



The Relationship Between Nature Connectedness and Eudaimonic Well-Being: A Meta-analysis

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Abstract

Nature connectedness relates to an individual's subjective sense of their relationship with the natural world. A recent meta-analysis has found that people who are more connected to nature also tend to have higher levels of self-reported hedonic well-being; however, no reviews have focussed on nature connection and eudaimonic well-being. This meta-analysis was undertaken to explore the relationship of nature connection with eudaimonic well-being and to test the hypothesis that this relationship is stronger than that of nature connection and hedonic well-being. From 20 samples ($n=4758$), a small significant effect size was found for the relationship of nature connection and eudaimonic well-being ($r=0.24$); there was no significant difference between this and the effect size (from 30 samples $n=11,638$) for hedonic well-being ($r=0.20$). Of the eudaimonic well-being subscales, personal growth had a moderate effect size which was significantly larger than the effect sizes for autonomy, purpose in life/meaning, self-acceptance, positive relations with others and environmental mastery, but not vitality. Thus, individuals who are more connected to nature tend to have greater eudaimonic well-being, and in particular have higher levels of self-reported personal growth.

Keywords Nature connection/connectedness · Eudaimonic well-being · Hedonic well-being · Psychological well-being · Personal growth · Meta-analysis

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1 Introduction

Many would argue that nature and the human psyche are inextricably linked, and that this relationship is of fundamental importance to human and environmental health: the risks of being disconnected from nature are the development of behaviours and attitudes that ultimately damage our physical and mental health and cause irreparable harm to the planet (Mayer and Frantz 2004). Understanding the causes and consequences of our relationship with nature is therefore crucial. Individuals commonly report feeling emotionally close to, and an integral part of nature, and this is reflected in the construct of nature connectedness (NC) (Mayer and Frantz 2004). The importance of this sense of relatedness is evidenced by numerous studies linking NC with a range of well-being measures including hedonic ('feeling good') and eudaimonic ('functioning well') indicators (e.g. Capaldi et al. 2014; Howell et al. 2011; Nisbet and Zelenski 2013; Pensini et al. 2016).

There have been some mixed results in the research on NC and well-being, and a number of authors have suggested that this may be because different aspects of well-being relate to NC in different ways (e.g. Howell and Passmore 2013; Capaldi et al. 2014). Furthermore, it has been suggested that the link between NC and eudaimonic well-being (EWB) may be stronger than the link between NC and hedonic well-being (HWB) (e.g. Capaldi et al. 2014; Howell et al. 2011). For example, Howell et al. (2011) found that 'feeling good' aspects of well-being were less reliably associated with NC than 'functioning well' aspects of well-being. Other studies have also found that current mood and subjective well-being had relatively low correlations with NC, compared with eudaimonic measures of well-being (e.g. Cervinka et al. 2012; Howell et al. 2013). The possibility that EWB and HWB may have different strengths of association with NC would be consistent with evidence from other well-being research that, although EWB and HWB are related, they tend to be associated with different motives, behaviours and experiences. For example, EWB has been found to relate more strongly than HWB to experiences which enable personal growth and development, and with being challenged and striving to achieve something (Waterman 1993). Likewise, eudaimonic motives and behaviours are more likely than hedonic motives and behaviours to predict EWB outcomes such as meaning, elevating experiences and sense of connection with a greater whole (Henderson et al. 2013; Huta and Ryan 2010). There is also evidence that increases in EWB may sometimes be accompanied by reduced HWB (McMahan and Estes 2011; Ryan and Deci 2001). For example, NC is known to predict pro-environmental behaviours (Mayer and Frantz 2004) and such behaviours, because they can be costly, time-consuming or difficult, may be more likely to lead to EWB but not HWB (Venhoeven et al. 2013). Also worthy of note is the fact that eudaimonia is more likely to be associated with long-term and enduring well-being, whereas HWB is more likely to dissipate in the short-term (McMahan and Estes 2011). As NC is known to increase over time if individuals visit nature frequently (Richardson et al. 2016a), it is thus plausible that NC is more strongly associated with EWB than HWB for this additional reason.

This possibility deserves further consideration, particularly as there is a relative lack of research into the relationship between nature and EWB (Cleary et al. 2017). A recent meta-analysis has found that NC and hedonic well-being (HWB) (as measured by positive affect, vitality and life satisfaction) are associated (Capaldi et al. 2014), but there have been no systematic reviews focussing on NC and EWB which provide a qualitative synthesis of research in this area. There is also a lack of understanding of the potential explanatory mechanisms involved in the NC-EWB relationship (Cleary et al. 2017).

