach's alpha	$\alpha$ 0.90	$\alpha$ 0.78	$\alpha$ N/A <sup>9</sup>	$\alpha$ 0.89	$\alpha$ 0.76	$\alpha$ 0.80	$\alpha$ 0.68	$\alpha$ ranged from 0.51 – 0.74	N/A	N/A	N/A	N/A	
NR-scale	$\alpha$ 0.84	Bahar (2017)	-	-	-	-	-	-	-	-	-	-	-	1 (4.2%)
CNI	$\alpha$ 0.84	-	Duron-Ramos (2020)	-	-	-	-	-	Ebersbach (2019)	-	-	-	-	3 (12.5%)
			Barrera-Hernandez (2020)											
CEPS	$\alpha$ 0.85	-	-	-	-	-	-	-	Collado & Corraliza (2015)	-	-	-	-	1 (4.2%)
R-NEP	$\alpha$ 0.79	-	-	-	-	Hoover (2020)	-	-	-	-	-	-	-	1 (4.2%)
NEP <sup>4</sup>	$\alpha$ 0.82	-	-	Collado (2019)	-	-	-	-	-	-	-	-	-	2 (8.3%)
				Collado, & Evans (2015)										
NEP <sup>5</sup>	$\alpha$ 0.70	-	-	-	-	-	-	-	Collado (2013)	-	-	-	-	1 (4.2%)



Table 3 continued

EAN	$\alpha$ 0.81	-	-	Collado & Evans (2015)	-	-	-	-	Collado (2013)	-	-	-	-	2 (8.3%)
CHEAKS	$\alpha$ 0.89	-	-	-	Duerden (2010)	-	-	-	-	-	-	-	-	1 (4.2%)
CNS	$\alpha$ 0.84	-	-	-	-	Solano-Pinto (2020)	-	-	Barros (2020) <sup>1</sup>	-	-	-	-	3 (12.5%)
CNS <sup>6</sup>	$\alpha$ 0.77	-	-	-	-	-	-	-	Gould (2018) <sup>1</sup>	-	-	-	-	1 (4.2%)
DCN scale <sup>8</sup>	$\alpha$ 0.89	-	-	-	-	-	Otto (2017)	-	-	-	-	-	-	1 (4.2%)
DCN scale <sup>7</sup>	$\alpha$ 0.89	-	-	Krettenauer (2020)	-	-	-	-	-	-	-	-	-	1 (4.2%)
CATES-PV	$\alpha$ 0.68	-	-	-	-	-	-	Kim (2020)	-	-	-	-	-	1 (4.2%)
Custom	$\alpha$ ranged from 0.48 – 0.92	-	-	-	-	-	-	-	Clayton (2019)	Huang (2005)	Douglas (2009)	-	-	4 (17%)
Focus group	N/A	-	-	-	-	-	-	-	-	Douglas (2009)	Barros (2020)	-	-	2 (8.3%)
Participant observation	N/A	-	-	-	-	-	-	-	-	Douglas (2009)	-	-	-	1 (4.2%)
Pictorial based response	N/A	-	-	-	-	-	-	-	-	-	-	Blanchet-Cohen (2008)	-	1 (4.2%)

Table 3 continued

Interview	N/A	-	-	-	-	-	-	-	-	Aguirre-Bielschowsky (2012)	-	-	Buttigieg (2013)	5 (20.8%)
										Blanchet-Cohen (2008)				
	<b>Total studies</b>	1 (4.2%)	2 (8.3%)	3 (12.5%)	1 (4.2%)	2 (8.3%)	1 (4.2%)	1 (4.2%)	8 (33.3%)	4 (17%)	1 (4.2%)	1 (4.2%)	1 (4.2%)	

Notes. N/A = Not applicable; Custom = Custom scale; Enviro = Environmental; NR-scale = Nature Relatedness scale (Nisbet et al., 2009); CNI = Connection to Nature index (Cheng & Monroe, 2012); CNS = Connectedness to Nature scale (Mayer & Frantz, 2004); CEPS = Children’s Environmental Perceptions scale (Larson et al., 2011); EAN = Modified Emotional Affinity Toward Nature (EAN) scale adapted for use with teenagers (Müller et al. 2009); NEP = New Environmental Paradigm (Dunlap, 2008); CHEAKS = The Children’s Environmental Attitude and Knowledge scale (Leeming & Dwyer, 1995); R-NEP = Revised New Ecological Paradigm (Dunlap et al., 2000); CATES - PV = The Children’s Attitudes toward the Environment scale - Preschool Version (Musser & Diamond, 1999) adapted to measure a nature-friendly attitude (Soh, 2007 & Kim, 2013); DCN = Disposition to Connect to Nature scale (Brügger et al., 2011); CREBS = Children’s Responsible Environmental Behavior scale (Erdoğan et al., 2012); GEB = The General Ecological Behavior scale (Kaiser, 1998; Kaiser & Wilson, 2004); PEBS = Modified Pro-Environmental Behavior scale (Markle 2013); BBEAS = Behaviour-Based Environmental Attitude scale (Kaiser et al., 2007).

- <sup>1</sup> Single item measure for PEB Cronbach’s alpha NA
- <sup>2</sup> GEB scale adapted for use with children (Frajó et al. 2012)
- <sup>3</sup> GEB scale adapted for use with children (Collado, Evans, & Sorrel, 2017; Evans et al., 2007)
- <sup>4</sup> NEP adapted for use with children (Evans et al., 2007)
- <sup>5</sup> NEP adapted for use with children (Manoli et al., 2007)
- <sup>6</sup> Subset of items from the CNS
- <sup>7</sup> Modified version (Krettenauer, 2017) of the DCN
- <sup>8</sup> Shortened version of the DCN
- <sup>9</sup> Cronbach’s alpha N/A due to underlying Rasch model

### 3.1.1 Participant Demographics

Based on the sixteen studies (66.8%,  $n = 6,199$ ) that provided sufficient age information for participants, the pooled mean age at the time of the study was 12.9 (SD = 1.9). Based on the fifteen studies (62.5%,  $n = 6,165$ ) that provided sufficient age information in reference to childhood CN, the pooled mean age was 12 (SD = 1.9), with an age range of 0 – 21 years. Based on the twenty studies (83.3%,  $n = 7,622$ ) that reported on gender, the pooled sample consisted of 57.3% female ( $n = 4,904$ ) and 42.7% male ( $n = 3,660$ ) (see Table 4).

Table 4

#### *Sample Demographics*

	$N_{\text{studies}}$	$N_{\text{participants}}$	%	$M_{\text{pooled}}$	$SD_{\text{Pooled}}$	Age Range
<i>Participant demographics</i>						
Age (years)	16	6,199		12.9	1.9	
Age childhood nature connectedness was related to	15	6,165		12	1.9	0-21 years
Gender	20					
Female		3,962	57.3%			
Male		3,660	42.7%			
		7,622	100%			

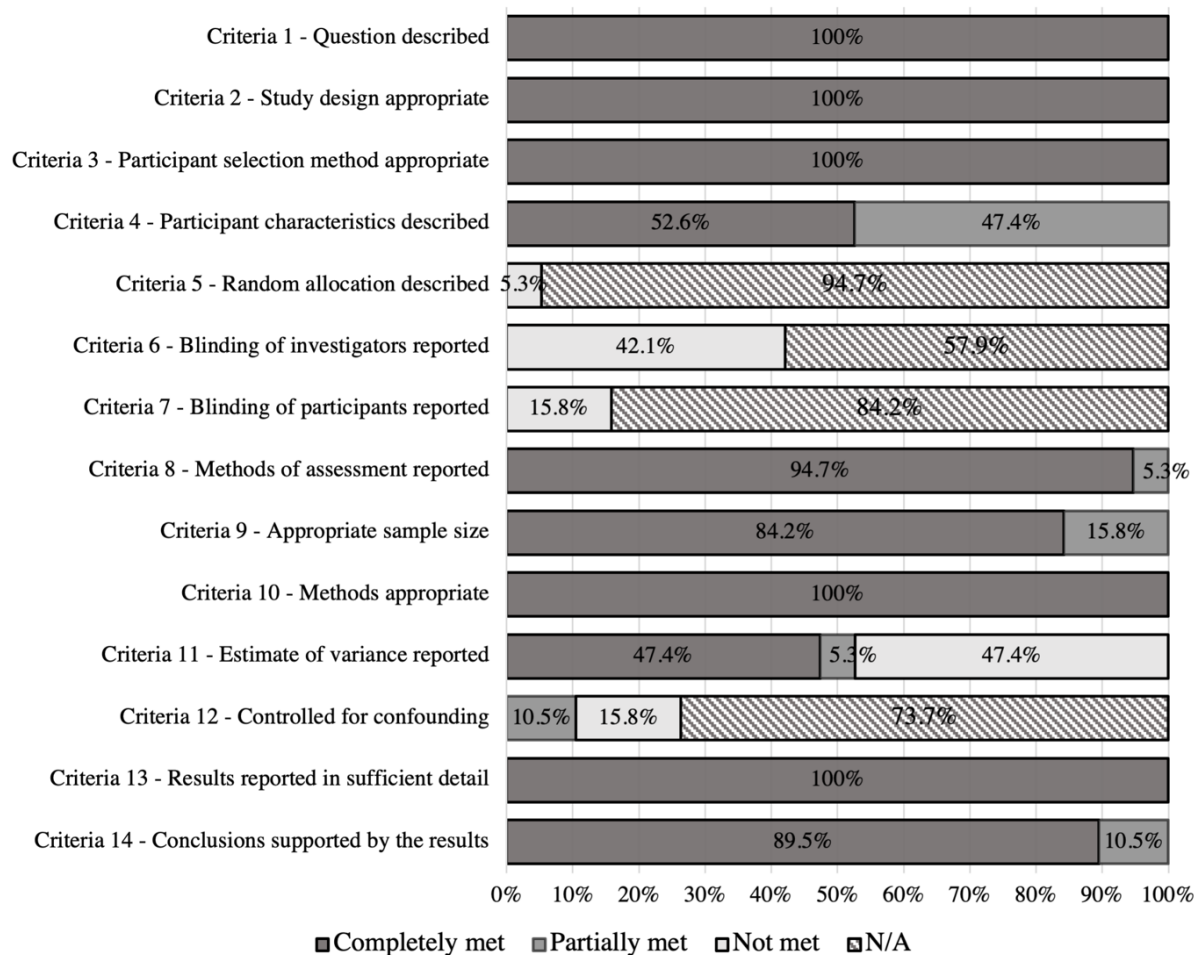
### 3.2 Risk of Bias in Individual Studies

Reporting quality was high, and risk of bias was low in most included studies, with an overall summary score of 83.6% (range = 61.5%-100%). The mean summary score for quantitative studies was 84.1% (range = 61.5%-100%), 81.9% (range = 65%-100%) for

qualitative studies, and 86.7% (range = 70%-100%) for mixed methods studies (see Appendix D). All studies met the liberal criteria (55%) for inclusion in the meta-analyses as provided by Kmet et al. (2004).

The majority of risk of bias criteria were adequately addressed for all study types. However, there were some criteria that were less consistently fulfilled. Only half of the included quantitative studies had some form of variance reported for outcome metrics (Criteria 11; 50%). Similarly, interventional blinding of investigators was applicable for 42.1% of studies and was not appropriately described within these studies (Criteria 6; 0%). Controlling for confounds was applicable for 26.3% of studies but was poorly described within these studies (Criteria 12; 20%). Interventional blinding of participants was applicable for 15.8% of studies and was also not described within these studies (Criteria 7; 0%). Random allocation to treatment group was only applicable to one study (Ebersbach et al., 2019), but was not appropriately described (Criteria 5; 0%) (see Figure 2).

Qualitative studies also appropriately addressed the majority of risk of bias criteria, except for studies describing reflexivity of the account (Criteria 10; 18.8%) (see Figure 3). All mixed methods studies adequately addressed each of the risk of bias criteria (see Figure 4).



*Figure 2.* Proportion of quantitative studies meeting the QualSyst Tool criteria (Kmet et al., 2004).