Many existing theories concerning the effects of nature on well-being were originally developed a number of years ago and have not been the subject of recent major revision (McMahan and Estes 2015). For example the biophilia hypothesis (Wilson 1984) suggests that people have an innate need to affiliate with nature, and that satisfaction of this need results in well-being benefits such as improved positive affect; stress reduction theory (SRT; Ulrich et al. 1991) predicts that decreased physiological and psychological stress responses result from exposure to nature and thus results in improved well-being, and attention restoration theory (ART; Kaplan 1995) predicts that exposure to nature helps reduce attentional fatigue thus leading to improved cognitive functioning and positive affect. However, a number of authors have suggested that current theories may not provide a complete explanation of the wellbeing benefits of nature (Cleary et al. 2017; Schweitzer et al. 2018). Furthermore, current explanatory theories tend to be couched more in terms of contact with nature than connection with nature. There is therefore a clear need for greater understanding of the relationship between NC and EWB, as well as a need to develop comprehensive theoretical frameworks which encompass EWB (Cleary et al. 2017). Meta-analysis has been used here in order to consolidate results from a number of studies to create a single more precise assessment of the magnitude of the relationship between NC and EWB (the effect size), compare this with the relationship of NC and HWB, and examine potential moderators of this relationship. Although causation cannot be inferred from meta-analysis, if different strengths of association between NC and different types of well-being were to be found, then that may signal the possibility that different causal mechanisms are involved. This meta-analysis therefore also aims to test the hypothesis that the link between NC and EWB may be stronger than the link between NC and HWB, in order to guide theory development and inform future research into potential causal pathways between NC and EWB.

1.1 Well-Being

The philosophical origins of eudaimonia can be traced back to the works of Aristotle, who described eudaimonia as a consequence of living in accordance with one's 'daimon' or true self, in accordance with one's values, and fulfilling one's best potential (self-realisation) (Waterman 2008). By contrast, hedonia relates to maximising pleasure and is rooted in the philosophy of Aristippus (Venhoeven et al. 2013). The contrast between these two philosophies has provoked much debate as to the best ways to conceptualise and measure well-being (e.g. Kashdan et al. 2008; Waterman 2008). In particular the validity of conceptualising well-being solely as 'happiness' has been questioned by a number of authors (e.g. Ryff 1989; Waterman 2008), who advocate the importance of defining well-being in terms of optimal psychological functioning.

EWB is often measured with Ryff's scale of psychological well-being (Ryff 1989), which has six subscales: personal growth relates to being open to new ideas and experiences, and realizing one's full potential; purpose in life links to the presence of goals in life, and feelings of meaningfulness; autonomy comprises self-determination and independence; environmental mastery describes a sense of competence in managing the context in which one lives; self-acceptance refers to having a positive attitude towards the self; and positive relations with others relates to having warm and trusting relations. Another aspect of well-being—vitality—is a part of what it means to be fully functioning and psychologically well (Ryan and Deci 2001). Vitality is defined as having physical and mental energy

and is associated with feeling more alive and more engaged with the world, and with being outdoors, in the presence of natural elements (Ryan et al. 2010).

EWB is related to, but distinct from, HWB (Huta and Ryan 2010; Ryan and Deci 2001) and it is likely that eudaimonia and hedonia each influence and nurture the development of the other (Fredrickson 2004). Understanding the nature of this reciprocity may be found in functional theories of positive affect and well-being such as Frederickson's broaden and build theory (Fredrickson 2004), which proposes that positive emotions, as well as being an indicator of HWB, have an important role in the development of optimal functioning over the long term. For example, joy 'creates the urge to play, push the limits and be creative', and contentment 'creates the urge to sit back and savour life's current circumstances and integrate these circumstances into new views of self and the world' (Fredrickson 2004, p. 1369). Positive emotions widen the array of possible thoughts and actions available to an individual, enabling them to build resources and grow psychologically.

1.2 Nature Connectedness

Given the range of well-being benefits associated with nature contact (e.g. Bowler et al. 2010; McMahan and Estes 2015), there is growing concern that modern ways of living, particularly in western cultures, undermine our sense of belonging to nature (Bragg 1996; Roszak 1995), and that this may be contributing to increased rates of mental and emotional ill-health (Windhorst and Williams 2015). Consequently, there is increasing emphasis on the importance of feeling connected with nature (over and above simply spending time in nature) as a potential means of developing and maintaining our well-being. NC has been described as 'an individual's trait level of feeling emotionally connected to the natural world' (Cervinka et al. 2012, p. 380), and studies have shown that NC tends to be higher in people who have previous (childhood) experience of nature (Hinds and Sparks 2008) and in those who experience nature more frequently (Mayer and Frantz 2004). Correlational studies have shown that NC is associated with a variety of eudaimonic well-being indicators, such as autonomy, vitality, meaning, and personal growth (Cervinka et al. 2012; Howell et al. 2011; Nisbet and Zelenski 2013; Pensini et al. 2016), as well as with hedonic well-being (Capaldi et al. 2014). There is some evidence that NC may mediate the relationship between exposure to nature and well-being (Mayer et al. 2009; Webber et al. 2015; Pensini et al. 2016), but the evidence is not consistent as other studies have found that NC does not influence the relationship between nature exposure and wellbeing (Passmore and Howell 2014; Passmore and Holder 2017).