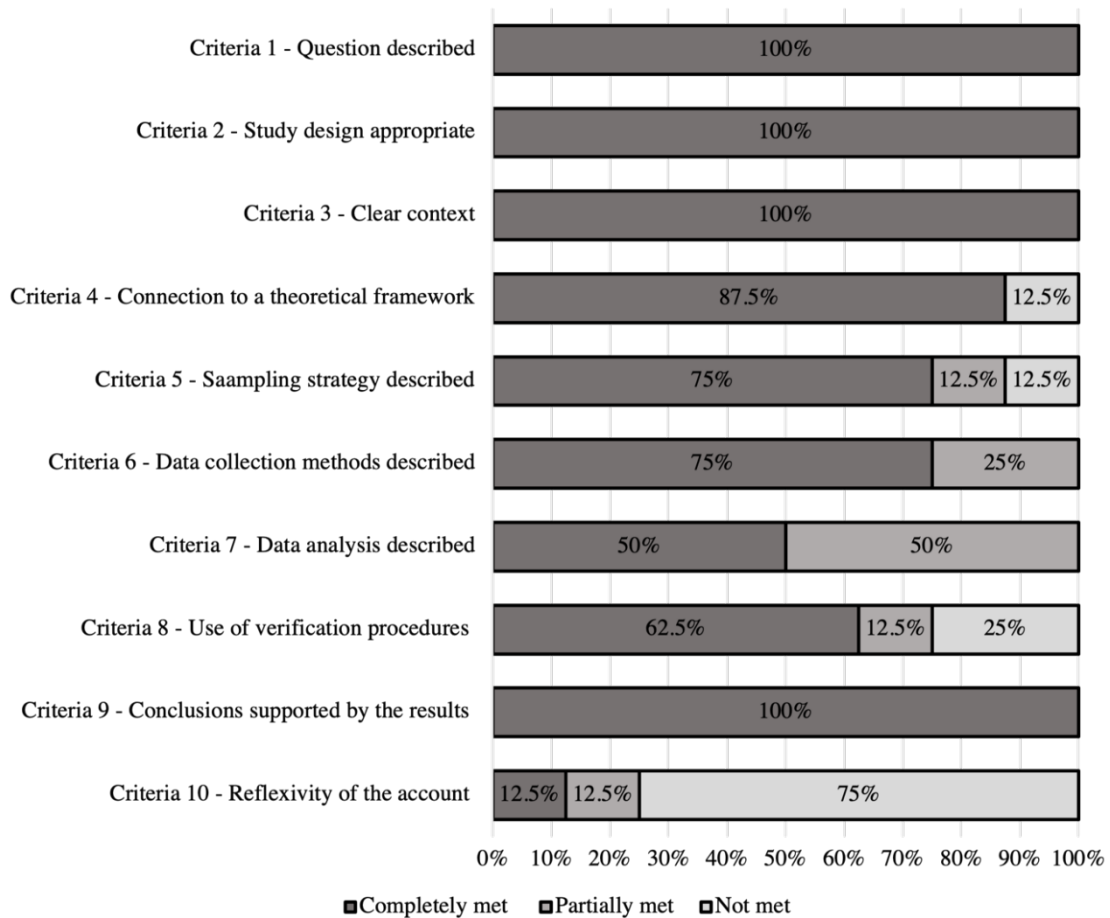


Figure 3. Proportion of qualitative studies meeting the QualSyst Tool criteria (Kmet et al., 2004).

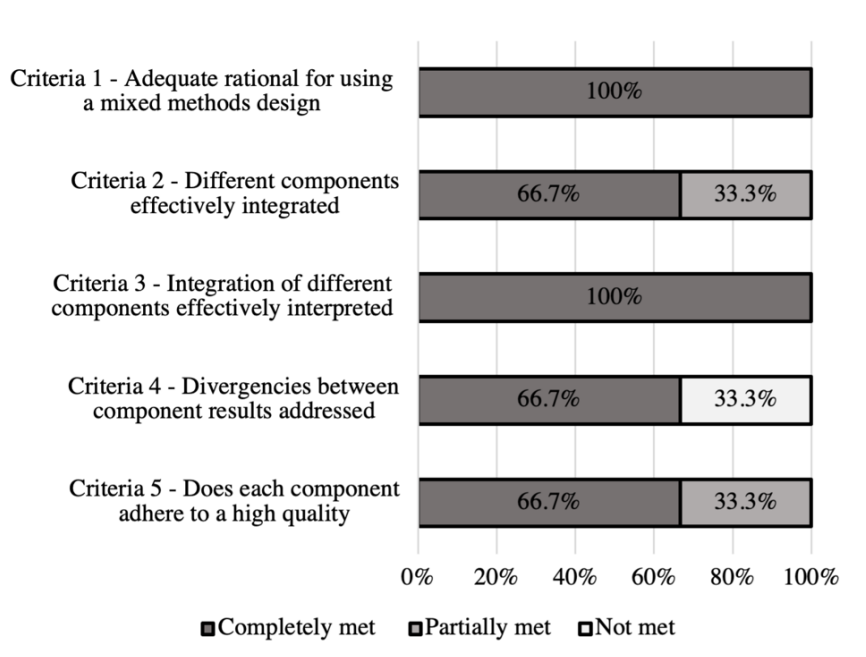


Figure 4. Proportion of mixed methods studies meeting the MMAT criteria (Hong et al., 2018).

### 3.3 Systematic Review

#### 3.3.1 Overall Findings

While the research included in this study has been conducted on child and youth populations between the ages of 4-21 years, there has been more focus on ages between 9-12 years. Thirteen countries and five continents (Asia, Europe, North and South America, and Oceania) were represented in the included studies, with the majority of relevant studies reporting differences between cultures in the relationship between CN and PEB (Aguirre-Bielschowsky, Freeman, & Vass, 2012; Blanchet-Cohen, 2008; Gould et al., 2018; Huang & Yore, 2005; Krettenauer et al., 2020).

From looking at the main findings table it can be seen overall, there is a positive relationship between childhood CN and PEB reported. This relationship was positive for all but one of the included studies (Ebersbach et al., 2019), which showed a ceiling effect. The positive relationship between childhood CN and PEB holds true for both cross-sectional and longitudinal studies, as well as qualitative, quantitative, mixed methods studies, irrespective of whether or not an intervention was reported. Of the six studies (25%) that employed an intervention, the intervention approaches consisted of summer camps with and without environmental education, zoo trips, environmental engagement and education programs, conservation tasks, and growing projects. The duration of these interventions spanned from 1 day to 1 year. A wide variety of scales have been used for both CN ( $n = 13$ ) and PEB ( $n = 7$ ), not including custom scales. Seventeen (70.8%) studies were conducted in a school setting.



### 3.4 Meta-Analysis

#### 3.4.1 Effect Size

A very large estimated effect was found across the 16 pooled quantitative studies for the childhood CN and PEB relationship (Hedges'  $g = 1.120$ ,  $p < 0.001$ ) (see Table 5). The effects for all included studies were found to be positive except one, with the confidence intervals from only a single study crossing zero. Further, visual inspection of the forest plot shows a higher degree of variability in CI overlap between studies, indicating statistical heterogeneity is likely present (see Figure 5). Indeed, a large chi-squared statistic relative to its degrees of freedom confirms heterogeneity of effects ( $Q(15, n = 7,089) = 333.38$ ,  $p < 0.001$ ). The  $I^2$  statistic of 95.5% demonstrates that nearly all the variability across studies is due to heterogeneity rather than chance alone (Deeks et al., 2008).

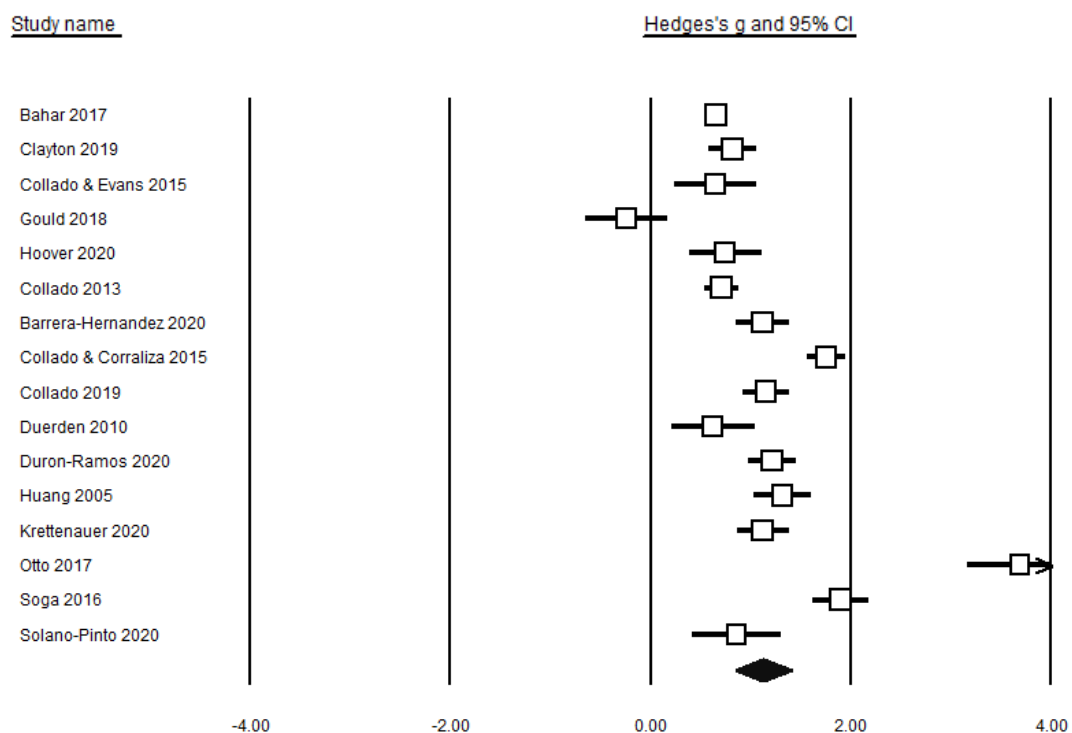


Figure 5. Forest plot showing Hedges'  $g$  with 95% CIs for individual studies, and overall summary effect (diamond).

Table 5

*Relationship between childhood CN and PEB*

<i>Study name</i>	<i>Statistic for each study</i>						
	Hedges' g	Standard error	Variance	Lower limit	Upper limit	z-value	p-value
Bahar 2017	0.65	0.05	0.00	0.55	0.75	13.04	< .001
Barrera-Hernandez 2020	1.12	0.13	0.02	0.86	1.38	8.37	< .001
Clayton 2019	0.82	0.12	0.01	0.59	1.06	6.83	.001
Collado & Staats 2013	0.71	0.08	0.01	0.55	0.87	8.67	< .001
Collado, & Evans 2015	0.65	0.21	0.04	0.25	1.05	3.16	.001
Collado & Corraliza 2015	1.76	0.09	0.01	1.58	1.94	19.08	< .001
Collado & Evans 2019	1.15	0.11	0.01	0.93	1.38	10.11	< .001
Duerden 2010	0.62	0.21	0.04	0.21	1.03	2.99	.002
Duron-Ramos 2020	1.22	0.12	0.01	0.99	1.44	10.39	< .001
Gould 2018	-0.24	0.21	0.04	-0.64	0.16	-1.18	.237
Hoover 2020	0.75	0.18	0.03	0.39	1.10	4.12	< .001
Huang 2005	1.31	0.14	0.02	1.03	1.60	9.12	< .001
Krettenauer 2020	1.12	0.13	0.02	0.87	1.38	8.70	< .001
Otto 2017	3.69	0.26	0.07	3.18	4.21	13.99	< .001
Soga 2016	1.90	0.14	0.02	1.63	2.18	13.69	< .001
Solano-Pinto (2020)	0.86	0.22	0.05	0.42	1.30	3.85	< .001
<b>Total</b>	<b>1.12</b>	<b>0.14</b>	<b>0.02</b>	<b>0.84</b>	<b>1.40</b>	<b>7.833</b>	<b>&lt; .001</b>

### 3.4.2 Subgroup Analysis

A random effects subgroup analysis was conducted to investigate age and location as a potential cause of heterogeneity. A larger effect was found for children (6 - 12 years) (Hedges'  $g = 1.41$ ,  $p = < .001$ ), compared to adolescents (>13 years) (Hedges'  $g = 0.64$ ,  $p = < .001$ ), but with both groups still reflecting significant positive effects (see Figure 6). Comparison of these effects using Cochran's  $Q$  test indicated the difference between the subgroups was statistically significant ( $Q(1, n = 7,089) = 10.01$ ,  $p = .002$ ). Considerable heterogeneity was still evident within the child subgroup ( $Q(9, n = 4,184) = 204.4$ ,  $p = < .001$ ;  $I^2 = 95.6\%$ ), however, sample size limited the possibility of further subgroupings.

Less heterogeneity was evident for adolescents compared to children, although still to a statistically significant degree ( $Q(5, n = 2,905) = 33.11, p = < .001; I^2 = 84.9\%$ ).

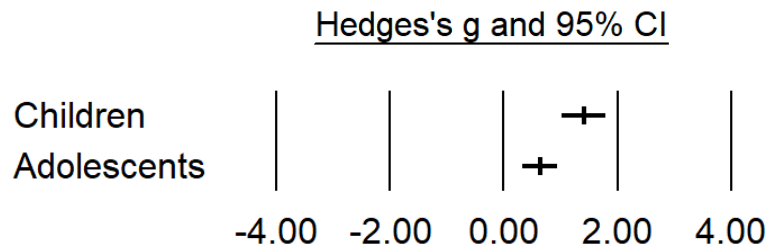


Figure 6. Forest plot showing Hedges' g and 95% CIs for age subgroup analysis.

Regarding location, studies were able to be grouped into three continental regions: Europe (6 studies), Asia (5 studies), and North America (7 studies). Effects in all regions were positive and statistically significant. The largest effect was found for studies conducted in Europe (Hedges'  $g = 1.45, p = < .001$ ), followed by Asia (Hedges'  $g = 0.95, p = < .001$ ), and then North America (Hedges'  $g = 0.87, p = < .001$ ) (see Figure 7). Comparison of these effects using Cochran's  $Q$  test indicated the difference between subgroup analysis was not statistically significant ( $Q(2, n = 7,089) = 2.7, p = .261$ ). Substantial heterogeneity was still evident within regional subgroups, and was greatest for Europe ( $Q(5, n = 2,101) = 170.43, p = < .001; I^2 = 97.1\%$ ), followed by Asia ( $Q(4, n = 3,343) = 81.23, p = < .001; I^2 = 95.1\%$ ), and North America ( $Q(6, n = 1,645) = 51.72, p = < .001; I^2 = 88.4\%$ ).

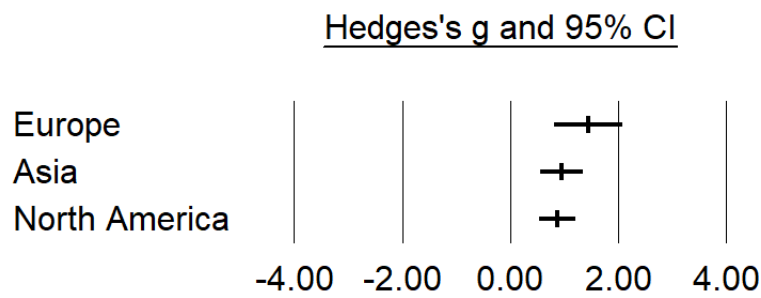


Figure 7. Forest plot showing Hedges' g and 95% CIs for location subgroup analysis.

### 3.4.3 Risk of Bias Across Studies

On visual inspection, the funnel plot of standard error by Hedges' g showed a moderately symmetrical distribution with additional horizontal scatter (see Figure 8). This indicates a low risk of bias with evidence of heterogeneity. Rosenthal's Fail-safe N test was used to quantify the number of studies with a null effect that would be needed to reverse the significant overall effect found. The test indicated 4,723 unidentified null results would be required to overturn the effects shown, suggesting the possibility of bias across studies is highly unlikely.

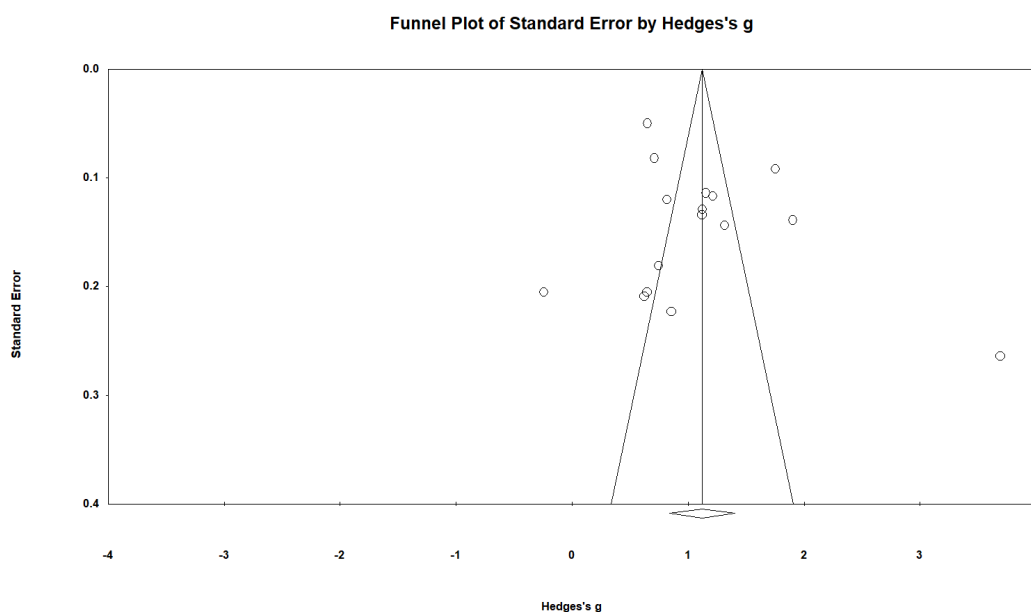


Figure 8. Funnel plot of standard error by Hedges' g for influence of childhood CN on PEB.

## **Chapter 4**

### **Discussion**

#### **4.1 Overall Findings**

The primary aim of this systematic review and meta-analysis was to evaluate childhood CN and its influence on PEB. Twenty-four studies were included as relevant to the topic question and meeting inclusion criteria. As childhood CN is a relatively new research interest, and to fully capture the state of the literature, quantitative, qualitative, and mixed method studies were included in the systematic review to gain a complete insight into the area. From the twenty-four included studies, sixteen quantitative studies were suitable for meta-analysis. Meta-analysis identified a very large effect for the association of childhood CN on PEB in a pooled sample of 7,089 children and youth. Subgroup analysis revealed the effect of CN on PEB is stronger in children compared to adolescents, but is significant in both age groups, and that the effects appear to be consistent across geographical location. The findings from this systematic review and meta-analysis need be interpreted with caution due to the level of heterogeneity and potential bias due to an absence of blinding of investigators and subjects as well as lack of control for confounds in many studies. Combined, the findings indicate the need for better standardisation of measures and a deeper theoretical development of our human-nature interactions. Despite these limitations, the evidence suggests there is indeed a positive relationship between childhood CN and PEB.

#### **4.2 Childhood Connection to Nature and its Influence on Pro-Environmental Behaviour**

Due to human actions, climate change is quickly becoming the most pressing concern of our time. Without taking urgent action to mitigate environmental degradation there may not be a liveable world for future generations (Burke et al., 2018; UN General Assembly, 1990). Previous research has indicated repeated commitment to PEB can substantially alleviate these climate effects, emphasising the importance of identifying factors that increase

involvement in environmental stewardship (Barrera-Hernández et al., 2020; Bradley, Babutsidze, Chai, & Reser, 2020). CN has been recognised as one of the strongest predictors of PEB in both adult and child populations, though, limited research has been conducted on the latter (Chawla & Gould, 2020; Hahn, 2021; Martin et al., 2020). Of the literature that has been conducted on younger populations, findings indicate children who engage more frequently in nature are more likely to develop a CN and therefore engage in more PEB (Duerden & Witt, 2010; Hahn, 2021; Martin et al., 2020; Otto & Pensini, 2017; Ramkissoon et al., 2012). However, it has also suggested that being more connected with the environment can theoretically lead to a sense of hopelessness under conditions of environmental decline, reducing children's capacity and willingness to engage in PEB and instead fall into patterns of avoidance (Chawla & Gould, 2020; Cunsolo & Ellis, 2018; Hahn, 2021; Ojala, 2015). The results of the current study found an overwhelmingly positive effect for the relationship of CN in childhood on PEB, meaning children who felt more connected with the natural world were more likely to engage in PEB. This is possibly in part due to the fact most studies focussed on positive childhood experiences and outdoor/environmental programs designed to facilitate interest, education, and safe engagement without a focus on the possible negative emotions one can experience. Irrespective, these results extend and support current recommendations on childhood nature connection to assist in the global climate crisis by encouraging the development of environmental stewards from an early age (Halpenny, 2010). Although the results support the relationship between childhood CN and PEB, we are not able to imply direct causation based on the current literature. Indeed, studies have referenced the fact that childhood CN may be mediating the relationship between contact with nature and PEB (Collado & Evans, 2019; Collado et al., 2013; Otto & Pensini, 2017; Pensini, Horn, & Caltabiano, 2016; Rosa et al., 2018; Soga et al., 2016). However, the vast majority of studies conducted in the field are correlational and from cross-sectional samples with limited

exploration on contributing factors to the CN-PEB relationship. Thus, more experimental and longitudinal studies are needed to confirm this finding. Furthermore, the causal relationships are likely to be more complex, as a range of possible mediators including environmental knowledge, identity formation, sociocultural factors, locus of control, significant life experiences (SLE), biocentric values, place attachment and more (Aguirre-Bielschowsky et al., 2012; Buttigieg & Pace, 2013; Dewey, 2021; Eames, Barker, & Scarff, 2018; Gatersleben, Murtagh, & Abrahamse, 2014; Huang & Yore, 2005; Krettenauer et al., 2020; Ramkissoon et al., 2012) have been proposed to play a significant role in promoting PEB. As such, future research should aim to investigate these factors also.

Heterogeneity was found across the included studies, signifying substantial variability across the effects. As discussed in previous literature (Blanchet-Cohen, 2008; Collado et al., 2015; Krettenauer et al., 2020), one likely reason for this variance was a difference between child and adolescent age groups. Therefore, age as a potential source of heterogeneity was explored further in the subgroup analysis. While adolescents are still shown to hold appreciation for the natural world, they are more inclined toward urban infrastructures that afford personal growth by gaining respect from peers and establishing future goals. Whereas younger children have been found to be more responsive and open minded to programs that foster connection with the natural world and more likely to engage in PEB (Bahar & Sahin, 2017; Chawla & Gould, 2020; Collado et al., 2015; Hahn, 2021; Kaplan & Kaplan, 2002). The results of the present study were consistent with this previous work. The child (6-12 years) subgroup indicated a larger effect than that found within the adolescent (>13 years) subgroup, with a significant difference between the ages. These results suggest interventions designed to promote CN and PEB should be implemented as early as possible to develop a deeply entrenched connection. Previous research has further emphasised that nature experiences amongst younger children ideally allow for a self-directed experience — in the

child's own way, and at their own pace (Hoover, 2021). This allows children to overcome fear and discomfort in nature gradually, is likely to facilitate a positive experience through development of feelings of empathy and compassion toward the environment, and increase willingness to participate in PEB (Chawla & Gould, 2020; Duerden & Witt, 2010).

Subgroup analysis was also conducted on location as a potential source of heterogeneity. Comparative studies conducted by Huang and Yore (2005), and Krettenauer et al. (2020) have indicated children from different countries hold different perceptions about the environment. Similarly, a study conducted by Gould et al. (2018) found culture is an important factor in the CN-PEB relationship. Although majority of the research has focused on individuals living in Western societies, it is also important to highlight, as specified by the World Trade Organisation (WTO) (2014), individuals living in developing countries have just as much of an impact on the health of the planet as Western societies (Duron-Ramos et al., 2020). It is possible that less densely populated and developed locations may be more culturally aware, spend more time outdoors, feel more connected to the environment, and engage in more PEB (Bruni et al., 2017; Chawla & Gould, 2020). Despite this possibility, the results of the present study show that all three represented continents showed a positive effect of similar magnitude, suggesting that the connection between CN and PEB is a universal phenomenon. This finding should nevertheless be interpreted with caution, as several global regions are still not represented in the literature, including Africa, Oceania, and South America. An explanation for the cultural differences reported in the broader literature is that researchers may have misinterpreted divergences in measurement scale outcomes as reflecting differences across regions. This idea is consistent with the large heterogeneity found within continental groups, yet non-difference in overall effect between these groups. It is recommended further research is conducted cross culturally using consistent methodology to fully ascertain whether cultural differences exist or not.



### **4.3 Implications for the Current Study**

In addition to the aforementioned implications, the research emphasises children are just as much social actors as adult populations. Therefore, it is important to show children they are not alone in the fight against climate change, and support them to build a sense of agency regarding the natural environment (Chawla & Gould, 2020; James & Prout, 2003). With the correct implementation of interventions children will build agency, feel confident in their capabilities of overcoming the current level of environmental loss, and have the knowledge to apply strategies to protect the natural world (Blanchet-Cohen, 2008; Marlon et al., 2019). Previous research has employed an array of programs such as environmental education (EE) programs, school programs, nature camps, immersion experiences, and growing projects to promote contact with nature, CN, and knowledge about the effects of unsustainable human actions and how these effects can be mitigated to facilitate engagement in PEB. (Aguirre-Bielschowsky et al., 2012; Collado et al., 2013; Duerden & Witt, 2010; Kim, Jung, Han, & Sohn, 2020). However, these interventions do not consider populations who do not have direct access to nature. Future strategies need to consider the constant surge of industrialisation and urbanisation in today's world with a steep decline in access to natural areas. This realisation should inform the design of interventions which also promote CN and PEB through indirect sources such as books or technology (Soga et al., 2016). By developing and implementing strategies which target specific populations, a stronger sense of agency, confidence, and knowledge around protecting the natural environment will be fostered in children with otherwise limited opportunities to build CN and support commitment to PEB (Chawla & Gould, 2020; James & Prout, 2003).

### **4.4 Limitations of the Present Study & Suggestions for Future Research**

There were several limitations noted within the current study which should be taken into consideration when interpreting the findings. Firstly, the use of a stringent search

strategy may have impacted the number of studies included within the systematic review and meta-analysis due to failing to capture all possible relevant studies. This is shown in the fact that studies published in languages other than English were not included, meaning it is possible language bias was a factor, in that studies conducted and reported by other cultures may have offered different insights which were not included and evaluated. Secondly, only peer reviewed databases were searched, meaning grey literature were not included within the current research. While this helped ensure a higher quality of study was reviewed, it also may mean that relevant contributions to our relatively undeveloped understanding of the childhood CN-PEB relationship were missed.

The presence of heterogeneity found within the overall analysis as well as within the subgroup analyses is a major limitation identified within the present study, suggesting methodological diversity remains undefined within the research area. As previously mentioned, a suggestion for the cause of this diversity is the variations in the implemented CN measurement scales (Gould et al., 2018). Although each of the CN measurement scales fit into the operationalisation outlined in this study, they each emphasise different aspects of what we have defined as CN. For example, the present study identified thirteen different measures of CN excluding custom scales (Brügger, Kaiser, & Roczen, 2011; Cheng & Monroe, 2012; Dunlap, 2008; Evans et al., 2007; Fraijo Sing, Corral Verdugo, Tapia Fonllem, & García Vázquez, 2012; Krettenauer, 2017; Larson, Green, & Castleberry, 2011; Leeming, Dwyer, & Bracken, 1995; Manoli, Johnson, & Dunlap, 2007; Mayer & Frantz, 2004; Müller, Kals, & Pansa, 2009; Musser & Diamond, 1999; Nisbet et al., 2009). Thus, indicating huge variability across the single construct and questioning whether each measurement scale is indeed measuring the same construct or something different. One explanation for these divergences across measurement scales is that CN is indeed thought of as a multifactorial construct and each of the included studies have measured a valid dimension of CN, albeit not

the construct as a whole. This idea is supported by Cheng and Monroe (2012) who identified different dimensions of children's CN in their Connection to Nature Index including enjoyment of nature, empathy for creatures, sense of oneness, and sense of responsibility. Consequently, all dimensions of CN should be identified and a standardised scale developed to homogenise the field and provide more reliable inferences.

A further limitation is the reliance on explicit self-report outcome measures within the field. This is problematic as the link between self-reported behaviour and actual behaviour can be quite weak and influenced by biases such as the social desirability bias, where individuals report behaving in more socially desirable ways in the attempt to appear more altruistic (Bruni et al., 2017; Buttigieg & Pace, 2013; Chung & Monroe, 2003). To account for the risk of social desirability bias it is suggested future research check the validity of children's responses against parental judgement, through direct observation, or by using implicit measures (Bruni et al., 2017; Collado & Evans, 2019). Implicit measures should be implemented over explicit measures where possible as they are able to identify unconscious mental processes without requiring introspection (Nosek, Greenwald, & Banaji, 2005). Implicit measures such as the Implicit Association Test for Nature (IAT Nature) (Schultz, Shriver, Tabanico, & Khazian, 2004) assess the strength of an individual's unconscious associations between concepts and attributes through reaction time data. When executing a series of categorization tasks, the difference in reaction time speed is used to calculate the strength of these unconscious associations, limiting any social desirability bias (Bruni et al., 2017). Furthermore, it is important to highlight the application and interpretation of IATs more generally as they are not yet fully understood and should be interpreted with caution (Nosek et al., 2005). Therefore, it is recommended to not only implement strategies that reduce social desirability bias, but also further explore the reliability and usability of implicit measures in human-nature relationship studies.

Expanding on the previously mentioned concerns of a reliance on cross-sectional, correlational study designs within the field. It is important to stress that cross-sectional studies limit the ability to analyse behaviour over an extended period of time, make casual inference, and are susceptible to biases such as non-response bias, recall bias, and sampling bias (Wang & Cheng, 2020). Although the correlational study design has been able to uncover that there is a relationship between childhood CN and PEB, it is unable to fully elucidate the reason as to why the connection exists, and the directionality of effects (Curtis, Comiskey, & Dempsey, 2016). To minimise these biases and add further understanding of the causal processes of the CN-PEB relationship, it is suggested longitudinal research is employed within the field to monitor development of CN and PEB over time. Although time consuming, longitudinal research is not only valuable for extended observation but is also applicable to development and improvement of the research area. Previous research implies early implementation of environmental contact and education is essential to create longer-lasting feelings of CN and involvement in PEB by reinforcing environmental attitudes, beliefs, and behaviours early on (Barrera-Hernández et al., 2020; Halpenny, 2010). By conducting longitudinal/lifetime research, effects of early interventions and their influence on future PEB will be determined, as well as being able to identify if adolescents who experience a greater disconnect from nature then reconnect with nature later on in life (Barrera-Hernández et al., 2020; Keith, Given, Martin, & Hochuli, 2021). Along with this longitudinal design, it is suggested that a mixed methods methodology be employed. Where emphasis is given to quantitative data and hypotheses to make inferences from statistical data and qualitative data to gain additional insights into the development of CN and PEB.

#### **4.5 Conclusion**

The current systematic review and meta-analysis aimed to identify if childhood CN influenced engagement in PEB. Majority of the literature on CN and PEB has been conducted

on adult populations, however, evidence suggests CN begins in childhood. This study found a very large effect for higher CN in childhood in promoting PEB, regardless of age or location. These results support previous research (Chawla & Gould, 2020; Hahn, 2021; Martin et al., 2020; Otto & Pensini, 2017), and show promising evidence for promoting childhood nature engagement and connection, which is likely to increase PEB and help mitigate environmental degradation. Nevertheless, further research is needed on cross cultural populations to confirm a universal phenomenon. Further, there is a need to further investigate the components that comprise CN and inform development a standardisation of measurement scales to increase reliability in the field. Although inconsistencies and weaknesses have been identified within the field, valuable inferences are able to be drawn from the findings presented. Ultimately, children are the environmental stewards of the future. By promoting CN at a young age lifelong associations can be established, promoting dedication and pride in taking care of the environment by developing values which affiliate the self with the natural world, and which will help protect future generations and the natural world from extinction. It is therefore critical that research into childhood CN and PEB continues, to assist in identifying how best to promote connection across populations, understand what mediating factors affect this connection, and to develop a more comprehensive and applied understanding of our human-nature connection.

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## Appendices

### Appendix A: Logic Grids with Boolean Operators

#### Education Research Complete

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
“Connect* to nature”		MH “Children”		“Pro-environmental behaviour*”
OR		OR		OR
“Connect* with nature”		MH “Adolescence”		“Pro-ecological behaviour*”
OR		OR		OR
“Connect* with the environment”		MH “Teenagers”		“Environmental behaviour*”
OR		Child*		OR
“Connect* to the environment”		OR		“Ecological behaviour*”
OR		Girl*		OR
“Connect* with the natural environment”		OR		“Sustainable behaviour*”
OR		Boy		OR
“Connect* to the natural environment”		OR		“Eco-friendly behaviour*”
OR		Boys		OR
“Connect* with the natural environment”		OR		“Ecologically sound behaviour*”
OR		Adolescen*		OR
“Care for nature”		OR		“Pro-environmental behavior*”
OR		Youth		OR
“Nature connect*”		OR		“Pro-ecological behavior*”
OR		“Young person*”		OR
“Nature contact”		OR		“Environmental behavior*”
OR		“Young people”		OR
“Nature relat*”		OR		“Ecological behavior*”
OR		Juvenile*		OR
“Nature activit*”		OR		“Sustainable behavior*”
OR		Minor*		OR
“Nature engagement”		OR		“Eco-friendly behavior*”
OR		Junior*		OR
“Nature experience*”		OR		“Ecologically sound behavior*”
OR		Kid		OR
“Nature association*”		OR		“Pro-ecological conduct”
OR		Kids		OR
“Nature-based experience*”		OR		“Environmental conduct”
OR		P\$ediatric		OR
“Nature-based recreation”		OR		“Ecological conduct”
OR		Teen*		OR
“Environment* connect*”		OR		“Sustainable conduct”
OR		Schoolchild*		OR
“Environment* relat*”				“Eco-friendly conduct”
OR				OR
“Environment* activit*”				“Ecologically sound conduct”
OR				OR
“Environment* engagement”				“Pro-ecological action*”
OR				OR
“Environment* contact”				“Environmental action*”
OR				OR
“Environment* association*”				“Ecological action*”
OR				OR
“Environment* experience*”				“Sustainable action*”
				OR
				“Eco-friendly action*”
				OR
				“Ecologically sound action*”
				OR

<p>OR          “Emotional affinity toward* nature”          OR          “Emotional affinity toward* the environment”          OR          “Inclusion of nature in self”          OR          “Inclusion of the environment in self”          OR          “Unstructured nature play”          OR          “Interaction* with nature”          OR          “Interaction* with the environment”          OR          “Meaning in nature”          OR          “Human-nature connect*”          OR          “Exposure to nature”          OR          “Exposure to the natural environment”          OR          “Relate* to nature”</p>			<p>“Pro-ecological effort*”          OR          “Environmental effort*”          OR          “Ecological effort*”          OR          “Sustainable effort*”          OR          “Eco-friendly effort*”          OR          “Ecologically sound effort*”          OR          “Pro-ecological habit*”          OR          “Environmental habit*”          OR          “Ecological habit*”          OR          “Sustainable habit*”          OR          “Eco-friendly habit*”          OR          “Ecologically sound habit*”          OR          “Pro-ecological practice*”          OR          “Environmental practice*”          OR          “Ecological practice*”          OR          “Sustainable practice*”          OR          “Eco-friendly practice*”          OR          “Ecologically sound practice*”          OR          “Pro-ecological stewardship”          OR          “Environmental stewardship”          OR          “Ecological stewardship”          OR          “Sustainable stewardship”          OR          “Eco-friendly stewardship”          OR          “Ecologically sound stewardship”          OR          “Pro-ecological management”          OR          “Environmental management”          OR          “Ecological management”          OR          “Sustainable management”          OR          “Eco-friendly management”          OR          “Ecologically sound management”</p>
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			OR “Environmentalism” OR “Pro-nature conservation*” OR “Environmental conservation*” OR “Sustainability” OR “Pro-environmentalism” OR “Frugality” OR “Active care for nature” OR “Bio-diversity conservation” OR “Ecological mitigation” OR “Environmental mitigation” OR “Climate change mitigation” OR Recycling OR “Environment* sustainability” OR “Environment* concern” OR Worldview OR “Ecological worldview”
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## Embase

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
'Connect* to nature':ti,ab		Adolescent/de		Sustainability/de
OR		OR		OR
'Connect* with nature':ti,ab		Adolescence/de		'Climate change'/de
OR		OR		OR
'Connect* with the environment':ti,ab		Child/de		'Environmental psychology'/de
OR		OR		OR
'Connect* to the environment':ti,ab		Childhood/de		'Pro-environmental behaviour*':ti,ab
OR		'Pre-school child'/de		OR
'Connect* with the natural environment':ti,ab		Juvenile/de		'Pro-ecological behaviour*':ti,ab
OR		OR		OR
'Connect* to the natural environment':ti,ab		'School child'/de		'Environmental behaviour*':ti,ab
OR		OR		OR
'Care for nature':ti,ab		Child*:ti,ab		'Ecological behaviour*':ti,ab
OR		OR		OR
'Nature connect*':ti,ab		Girl*:ti,ab		'Sustainable behaviour*':ti,ab
OR		OR		OR
'Nature contact':ti,ab		Boy:ti,ab		'Eco-friendly behaviour*':ti,ab
OR		OR		OR
'Nature relat*':ti,ab		Boys:ti,ab		'Ecologically sound behaviour*':ti,ab
OR		OR		OR
'Nature activit*':ti,ab		Adolescen*:ti,ab		'Pro-environmental behavior*':ti,ab
OR		OR		OR
'Nature engagement':ti,ab		Youth:ti,ab		'Pro-ecological behavior*':ti,ab
OR		OR		OR
'Nature experience*':ti,ab		'Young person*':ti,ab		OR
OR		OR		'Environmental behavior*':ti,ab
'Nature association*':ti,ab		'Young people':ti,ab		OR
OR		OR		'Ecological behavior*':ti,ab
'Nature-based experience*':ti,ab		Juvenile*:ti,ab		OR
OR		OR		'Sustainable behavior*':ti,ab
'Nature-based recreation':ti,ab		Minor*:ti,ab		OR
OR		OR		'Eco-friendly behavior*':ti,ab
'Environment* connect*':ti,ab		Junior*:ti,ab		OR
OR		OR		'Ecologically sound behavior*':ti,ab
'Environment* relat*':ti,ab		Kid:ti,ab		OR
OR		OR		'Pro-ecological conduct':ti,ab
'Environment* activit*':ti,ab		Kids:ti,ab		OR
OR		OR		'Environmental conduct':ti,ab
'Environment* engagement':ti,ab		P\$ediatric:ti,ab		OR
OR		OR		'Ecological conduct':ti,ab
'Environment* contact':ti,ab		Teen*:ti,ab		OR
OR		OR		'Sustainable conduct':ti,ab
'Environment* association*':ti,ab		Schoolchild*:ti,ab		OR
OR				'Eco-friendly conduct':ti,ab
'Environment* experience*':ti,ab				OR
OR				'Ecologically sound conduct':ti,ab
				OR
				'Pro-ecological action*':ti,ab
				OR
				'Environmental action*':ti,ab
				OR
				'Ecological action*':ti,ab
				OR

<p>‘Emotional affinity toward* nature’:ti,ab OR ‘Emotional affinity toward* the environment’:ti,ab OR ‘Inclusion of nature in self’:ti,ab OR ‘Inclusion of the environment in self’:ti,ab OR ‘Unstructured nature play’:ti,ab OR ‘Interaction* with nature’:ti,ab OR ‘Interaction* with the environment’:ti,ab OR ‘Meaning in nature’:ti,ab OR ‘Human-nature connect*’:ti,ab OR ‘Exposure to nature’:ti,ab OR ‘Exposure to the natural environment’:ti,ab OR ‘Relate* to nature’:ti,ab</p>			<p>‘Sustainable action*’:ti,ab OR ‘Eco-friendly action*’:ti,ab OR ‘Ecologically sound action*’:ti,ab OR ‘Pro-ecological effort*’:ti,ab OR ‘Environmental effort*’:ti,ab OR ‘Ecological effort*’:ti,ab OR ‘Sustainable effort*’:ti,ab OR ‘Eco-friendly effort*’:ti,ab OR ‘Ecologically sound effort*’:ti,ab OR ‘Pro-ecological habit*’:ti,ab OR ‘Environmental habit*’:ti,ab OR ‘Ecological habit*’:ti,ab OR ‘Sustainable habit*’:ti,ab OR ‘Eco-friendly habit*’:ti,ab OR ‘Ecologically sound habit*’:ti,ab OR ‘Pro-ecological practice*’:ti,ab OR ‘Environmental practice*’:ti,ab OR ‘Ecological practice*’:ti,ab OR ‘Sustainable practice*’:ti,ab OR ‘Eco-friendly practice*’:ti,ab OR ‘Ecologically sound practice*’:ti,ab OR ‘Pro-ecological stewardship’:ti,ab OR ‘Environmental stewardship’:ti,ab OR ‘Ecological stewardship’:ti,ab OR ‘Sustainable stewardship’:ti,ab OR ‘Eco-friendly stewardship’:ti,ab OR ‘Ecologically sound stewardship’:ti,ab OR ‘Pro-ecological management’:ti,ab OR</p>
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			'Environmental management':ti,ab OR 'Ecological management':ti,ab OR 'Sustainable management':ti,ab OR 'Eco-friendly management':ti,ab OR 'Ecologically sound management':ti,ab OR 'Environmentalism':ti,ab OR 'Pro-nature conservation*':ti,ab OR 'Environmental conservation*':ti,ab OR 'Sustainability':ti,ab OR 'Pro-environmentalism':ti,ab OR 'Frugality':ti,ab OR 'Active care for nature':ti,ab OR 'Bio-diversity conservation':ti,ab OR 'Ecological mitigation':ti,ab OR 'Environmental mitigation':ti,ab OR 'Climate change mitigation':ti,ab OR Recycling:ti,ab OR 'Environment* sustainability':ti,ab OR 'Ecological worldview':ti,ab OR Worldview:ti,ab OR 'Environment* concern':ti,ab
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ERIC

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
(TI,AB(Nature OR "Natural environment" OR Environment OR Environmental OR "Human-nature" OR "Nature-based") NEAR/3 TI,AB(Connect* OR Relate* OR "Care for" OR Contact OR Relationship* OR Activit* OR Engagement OR Experience* OR Association* OR "Emotional affinity" OR Meaning OR Exposure OR Interaction* OR Recreation*)) OR AB, TI("Inclusion of nature in self") OR AB, TI("Inclusion of the environment in self") OR AB, TI("Relational values") OR AB, TI("Unstructured nature play")		MAINSUBJECT.EXACT("Adolescents") OR MAINSUBJECT.EXACT("Preadolescents") OR MAINSUBJECT.EXACT("Early adolescents") OR MAINSUBJECT.EXACT("Childhood attitudes") OR MAINSUBJECT.EXACT("Adolescent attitudes") OR MAINSUBJECT.EXACT("Preschool children") OR MAINSUBJECT.EXACT("Young children") OR MAINSUBJECT.EXACT("Children") OR MAINSUBJECT.EXACT("Youth") OR AB, TI(Child*) OR AB, TI(Girl) OR AB, TI(Girls) OR AB, TI(Boy) OR AB, TI(Boys) OR AB, TI(Adolescence) OR AB, TI(Adolescent) OR AB, TI(Adolescents) OR AB, TI(Youth) OR AB, TI("Young person") OR AB, TI("Young persons") OR AB, TI("Young people") OR AB, TI(Juvenile) OR AB, TI(Juveniles) OR AB, TI(Minor) OR		MAINSUBJECT.EXACT("Recycling") OR MAINSUBJECT.EXACT("Conservation (environment)") OR MAINSUBJECT.EXACT("Sustainable development") OR MAINSUBJECT.EXACT("Ecology") OR MAINSUBJECT.EXACT("Climate") OR AB, TI("Pro-environmental behavior") OR AB, TI("Pro-environmental behaviors") OR AB, TI("Pro-ecological behavior") OR AB, TI("Pro-ecological behaviors") OR AB, TI("Environmental behaviors") OR AB, TI("Environmental behavior") OR AB, TI("Ecological behavior") OR AB, TI("Ecological behaviors") OR AB, TI("Sustainable behavior") OR AB, TI("Sustainable behaviors") OR AB, TI("Eco-friendly behavior") OR AB, TI("Eco-friendly behaviors") OR AB, TI("Ecologically sound behavior") OR AB, TI("Ecologically sound behaviors") OR AB, TI("Pro-environmental behaviour?") OR AB, TI("Pro-ecological behaviour?") OR

	<p>AB, TI(Minors) OR AB, TI(Junior) OR AB, TI(Juniors) OR AB, TI(Kid) OR AB, TI(Kids) OR AB, TI(Paediatric) OR AB, TI(Pediatric) OR AB, TI(Teen*) OR AB, TI(Schoolchild) OR AB, TI(Schoolchildren)</p>	<p>AB, TI(“Environmental behaviour?”) OR AB, TI(“Ecological behaviour?”) OR AB, TI(“Sustainable behaviour?”) OR AB, TI(“Eco-friendly behaviour?”) OR AB, TI(“Ecologically sound behaviour?”) OR AB, TI(“Pro-ecological conduct”) OR AB, TI(“Environmental conduct”) OR AB, TI(“Ecological conduct”) OR AB, TI(“Sustainable conduct”) OR AB, TI(“Eco-friendly conduct”) OR AB, TI(“Ecologically sound conduct”) OR AB, TI(“Pro-ecological action?”) OR AB, TI(“Environmental action?”) OR AB, TI(“Ecological action?”) OR AB, TI(“Sustainable action?”) OR AB, TI(“Eco-friendly action?”) OR AB, TI(“Ecologically sound action?”) OR AB, TI(“Pro-ecological effort?”) OR AB, TI(“Environmental effort?”) OR AB, TI(“Ecological effort?”) OR AB, TI(“Sustainable effort?”) OR AB, TI(“Environmental habit?”) OR AB, TI(“Ecological habit?”) OR AB, TI(“Sustainable habit?”) OR AB, TI(“Eco-friendly habit?”) OR AB, TI(“Ecologically sound habit?”)</p>
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			<p>OR</p> <p>AB, TI("Pro-ecological practice?")</p> <p>OR</p> <p>AB, TI("Environmental practice?")</p> <p>OR</p> <p>AB, TI("Ecological practice?")</p> <p>OR</p> <p>AB, TI("Sustainable practice?")</p> <p>OR</p> <p>AB, TI("Eco-friendly practice?")</p> <p>OR</p> <p>AB, TI("Ecologically sound practice?")</p> <p>OR</p> <p>AB, TI("Pro-ecological stewardship")</p> <p>OR</p> <p>AB, TI("Environmental stewardship")</p> <p>OR</p> <p>AB, TI("Ecological stewardship")</p> <p>OR</p> <p>AB, TI("Sustainable stewardship")</p> <p>OR</p> <p>AB, TI("Eco-friendly stewardship")</p> <p>OR</p> <p>AB, TI("Ecologically sound stewardship")</p> <p>OR</p> <p>AB, TI("Pro-ecological management")</p> <p>OR</p> <p>AB, TI("Environmental management")</p> <p>OR</p> <p>AB, TI("Ecological management")</p> <p>OR</p> <p>AB, TI("Sustainable management")</p> <p>OR</p> <p>AB, TI("Eco-friendly management")</p> <p>OR</p> <p>AB, TI("Ecologically sound management")</p> <p>OR</p> <p>AB, TI(Environmentalism)</p> <p>OR</p> <p>AB, TI("Pro-nature conservation")</p> <p>OR</p> <p>AB, TI("Environmental conservation")</p> <p>OR</p>
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				AB, TI(Sustainability) OR AB, TI("Pro-environmentalism") OR AB, TI(Frugality) OR AB, TI("Active care for nature") OR AB, TI("bio-diversity conservation") OR AB, TI("Ecological mitigation") OR AB, TI("Environmental mitigation") OR AB, TI("Climate change mitigation") OR AB, TI(Recycling) OR AB, TI("Environment sustainability") OR AB, TI("Environmental sustainability") OR AB, TI("Ecological worldview") OR AB, TI(Worldview) OR AB, TI("Environment concern") OR AB, TI("Environmental concern")
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## PsycINFO

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
Connect* to nature.tw OR Connect* with nature.tw OR Connect* with the environment.tw OR Connect* to the environment.tw OR Connect* with the natural environment.tw OR Connect* to the natural environment.tw OR Care for nature.tw OR Nature Connect*.tw OR Nature contact.tw OR Nature Relat*.tw OR Nature activit*.tw OR Nature engagement.tw OR Nature experience*.tw OR Nature association*.tw OR Nature based experience*.tw OR Nature based recreation.tw OR Environment* connect*.tw OR Environmenta* relat*.tw OR Environment* activit*.tw OR Environment* engagement.tw OR Environment* contact.tw OR Environment* association*.tw		Early adolescence.sh OR Childhood development.sh OR Adolescent development.sh OR Adolescent behaviour.sh OR Child*.tw OR Girl*.tw OR Boy.tw OR Boys.tw OR Adolescen*.tw OR Youth.tw OR Young person*.tw OR Young people.tw OR Juvenile*.tw OR Minor*.tw OR Junior*.tw OR Kid.tw OR Kids.tw OR P?ediatric.tw OR Teen*.tw OR Schoolchild*.tw		Environmental attitudes.sh OR Sustainable development.sh OR Conservation (ecological behavior).sh OR Ecological factors.sh OR Behavioral ecology.sh OR Ecological psychology.sh OR Environmental effects.sh OR Environmental psychology.sh OR Pro-environmental behaviour*.tw OR Pro-ecological behaviour*.tw OR Environmental behaviour*.tw OR Ecological behaviour*.tw OR Sustainable behaviour*.tw OR Eco-friendly behaviour*.tw OR Ecologically sound behaviour*.tw OR Pro-environmental behavior*.tw OR Pro-ecological behavior*.tw OR Environmental behavior*.tw OR Ecological behavior*.tw OR Sustainable behavior*.tw OR Eco-friendly behavior*.tw OR Ecologically sound behavior*.tw OR Pro-ecological conduct.tw OR Environmental conduct.tw OR Ecological conduct.tw OR Sustainable conduct.tw OR Eco-friendly conduct.tw OR Ecologically sound conduct.tw

<p>OR  Environment*  experience*.tw  OR  Emotional affinity  toward* nature.tw  OR  Emotional affinity  toward* the  environment.tw  OR  Inclusion of nature in  self.tw  OR  Inclusion of the  environment in self.tw  OR  Unstructured nature  play.tw  OR  Interaction* with  nature.tw  OR  Interaction* with the  environment.tw  OR  Meaning in nature.tw  OR  Human-nature  connect*.tw  OR  Exposure to nature.tw  OR  Exposure to the natural  environment.tw  OR  Relate* to nature.tw</p>			<p>OR  Pro-ecological action*.tw  OR  Environmental action*.tw  OR  Ecological action*.tw  OR  Sustainable action*.tw  OR  Eco-friendly action*.tw  OR  Ecologically sound action*.tw  OR  Pro-ecological effort*.tw  OR  Environmental effort*.tw  OR  Ecological effort*.tw  OR  Sustainable effort*.tw  OR  Eco-friendly effort*.tw  OR  Ecologically sound effort*.tw  OR  Pro-ecological habit*.tw  OR  Environmental habit*.tw  OR  Ecological habit*.tw  OR  Sustainable habit*.tw  OR  Eco-friendly habit*.tw  OR  Ecologically sound habit*.tw  OR  Pro-ecological practice*.tw  OR  Environmental practice*.tw  OR  Ecological practice*.tw  OR  Sustainable practice*.tw  OR  Eco-friendly practice*.tw  OR  Ecologically sound practice*.tw  OR  Pro-ecological stewardship.tw  OR  Environmental stewardship.tw  OR  Ecological stewardship.tw  OR  Sustainable stewardship.tw  OR  Eco-friendly stewardship.tw  OR  Ecologically sound stewardship.tw</p>
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				OR Pro-ecological management.tw OR Environmental management.tw OR Ecological management.tw OR Sustainable management.tw OR Eco-friendly management.tw OR Ecologically sound management.tw OR Environmentalism.tw OR Pro-nature conservation*.tw OR Environmental conservation*.tw OR Sustainability.tw OR Pro-environmentalism.tw OR Frugality.tw OR Active care for nature.tw OR Bio-diversity conservation.tw OR Recycling.tw OR environment* sustainability.tw OR Ecological mitigation.tw OR Environmental mitigation.tw OR Climate change mitigation.tw OR Ecological worldview.tw OR Worldview.tw OR Environment* concern.tw
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## PubMed

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
Connect to nature[tw]		“Child”[mh:noexp]		Pro-environmental
OR		OR		behaviour*[tw]
Connection to nature[tw]		“Child,		OR
OR		preschool”[mh:noexp]		Pro-ecological behaviour*[tw]
Connections to nature[tw]		OR		OR
OR		“Adolescent”[mh:noexp]		Environmental behaviour*[tw]
Connecting to nature[tw]		OR		OR
OR		Child*[tw]		Ecological behaviour*[tw]
Connectedness to nature[tw]		OR		OR
OR		Girl*[tw]		Sustainable behaviour*[tw]
Connect with nature[tw]		OR		OR
OR		Boy[tw]		Eco-friendly behaviour*[tw]
Connection with nature[tw]		OR		OR
OR		Boys[tw]		Ecologically sound
Connections with nature[tw]		OR		behaviour*[tw]
OR		Adolescen*[tw]		OR
Connectedness with nature[tw]		OR		Pro-environmental
OR		Youth[tw]		behavior*[tw]
Connecting with nature[tw]		OR		OR
OR		Young person*[tw]		Pro-ecological behavior*[tw]
Connect with the		OR		OR
environment[tw]		Young people[tw]		Environmental behavior*[tw]
OR		OR		OR
Connection with the		Juvenile*[tw]		Ecological behavior*[tw]
environment[tw]		OR		OR
OR		Minor*[tw]		Sustainable behavior*[tw]
Connections with the		OR		OR
environment[tw]		Junior*[tw]		Eco-friendly behavior*[tw]
OR		OR		OR
Connectedness with the		Kid[tw]		Ecologically sound
environment[tw]		OR		behavior*[tw]
OR		Kids[tw]		OR
Connecting with the		OR		Pro-ecological conduct[tw]
environment[tw]		Paediatric[tw]		OR
OR		OR		Environmental conduct[tw]
Connect to the		Pediatric[tw]		OR
environment[tw]		OR		Ecological conduct[tw]
OR		Teen*[tw]		OR
Connection to the		OR		Sustainable conduct[tw]
environment[tw]		Schoolchild*[tw]		OR
OR				Eco-friendly conduct[tw]
Connections to the				OR
environment[tw]				Ecologically sound
OR				conduct[tw]
Connectedness to the				OR
environment[tw]				Pro-ecological action*[tw]
OR				OR
Connecting to the				Environmental action*[tw]
environment[tw]				OR
OR				Ecological action*[tw]
Connect with the natural				OR
environment[tw]				Sustainable action*[tw]
OR				OR
Connection with the natural				Eco-friendly action*[tw]
environment[tw]				OR
OR				Ecologically sound action*[tw]
				OR



Connections with the natural environment[tw] OR Connectedness with the natural environment[tw] OR Connecting with the natural environment[tw] OR Connect to the natural environment[tw] OR Connection to the natural environment[tw] OR Connections to the natural environment[tw] OR Connectedness to the natural environment[tw] OR Connecting to the natural environment[tw] OR Care for nature[tw] OR Nature Connect*[tw] OR Nature contact[tw] OR Nature Relat*[tw] OR Nature activit*[tw] OR Nature engagement[tw] OR Nature experience*[tw] OR Nature association*[tw] OR Nature based experience*[tw] OR Nature based recreation[tw] OR Environment connect*[tw] OR Environmental connect*[tw] OR Environment relat*[tw] OR Environmental relat*[tw] OR Environment activit*[tw] OR Environmental activit*[tw] OR Environment engagement[tw] OR Environmental engagement[tw] OR			Pro-ecological effort*[tw] OR Environmental effort*[tw] OR Ecological effort*[tw] OR Sustainable effort*[tw] OR Eco-friendly effort*[tw] OR Ecologically sound effort*[tw] OR Pro-ecological habit*[tw] OR Environmental habit*[tw] OR Ecological habit*[tw] OR Sustainable habit*[tw] OR Eco-friendly habit*[tw] OR Ecologically sound habit*[tw] OR Pro-ecological practice*[tw] OR Environmental practice*[tw] OR Ecological practice*[tw] OR Sustainable practice*[tw] OR Eco-friendly practice*[tw] OR Ecologically sound practice*[tw] OR Pro-ecological stewardship[tw] OR Environmental stewardship[tw] OR Ecological stewardship[tw] OR Sustainable stewardship[tw] OR Eco-friendly stewardship[tw] OR Ecologically sound stewardship[tw] OR Pro-ecological management[tw] OR Environmental management[tw] OR Ecological management[tw] OR Sustainable management[tw] OR
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Environment contact[tw] OR Environmental contact[tw] OR Environment association*[tw] OR Environmental association*[tw] OR Environment experience*[tw] OR Environmental experience*[tw] OR Emotional affinity toward nature[tw] OR Emotional affinity towards nature[tw] OR Emotional affinity toward the environment[tw] OR Emotional affinity towards the environment[tw] OR Inclusion of nature in self[tw] OR Inclusion of the environment in self[tw] OR Unstructured nature play[tw] OR Interaction with nature[tw] OR Interactions with nature[tw] OR Interaction with the environment[tw] OR Interactions with the environment[tw] OR Meaning in nature[tw] OR Human-nature connect*[tw] OR Exposure to nature[tw] OR Exposure to the natural environment[tw] OR Relate to nature[tw] OR Relatedness to nature[tw] OR Relations to nature[tw]				Eco-friendly management[tw] OR Ecologically sound management[tw] OR Environmentalism[tw] OR Pro-nature conservation*[tw] OR Environmental conservation*[tw] OR Sustainability[tw] OR Pro-environmentalism[tw] OR Frugality[tw] OR Active care for nature[tw] OR Bio-diversity conservation[tw] OR Ecological mitigation[tw] OR Environmental mitigation[tw] OR Climate change mitigation[tw] OR Recycling[tw] OR Environment* sustainability[tw] OR Ecological worldview[tw] OR Worldview[tw] OR Environment* concern[tw]
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Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
“Connect* to nature”		Child*		“Pro-environmental behaviour*”
OR		OR		OR
“Connect* with nature”		Girl*		“Pro-ecological behaviour*”
OR		OR		OR
“Connect* with the environment”		Boy		“Environmental behaviour*”
OR		OR		OR
“Connect* to the environment”		Boys		“Ecological behaviour*”
OR		OR		OR
“Connect* with the natural environment”		Adolescen*		“Sustainable behaviour*”
OR		OR		OR
“Connect* to the natural environment”		Youth		“Eco-friendly behaviour*”
OR		OR		OR
“Connect* to the natural environment”		“Young person*”		“Ecologically sound behaviour*”
OR		OR		OR
“Care for nature”		“Young people”		“Pro-environmental behavior*”
OR		OR		OR
“Nature Connect*”		Juvenile*		“Pro-ecological behavior*”
OR		OR		OR
“Nature contact”		Minor*		“Environmental behavior*”
OR		OR		OR
“Nature Relat*”		Junior*		“Ecological behavior*”
OR		OR		OR
“Nature activit*”		Kid		“Sustainable behavior*”
OR		OR		OR
“Nature engagement”		Kids		“Eco-friendly behavior*”
OR		OR		OR
“Nature experience*”		Paediatric		“Ecologically sound behavior*”
OR		OR		OR
“Nature association*”		Teen*		“Pro-ecological conduct”
OR		OR		OR
“Nature-based experience*”		Schoolchild*		“Environmental conduct”
OR				OR
“Nature-based recreation”				“Ecological conduct”
OR				OR
“Environment* connect*”				“Sustainable conduct”
OR				OR
“Environment* relat*”				“Eco-friendly conduct”
OR				OR
“Environment* activit*”				“Ecologically sound conduct”
OR				OR
“Environment* engagement”				“Pro-ecological action*”
OR				OR
“Environment* contact”				“Environmental action*”
OR				OR
“Environment* association*”				“Ecological action*”
OR				OR
“Environment* experience*”				“Sustainable action*”
OR				OR
“Emotional affinity toward* nature”				“Eco-friendly action*”
OR				OR
“Emotional affinity toward* the environment”				“Ecologically sound action*”
OR				OR
“Inclusion of nature in self”				“Pro-ecological effort*”
OR				OR
				“Environmental effort*”
				OR
				“Ecological effort*”
				OR
				“Sustainable effort*”

<p>“Inclusion of the environment in self” OR “Unstructured nature play” OR “Interaction* with nature” OR “Interaction* with the environment” OR “Meaning in nature” OR “Human-nature connect*” OR “Exposure to nature” OR “Exposure to the natural environment” OR “Relate* to nature”</p>			<p>OR “Eco-friendly effort*” OR “Ecologically sound effort*” OR “Pro-ecological habit*” OR “Environmental habit*” OR “Ecological habit*” OR “Sustainable habit*” OR “Eco-friendly habit*” OR “Ecologically sound habit*” OR “Pro-ecological practice*” OR “Environmental practice*” OR “Ecological practice*” OR “Sustainable practice*” OR “Eco-friendly practice*” OR “Ecologically sound practice*” OR “Pro-ecological stewardship” OR “Environmental stewardship” OR “Ecological stewardship” OR “Sustainable stewardship” OR “Eco-friendly stewardship” OR “Ecologically sound stewardship” OR “Pro-ecological management” OR “Environmental management” OR “Ecological management” OR “Sustainable management” OR “Eco-friendly management” OR “Ecologically sound management” OR Environmentalism OR “Pro-nature conservation*” OR “Environmental conservation*” OR</p>
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				Sustainability OR “Pro-environmentalism” OR Frugality OR “Active care for nature” OR “Bio-diversity conservation” OR “Ecological mitigation” OR “Environmental mitigation” OR “Climate change mitigation” OR Recycling OR “Environment* sustainability” OR “Ecological worldview” OR Worldview OR “Environment* concern”
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Sociological Abstracts

Connectedness to Nature	AND	Children	AND	Pro-Environmental Behaviour
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(TI,AB(Nature OR "Natural environment" OR Environment OR Environmental OR "Human-nature" OR "Nature-based") NEAR/3 TI,AB(Connect* OR Relate* OR "Care for" OR Contact OR Relationship* OR Activit* OR Engagement OR Experience* OR Association* OR "Emotional affinity" OR Meaning OR Exposure OR Interaction* OR Recreation*)) OR AB, TI("Inclusion of nature in self") OR AB, TI("Inclusion of the environment in self") OR AB, TI("Relational values") OR AB, TI("Unstructured nature play")	MAINSUBJECT.EXACT( "Adolescents") OR MAINSUBJECT.EXACT( "Preadolescents") OR MAINSUBJECT.EXACT( "Early adolescents") OR MAINSUBJECT.EXACT( "Childhood attitudes") OR MAINSUBJECT.EXACT( "Adolescent attitudes") OR MAINSUBJECT.EXACT( "Preschool children") OR MAINSUBJECT.EXACT( "Young children") OR MAINSUBJECT.EXACT( "Children") OR MAINSUBJECT.EXACT( "Youth") OR AB, TI(Child*) OR AB, TI(Girl) OR AB, TI(Girls) OR AB, TI(Boy) OR AB, TI(Boys) OR AB, TI(Adolescence) OR AB, TI(Adolescent) OR AB, TI(Adolescents) OR AB, TI(Youth) OR AB, TI("Young person") OR AB, TI("Young persons") OR AB, TI("Young people") OR AB, TI(Juvenile) OR AB, TI(Juveniles) OR AB, TI(Minor) OR AB, TI(Minors) OR AB, TI(Junior)	MAINSUBJECT.EXACT("Recyc ling") OR MAINSUBJECT.EXACT("Conse rvation (environment)") OR MAINSUBJECT.EXACT("Sustai nable development") OR MAINSUBJECT.EXACT("Ecolo gy") OR MAINSUBJECT.EXACT("Clima te") OR AB, TI("Pro-environmental behavior") OR AB, TI("Pro-environmental behaviors") OR AB, TI("Pro-ecological behavior") OR AB, TI("Pro-ecological behaviors") OR AB, TI("Environmental behaviors") OR AB, TI("Environmental behavior") OR AB, TI("Ecological behavior") OR AB, TI("Ecological behaviors") OR AB, TI("Sustainable behavior") OR AB, TI("Sustainable behaviors") OR AB, TI("Eco-friendly behavior") OR AB, TI("Eco-friendly behaviors") OR AB, TI("Ecologically sound behavior") OR AB, TI("Ecologically sound behaviors") OR AB, TI("Pro-environmental behaviour?") OR AB, TI("Pro-ecological behaviour?") OR AB, TI("Environmental behaviour?") OR AB, TI("Ecological behaviour?") OR
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		<p>OR                  AB, TI(Juniors)                  OR                  AB, TI(Kid)                  OR                  AB, TI(Kids)                  OR                  AB, TI(Paediatric)                  OR                  AB, TI(Pediatric)                  OR                  AB, TI(Teen*)                  OR                  AB, TI(Schoolchild)                  OR                  AB, TI(Schoolchildren)</p>	<p>AB, TI("Sustainable behaviour?")                  OR                  AB, TI("Eco-friendly                  behaviour?")                  OR                  AB, TI("Ecologically sound                  behaviour?")                  OR                  AB, TI("Pro-ecological conduct")                  OR                  AB, TI("Environmental conduct")                  OR                  AB, TI("Ecological conduct")                  OR                  AB, TI("Sustainable conduct")                  OR                  AB, TI("Eco-friendly conduct")                  OR                  AB, TI("Ecologically sound                  conduct")                  OR                  AB, TI("Pro-ecological action?")                  OR                  AB, TI("Environmental action?")                  OR                  AB, TI("Ecological action?")                  OR                  AB, TI("Sustainable action?")                  OR                  AB, TI("Eco-friendly action?")                  OR                  AB, TI("Ecologically sound                  action?")                  OR                  AB, TI("Pro-ecological effort?")                  OR                  AB, TI("Environmental effort?")                  OR                  AB, TI("Ecological effort?")                  OR                  AB, TI("Sustainable effort?")                  OR                  AB, TI("Environmental habit?")                  OR                  AB, TI("Ecological habit?")                  OR                  AB, TI("Sustainable habit?")                  OR                  AB, TI("Eco-friendly habit?")                  OR                  AB, TI("Ecologically sound                  habit?")                  OR                  AB, TI("Pro-ecological                  practice?")                  OR                  AB, TI("Environmental                  practice?")                  OR                  AB, TI("Ecological practice?")</p>
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			<p>OR                  AB, TI (“Sustainable practice?”)                  OR                  AB, TI (“Eco-friendly practice?”)                  OR                  AB, TI (“Ecologically sound practice?”)                  OR                  AB, TI (“Pro-ecological stewardship”)                  OR                  AB, TI (“Environmental stewardship”)                  OR                  AB, TI (“Ecological stewardship”)                  OR                  AB, TI (“Sustainable stewardship”)                  OR                  AB, TI (“Eco-friendly stewardship”)                  OR                  AB, TI (“Ecologically sound stewardship”)                  OR                  AB, TI (“Pro-ecological management”)                  OR                  AB, TI (“Environmental management”)                  OR                  AB, TI (“Ecological management”)                  OR                  AB, TI (“Sustainable management”)                  OR                  AB, TI (“Eco-friendly management”)                  OR                  AB, TI (“Ecologically sound management”)                  OR                  AB, TI (Environmentalism)                  OR                  AB, TI (“Pro-nature conservation”)                  OR                  AB, TI (“Environmental conservation”)                  OR                  AB, TI (Sustainability)                  OR                  AB, TI (“Pro-environmentalism”)                  OR                  AB, TI (Frugality)                  OR                  AB, TI (“Active care for nature”)                  OR                  AB, TI (“bio-diversity conservation”)                  OR                  AB, TI (“Ecological mitigation”)</p>
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			OR AB, TI ("Environmental mitigation") OR AB, TI ("Climate change mitigation") OR AB, TI (Recycling) OR AB, TI ("Environment sustainability") OR AB, TI ("Environmental sustainability") OR AB, TI ("Ecological worldview") OR AB, TI (Worldview) OR AB, TI ("Environment concern") OR AB, TI ("Environmental concern")
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**Appendix B:** Data Extraction Coding Sheet

Study Characteristics
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Citation	<ul style="list-style-type: none"> <li>• Lead author and year</li> <li>• Lead author and second author if lead author has 2 citations in a single year</li> </ul>
Geographical location	<ul style="list-style-type: none"> <li>• Country study was conducted in</li> </ul>
Setting	<ul style="list-style-type: none"> <li>• School</li> <li>• Summer camp</li> <li>• Environmental organisation</li> <li>• Conference</li> <li>• Kindergarten</li> <li>• College</li> <li>• University</li> <li>• Out of school program</li> </ul>
Study design	<ul style="list-style-type: none"> <li>• Longitudinal</li> <li>• Cross-sectional</li> <li>• Correlational</li> <li>• Quasi-experimental</li> <li>• Experimental</li> <li>• Qualitative</li> <li>• Mixed methods</li> </ul>
Sample size	<ul style="list-style-type: none"> <li>• n</li> </ul>
<b>Participant characteristics</b>	
Age at time of study	<ul style="list-style-type: none"> <li>• Mean</li> <li>• Standard deviation</li> <li>• Age range if mean and SD not reported</li> </ul>
Age CN was related to	<ul style="list-style-type: none"> <li>• Range</li> </ul>
Gender	<ul style="list-style-type: none"> <li>• % Male</li> </ul>
Race	<ul style="list-style-type: none"> <li>• % of participants</li> </ul>
<b>Outcome measure</b>	<ul style="list-style-type: none"> <li>• Connection to nature measure</li> <li>• Pro-environmental behaviour measure</li> </ul>
<b>Intervention Details</b>	<ul style="list-style-type: none"> <li>• Type of nature engagement</li> <li>• Number of sessions attended</li> <li>• Number of hours spent in each session</li> <li>• Frequency of sessions</li> <li>• Duration of intervention</li> </ul>
<b>Main behavioural findings</b>	
<b>Effect size data</b>	<ul style="list-style-type: none"> <li>• Pearson's correlations</li> <li>• Standardised coefficients</li> <li>• Unstandardised coefficients</li> <li>• P-value</li> <li>• Standard error</li> <li>• Sample size</li> </ul>

**Appendix C: Modified Appraisal Checklist**

(Hong et al., 2018; Kmet et al., 2004)

<b>Quantitative Criteria</b>		<b>Yes (2)</b>	<b>Partial (1)</b>	<b>No (0)</b>	<b>N/A</b>
<b>1.</b>	Question / objective sufficiently described?				
<b>2.</b>	Study design evident and appropriate?				
<b>3.</b>	Method of subject / comparison group selection or source of information / input variables described and appropriate?				
<b>4.</b>	Subject (and comparison group, if applicable) characteristics sufficiently described?				
<b>5.</b>	If random allocation to treatment group was possible, was it described?				
<b>6.</b>	If interventional and blinding of investigators was possible, was it described?				
<b>7.</b>	If interventional and blinding of subjects was possible, was it described?				
<b>8.</b>	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Means of assessment reported?				
<b>9.</b>	sample size appropriate?				
<b>10.</b>	Analytic methods described / justified and appropriate?				
<b>11.</b>	Some estimate of variance is reported for the main results?				
<b>12.</b>	Controlled for confounding?				
<b>13.</b>	Results reported in sufficient detail?				
<b>14.</b>	Conclusions supported by the results?				

<b>Qualitative Criteria</b>	<b>Yes (2)</b>	<b>Partial (1)</b>	<b>No (0)</b>
Question / objective sufficiently described?			
Study design evident and appropriate?			
Context for the study clear?			
Connection to a theoretical framework / wider body of knowledge?			
Sampling strategy described, relevant and justified?			
Data collection methods clearly described and systematic?			
Data analysis clearly described and systematic?			
Use of verification procedure(s) to establish credibility?			
Conclusions supported by the results?			
Reflexivity of the account?			

<b>Mixed Methods Criteria</b>	<b>Yes (2)</b>	<b>Partial (1)</b>	<b>No (0)</b>
Is there an adequate rationale for using a mixed methods design to address the research question?			
Are the different components of the study effectively integrated to answer the research question?			
Are the outputs of the integration of qualitative and quantitative components adequately interpreted?			
Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?			
Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?			

**Manual for Quality Scoring Quantitative Studies:***Definitions and Instructions for Quality Assessment Scoring***How to calculate the summary score**

- **Total sum** = (number of “yes” \* 2) + (number of “partials” \* 1)
- **Total possible sum** = 28 – (number of “N/A” \* 2)
- **Summary score:** total sum / total possible sum

**Quality assessment**1. *Question or objective sufficiently described?*

- **Yes:** Is easily identified in the introductory section (or first paragraph of methods section). Specifies (where applicable, depending on study design) *all* of the following: purpose, subjects/target population, and the *specific* intervention(s) /association(s)/descriptive parameter(s) under investigation. A study purpose that only becomes apparent after studying other parts of the paper is *not* considered sufficiently described.
- **Partial:** Vaguely/incompletely reported (e.g., “describe the effect of” or “examine the role of” or “assess opinion on many issues” or “explore the general attitudes”); *or* some information has to be gathered from parts of the paper other than the introduction/background/objective section.
- **No:** Question or objective is not reported or is incomprehensible.
- **N/A:** Should not be checked for this question.

2. *Design evident and appropriate to answer study question?*

(If the study question is not given, infer from the conclusions).

- **Yes:** Design is easily identified and is appropriate to address the study question / objective.
  - **Partial:** Design and /or study question not clearly identified, but gross inappropriateness is not evident; *or* design is easily identified but only partially addresses the study question.
  - **No:** Design used does not answer study question (e.g., a comparison group is required to answer the study question, but none was used); *or* design cannot be identified.
  - **N/A:** Should not be checked for this question.
3. *Method of subject selection (and comparison group selection, if applicable) or source of information/input variables (e.g., for decision analysis) is described and appropriate.*
- **Yes:** Described and appropriate. Selection strategy *designed* (i.e., consider sampling frame and strategy) to obtain an unbiased sample of the relevant target population or the entire target population of interest (e.g., consecutive patients for clinical trials, population-based random sample for case-control studies or surveys). Where applicable, inclusion/exclusion criteria are described and defined (e.g., “cancer” -- ICD code or equivalent should be provided). *Studies of volunteers:* methods and setting of recruitment reported. *Surveys:* sampling frame/ strategy clearly described and appropriate.
  - **Partial:** Selection methods (and inclusion/exclusion criteria, where applicable) are not completely described, but no obvious inappropriateness. Or selection strategy is not ideal (i.e., likely introduced bias) but did not likely

seriously distort the results (e.g., telephone survey sampled from listed phone numbers only; hospital based case-control study identified all cases admitted during the study period, but recruited controls admitted during the day/evening only). Any study describing participants only as “volunteers” or “healthy volunteers”. *Surveys*: target population mentioned but sampling strategy unclear.

- **No:** No information provided. *Or* obviously inappropriate selection procedures (e.g., inappropriate comparison group if intervention in women is compared to intervention in men). *Or* presence of selection bias which likely seriously distorted the results (e.g., obvious selection on “exposure” in a case-control study).
- **N/A:** Descriptive case series/reports.

4. *Subject (and comparison group, if applicable) characteristics or input variables/information (e.g., for decision analyses) sufficiently described?*

- **Yes:** Sufficient relevant baseline/demographic information clearly characterizing the participants is provided (or reference to previously published baseline data is provided). Where applicable, reproducible criteria used to describe/categorize the participants are clearly defined (e.g., ever-smokers, depression scores, systolic blood pressure > 140). If “healthy volunteers” are used, age and sex must be reported (at minimum). *Decision analyses*: baseline estimates for input variables are clearly specified.
- **Partial:** Poorly defined criteria (e.g. “hypertension”, “healthy volunteers”, “smoking”). *Or* incomplete relevant baseline / demographic information

(e.g., information on likely confounders not reported). *Decision analyses:* incomplete reporting of baseline estimates for input variables.

- **No:** No baseline / demographic information provided. *Decision analyses:* baseline estimates of input variables not given.
- **N/A:** Should not be checked for this question.

5. *If random allocation to treatment group was possible, is it described?*

- **Yes:** True randomization done - requires a description of the method used (e.g., use of random numbers).
- **Partial:** Randomization mentioned, but method is not (i.e. it may have been possible that randomization was not true).
- **No:** Random allocation not mentioned although it would have been feasible and appropriate (and was possibly done).
- **N/A:** Observational analytic studies. Uncontrolled experimental studies. Surveys. Descriptive case series / reports. Decision analyses.

6. *If interventional and blinding of investigators to intervention was possible, is it reported?*

- **Yes:** Blinding reported.
- **Partial:** Blinding reported but it is not clear who was blinded.
- **No:** Blinding would have been possible (and was possibly done) but is not reported.
- **N/A:** Observational analytic studies. Uncontrolled experimental studies. Surveys. Descriptive case series / reports. Decision analyses.



7. *If interventional and blinding of subjects to intervention was possible, is it reported?*

- **Yes:** Blinding reported.
- **Partial:** Blinding reported but it is not clear who was blinded.
- **No:** Blinding would have been possible (and was possibly done) but is not reported.
- **N/A:** Observational studies. Uncontrolled experimental studies. Surveys. Descriptive case series / reports.

8. *Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias?*

*Means of assessment reported?*

- **Yes:** Defined (or reference to complete definitions is provided) and measured according to reproducible, “objective” criteria (e.g., death, test completion – yes/no, clinical scores). Little or minimal potential for measurement / misclassification errors. *Surveys:* clear description (or reference to clear description) of questionnaire/interview content and response options. *Decision analyses:* sources of uncertainty are defined for all input variables.
- **Partial:** Definition of measures leaves room for subjectivity, *or* not sure (i.e., not reported in detail, but probably acceptable). *Or* precise definition(s) are missing, but no evidence or problems in the paper that would lead one to assume major problems. *Or* instrument/mode of assessment(s) not reported. *Or* misclassification errors may have occurred, but they did not

likely seriously distort the results (e.g., slight difficulty with recall of long-ago events; exposure is measured only at baseline in a long cohort study).

*Surveys*: description of questionnaire/interview content incomplete; response options unclear. *Decision analyses*: sources of uncertainty are defined only for some input variables.

- **No**: Measures not defined or are inconsistent throughout the paper. *Or* measures employ only ill-defined, subjective assessments, e.g., “anxiety” or “pain.” *Or* obvious misclassification errors/measurement bias likely seriously distorted the results (e.g., a prospective cohort relies on self-reported outcomes among the “unexposed” but requires clinical assessment of the “exposed”). *Surveys*: no description of questionnaire/interview content or response options. *Decision analyses*: sources of uncertainty are not defined for input variables.
- **N/A**: Descriptive case series / reports.

#### 9. *Sample size appropriate?*

- **Yes**: Seems reasonable with respect to the outcome under study and the study design. When statistically significant results are achieved for major outcomes, appropriate sample size can usually be assumed, unless large standard errors ( $SE > 1/2$  effect size) and/or problems with multiple testing are evident. *Decision analyses*: size of modeled cohort / number of iterations specified and justified.
- **Partial**: Insufficient data to assess sample size (e.g., sample seems “small” and there is no mention of power/sample size/effect size of interest and/or variance estimates aren’t provided). *Or* some statistically significant

results with standard errors  $> 1/2$  effect size (i.e., imprecise results). *Or* some statistically significant results in the absence of variance estimates.

*Decision analyses:* incomplete description or justification of size of modeled cohort / number of iterations.

- **No:** Obviously inadequate (e.g., statistically non-significant results and standard errors  $> 1/2$  effect size; or standard deviations  $> \_$  of effect size; or statistically non-significant results with no variance estimates and obviously inadequate sample size). *Decision analyses:* size of modeled cohort / number of iterations not specified.
- **N/A:** Most surveys (except surveys comparing responses between groups or change over time). Descriptive case series / reports.

10. *Analysis described and appropriate?*

- **Yes:** Analytic methods are described (e.g. “chi square”/ “t-tests”/“Kaplan-Meier with log rank tests”, etc.) and appropriate.
- **Partial:** Analytic methods are not reported and have to be guessed at, but are probably appropriate. *Or* minor flaws or some tests appropriate, some not (e.g., parametric tests used, but unsure whether appropriate; control group exists but is not used for statistical analysis). *Or* multiple testing problems not addressed.
- **No:** Analysis methods not described and cannot be determined. *Or* obviously inappropriate analysis methods (e.g., chi-square tests for continuous data, SE given where normality is highly unlikely, etc.). *Or* a study with a descriptive goal / objective is over-analysed.
- **N/A:** Descriptive case series / reports.

11. *Some estimate of variance (e.g., confidence intervals, standard errors) is reported for the main results/outcomes (i.e., those directly addressing the study question/objective upon which the conclusions are based)?*

- **Yes:** Appropriate variances estimate(s) is/are provided (e.g., range, distribution, confidence intervals, etc.). *Decision analyses:* sensitivity analysis includes all variables in the model.
- **Partial:** Undefined “+/-“ expressions. *Or* no specific data given, but insufficient power acknowledged as a problem. *Or* variance estimates not provided for all main results/outcomes. *Or* inappropriate variance estimates (e.g., a study examining change over time provides a variance around the parameter of interest at “time 1” or “time 2”, but does not provide an estimate of the variance around the difference). *Decision analyses:* sensitivity analysis is limited, including only some variables in the model.
- **No:** No information regarding uncertainty of the estimates. *Decision analyses:* No sensitivity analysis.
- **N/A:** Descriptive case series / reports. Descriptive surveys collecting information using open-ended questions.

12. *Controlled for confounding?*

- **Yes:** Randomized study, with comparability of baseline characteristics reported (or non-comparability controlled for in the analysis). *Or* appropriate control at the design or analysis stage (e.g., matching, subgroup analysis, multivariate models, etc). *Decision analyses:*

dependencies between variables fully accounted for (e.g., joint variables are considered).

- **Partial:** Incomplete control of confounding. *Or* control of confounding reportedly done but not completely described. *Or* randomized study without report of comparability of baseline characteristics. *Or* confounding not considered, but not likely to have seriously distorted the results.  
*Decision analyses:* incomplete consideration of dependencies between variables.
- **No:** Confounding not considered and may have seriously distorted the results. *Decision analyses:* dependencies between variables not considered.
- **N/A:** Cross-sectional surveys of a single group (i.e., surveys examining change over time or surveys comparing different groups should address the potential for confounding). Descriptive studies. Studies explicitly stating the analysis is strictly descriptive/exploratory in nature.

13. *Results reported in sufficient detail?*

- **Yes:** Results include major outcomes, and all mentioned secondary outcomes.
- **Partial:** Quantitative results reported only for some outcomes. *Or* difficult to assess as study question/objective not fully described (and is not made clear in the methods section), but results seem appropriate.
- **No:** Quantitative results are reported for a subsample only, or “n” changes continually across the denominator (e.g., reported proportions do not account for the entire study sample, but are reported only for those with complete data. i.e., the category of “unknown” is not used where needed).

*Or* results for some major or mentioned secondary outcomes are only qualitatively reported when quantitative reporting would have been possible (e.g., results include vague comments such as “more likely” without quantitative report of actual numbers).

- **N/A:** Should not be checked for this question.

14. *Do the results support the conclusions?*

- **Yes:** All the conclusions are supported by the data (even if analysis was inappropriate). Conclusions are based on all results relevant to the study question, negative as well as positive ones (e.g., they aren't based on the sole significant finding while ignoring the negative results). Part of the conclusions may expand beyond the results, if made *in addition to* rather than instead of those strictly supported by data, and if including indicators of their interpretative nature (e.g., “suggesting,” “possibly”).
- **Partial:** Some of the major conclusions are supported by the data, some are not. *Or* speculative interpretations are not indicated as such. *Or* low (or unreported) response rates call into question the validity of generalizing the results to the target population of interest (i.e., the population defined by the sampling frame/strategy).
- **No:** None or a very small minority of the major conclusions are supported by the data. *Or* negative findings clearly due to low power are reported as definitive evidence against the alternate hypothesis. *Or* conclusions are missing. *Or* extremely low response rates invalidate generalizing the

results to the target population of interest (i.e., the population defined by the sampling frame/ strategy).

- **N/A:** Should not be checked for this question.

### **Manual for Quality Scoring Qualitative Studies:**

#### *Definitions and Instructions for Quality Assessment Scoring*

#### **How to calculate the summary score**

- **Total sum** = (number of “yes” \* 2) + (number of “partials” \* 1)
- **Total possible sum** = 20
- **Summary score:** total sum / total possible sum

#### **Quality assessment**

##### 1. *Question / objective clearly described?*

- **Yes:** Research question or objective is clear by the end of the research process (if not at the outset).
- **Partial:** Research question or objective is vaguely/incompletely reported.
- **No:** Question or objective is not reported or is incomprehensible.

##### 2. *Design evident and appropriate to answer study question?*

(If the study question is not clearly identified, infer appropriateness from results/conclusions.)

- **Yes:** Design is easily identified and is appropriate to address the study question.

- **Partial:** Design is not clearly identified, but gross inappropriateness is not evident; *or* design is easily identified but a different method would have been more appropriate.
- **No:** Design used is not appropriate to the study question (e.g., a causal hypothesis is tested using qualitative methods); *or* design cannot be identified.

3. *Context for the study is clear?*

- **Yes:** The context/setting is adequately described, permitting the reader to relate the findings to other settings.
- **Partial:** The context/setting is partially described.
- **No:** The context/setting is not described.

4. *Connection to a theoretical framework / wider body of knowledge?*

- **Yes:** The theoretical framework/wider body of knowledge informing the study and the methods used is sufficiently described and justified.
- **Partial:** The theoretical framework/wider body of knowledge is not well described or justified; link to the study methods is not clear.
- **No:** Theoretical framework/wider body of knowledge is not discussed.

5. *Sampling strategy described, relevant and justified?*

- **Yes:** The sampling strategy is clearly described and justified. The sample includes the full range of relevant, possible cases/settings (i.e., more than simple convenience sampling), permitting conceptual (rather than statistical) generalizations.



- **Partial:** The sampling strategy is not completely described or is not fully justified. Or the sample does not include the full range of relevant, possible cases/settings (i.e., includes a convenience sample only).
- **No:** Sampling strategy is not described.

6. *Data collection methods clearly described and systematic?*

- **Yes:** The data collection procedures are systematic, and clearly described, permitting an “audit trail” such that the procedures could be replicated.
- **Partial:** Data collection procedures are not clearly described; difficult to determine if systematic or replicable.
- **No:** Data collection procedures are not described.

7. *Data analysis clearly described, complete and systematic?*

- **Yes:** Systematic analytic methods are clearly described, permitting an “audit trail” such that the procedures could be replicated. The iteration between the data and the explanations for the data (i.e., the theory) is clear (it is apparent how early, simple classifications evolved into more sophisticated coding structures which then evolved into clearly defined concepts/explanations for the data). Sufficient data is provided to allow the reader to judge whether the interpretation offered is adequately supported by the data.
- **Partial:** Analytic methods are not fully described. *Or* the iterative link between data and theory is not clear.
- **No:** The analytic methods are not described. *Or* it is not apparent that a link to theory informs the analysis.

8. *Use of verification procedure(s) to establish credibility of the study?*

- **Yes:** One or more verification procedures were used to help establish credibility/ trustworthiness of the study (e.g., prolonged engagement in the field, triangulation, peer review or debriefing, negative case analysis, member checks, external audits/inter-rater reliability, “batch” analysis).
- **No:** Verification procedure(s) not evident.

9. *Conclusions supported by the results?*

- **Yes:** Sufficient original evidence supports the conclusions. A link to theory informs any claims of generalizability.
- **Partial:** The conclusions are only partly supported by the data. *Or* claims of generalizability are not supported.
- **No:** The conclusions are not supported by the data. *Or* conclusions are absent.

10. *Reflexivity of the account?*

- **Yes:** The researcher explicitly assessed the likely impact of their own personal characteristics (such as age, sex and professional status) and the methods used on the data obtained.
- **Partial:** Possible sources of influence on the data obtained were mentioned, but the likely impact of the influence or influences was not discussed.
- **No:** There is no evidence of reflexivity in the study report.

**Manual for Quality Scoring Mixed Methods Studies:**

*Definitions and Instructions for Quality Assessment Scoring*

**How to calculate the summary score**

- **Total sum** = (number of “yes” \* 2) + (number of “partials” \* 1)
- **Total possible sum** = 10
- **Summary score:** total sum / total possible sum

**Quality assessment**

1. *Is there an adequate rationale for using a mixed methods design to address the research question?*

- **Yes:** The reasons for conducting a mixed methods study are clearly explained. Several reasons can be invoked such as to enhance or build upon qualitative findings with quantitative results and vice versa; to provide a comprehensive and complete understanding of a phenomenon or to develop and test instruments.
- **Partial:** The reasons for conducting a mixed methods study are only partially explained.
- **No:** There is no reasoning provided as to why a mixed methods study was conducted.

2. *Are the different components of the study effectively integrated to answer the research question?*

- **Yes:** The quantitative and qualitative components of the mixed methods study are explicitly integrated. Look for information on how qualitative and quantitative phases, results, and data were integrated. For instance, how data gathered by both research methods was brought together to form a complete picture (e.g., joint displays) and when integration occurred

(e.g., during the data collection-analysis or/and during the interpretation of qualitative and quantitative results).

- **Partial:** The quantitative and qualitative components are only partially integrated.
- **No:** There is no integration of the qualitative and quantitative components in the mixed methods study.

3. *Are the outputs of the integration of qualitative and quantitative components adequately interpreted?*

- **Yes:** The study appropriately interprets (meta-inference) the integration of qualitative and quantitative findings and shows the added value of conducting a mixed methods study rather than having two separate studies.
- **Partial:** Incomplete meta-inference, reducing the added value of conducting a mixed methods study.
- **No:** no meta-inference identified.

4. *Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?*

- **Yes:** When integrating the findings from the qualitative and quantitative components were divergences and inconsistencies (also called conflicts, contradictions, discordances, discrepancies, and dissonances) reported and explained, through strategies such as reconciliation, initiation, bracketing, and exclusion. Rate this criterion 'Yes' if there is no divergences or inconsistencies.
- **Partial:** Divergences and inconsistencies were reported but not explained.
- **No:** No divergences and inconsistencies were reported or explained, however, were present.

5. *Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?*

- The quality of the qualitative and quantitative components should be individually appraised to ensure that no important threats to trustworthiness are present. To appraise 5, use criteria for the qualitative and quantitative components. The quality of both components should be high for the mixed methods study to be considered of good quality. The premise is that the overall quality of a mixed methods study cannot exceed the quality of its weakest component. For example, if the quantitative component is rated high quality and the qualitative component is rated low quality, the overall rating for this criterion will be of low quality.

**Appendix D:** Assessment of Bias in Included Studies

## Quantitative

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Criteria 11	Criteria 12	Criteria 13	Criteria 14	Total score	Total possible score	Summery score
Bahar 2017	2	2	2	2	N/A	N/A	N/A	2	2	2	2	N/A	2	2	20	20	100%
Barrera-Hernandez 2020	2	2	2	2	N/A	N/A	N/A	2	2	2	0	N/A	2	2	18	20	90%
Barros 2020	2	2	2	2	N/A	N/A	N/A	2	2	2	0	N/A	2	2	18	20	90%
Clayton 2019	2	2	2	1	N/A	N/A	N/A	2	2	2	0	N/A	2	1	16	20	80%
Collado & Corraliza 2015	2	2	2	2	N/A	0	N/A	2	2	2	0	N/A	2	2	18	22	81.8%
Collado 2019	2	2	2	2	N/A	N/A	N/A	2	2	2	2	N/A	2	2	20	20	100%
Collado & Evans 2015	2	2	2	1	N/A	0	N/A	2	1	2	2	N/A	2	2	18	22	81.8%
Collado 2013	2	2	2	1	N/A	0	N/A	2	2	2	2	0	2	2	19	24	79.2%
Duerden 2010	2	2	2	2	N/A	0	0	2	2	2	2	0	2	2	20	26	76.9%
Duron-Ramos 2020	2	2	2	2	N/A	0	N/A	2	2	2	2	N/A	2	2	20	22	90.9%

Ebersbach 2019	2	2	2	2	0	0	0	2	2	2	0	1	2	2	19	28	67.9%
Gould 2018	2	2	2	1	N/A	N/A	N/A	2	1	2	0	N/A	2	2	16	20	80%
Hoover 2020	2	2	2	1	N/A	N/A	N/A	2	1	2	2	N/A	2	2	18	20	90%
Huang 2005	2	2	2	1	N/A	0	N/A	1	2	2	0	1	2	2	17	24	70.8%
Kim 2020	2	2	2	1	N/A	0	0	2	2	2	0	0	2	1	16	26	61.5%
Krettenauer 2020	2	2	2	2	N/A	N/A	N/A	2	2	2	2	N/A	2	2	20	20	100%
Otto 2017	2	2	2	1	N/A	N/A	N/A	2	2	2	0	N/A	2	2	17	20	85%
Soga 2016	2	2	2	1	N/A	N/A	N/A	2	2	2	1	N/A	2	2	18	20	90%
Solano-Pinto 2020	2	2	2	2	N/A	N/A	N/A	2	2	2	2	N/A	2	2	20	20	100%
<b>Total score</b>	38 / 38	38 / 38	38 / 38	29 / 38	0 / 2	0 / 16	0 / 6	37 / 38	35 / 38	38 / 38	19 / 38	2 / 10	38 / 38	36 / 38			
<b>%</b>	100%	100%	100%	76.3%	0%	0%	0%	97.4%	92.1%	100%	50%	20%	100%	94.7%			

Qualitative

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Total score	Total possible score	Summery score
Aguirre-Bielschowsky 2012	2	2	2	2	2	2	2	0	2	0	16	20	80%
Barros 2020	2	2	2	2	2	2	2	1	2	0	17	20	85%
Blanchet-Cohen 2008	2	2	2	2	2	2	1	2	2	0	17	20	85%
Buttigieg 2013	2	2	2	2	2	2	2	2	2	1	19	20	95%
Douglas 2009	2	2	2	2	1	1	1	0	2	0	13	20	65%
Duerden 2010	2	2	2	2	2	2	2	2	2	2	20	20	100%
Kim 2020	2	2	2	0	0	2	1	2	2	0	13	20	65%
Li 2015	2	2	2	2	2	1	1	2	2	0	16	20	80%
<b>Total score</b>	16/16	16/16	16/16	14/16	13/16	14/16	12/16	11/16	16/16	3/16			
<b>%</b>	100%	100%	100%	87.5%	81.3%	87.5%	75%	68.8%	100%	18.8%			



Mixed Methods

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Total score	Total possible score	Summery score
Barros 2020	2	1	2	2	2	9	10	90%
Duerden 2010	2	2	2	2	2	10	10	100%
Kim 2020	2	2	2	0	1	7	10	70%
<b>Total score</b>	6/6	5/6	6/6	4/6	5/6			
<b>%</b>	100%	83.3%	100%	66.7%	83.3%			