Three of the most commonly used NC measures are the Connectedness to Nature Scale (CNS) (Mayer and Frantz 2004), the Nature Relatedness (NR) scale (Nisbet et al. 2009), and the Inclusion of Nature with Self (INS) (Schultz 2002). The CNS includes fourteen statements such as 'I often feel a sense of oneness with the natural world around me' and 'my personal welfare is independent of the welfare of the natural world' (reverse scored). The NR scale includes questions such as 'I feel connected to all living things and the earth', and 'I take notice of wildlife wherever I am'. There are two versions of the NR scale: a 21-item version measuring three dimensions of connectedness (self-identity, experience and environmental behaviour), and a 6-item version comprising two dimensions (self-identity and experience). The Inclusion of Nature with Self (INS) (Schultz 2002) is a single item measure which assesses people's perception of themselves as being part of, or distinct from, the natural environment. It comprises a series of two circles depicting 'self'

and ‘nature’ with varying degrees of overlap, and individuals are asked to choose which set of circles best represents their relationship with nature.

Other measures include the Allo-Inclusive identity scale (AII) (Leary et al. 2008), the Connectivity with Nature (CWN) scale (Dutcher et al. 2007), and the Environmental Identity scale (EID) (Clayton 2003), which examine the extent to which a connection with the environment is part of an individual’s identity. The Connection to Nature Index (CNI) (Cheng and Monroe 2012) comprises four dimensions: enjoyment of nature, empathy for nature, sense of oneness and sense of responsibility, and the Commitment to Nature scale (COM) (Davis et al. 2009) assesses the sense of responsibility felt toward the environment, and attitudes about one’s own relationship with nature.

Although these measures vary in the extent to which they measure emotional, experiential or cognitive connection to nature, a review by Tam (2013) found strong convergence amongst them. Tam (2013) concluded that the various measures of NC can be considered as ‘markers of the same underlying construct’. In this review, therefore, it was assumed that all such measures can be treated the same for analytical purposes.

2 Methods

For the purposes of this study, the relationship of NC with two main well-being concepts was assessed: HWB, which relates to aspects of ‘feeling well’, and EWB which relates more to ‘functioning well’. Two main meta-analyses, one for each aspect of well-being, were conducted, to test the hypothesis that EWB is more strongly associated with NC than is HWB. Further meta-analyses were also undertaken on the subscales of the well-being measures, to assess any differences between them.

In this review, EWB was defined as comprising one or more of the six dimensions as measured by Ryff’s Psychological Well-being Scale—autonomy, personal growth, self-acceptance, life purpose, environmental mastery, positive relatedness (Ryff 1989), or vitality, or meaningfulness. Although Capaldi et al. (2014) included vitality as a hedonic construct, in this review, vitality was classed as a eudaimonic aspect of well-being because it is often conceptualised as such in the literature (e.g. Ryan and Deci 2001; Wolsko and Lindberg 2013; Zelenski and Nisbet 2014). Meaning was also included in the review as an aspect of EWB because it is conceptually similar to the Ryff purpose in life subscale. HWB was defined as one or more validated measures of life satisfaction and positive affect.

2.1 Search Strategy

Several databases were searched from 1999 (the date of first published NC tool) until June 2016, including PsychINFO, MEDLINE, PsychArticles, Science Direct (Elsevier), CINAHL Plus, PubMed Central, EBSCO e-journals and Biomedcentral.

References of included studies were searched, as well as studies citing the included studies. Authors of included studies were contacted as necessary for any additional information to afford meta-analysis. Well-being search terms included psychological well-being, subjective well-being, hedonic well-being, eudaimonic well-being, positive affect, life satisfaction, autonomy, personal growth, self-acceptance, life purpose, vitality, and happy/happiness. NC terms included variations of the following phrases: nature connectedness, nature relatedness, inclusion of nature in self, commitment to nature, emotional affinity with nature and relationship with nature.

2.2 Inclusion and Exclusion Criteria

Papers were included if they reported on the relationship between well-being and NC, included at least one validated measure of EWB (autonomy, purpose in life, environmental mastery, personal growth, self-acceptance, positive relatedness, meaningfulness or vitality), or HWB (positive affect, life satisfaction), and included a self-reported measure of trait NC. Studies had to include sufficient information (a correlation coefficient and sample size) in order that effect sizes could be coded. All study designs were included, but experimental designs were included only if they reported a baseline measure (before any experimental manipulation) of the relationship between well-being and NC. Studies not in the English language were excluded. This meta-analysis used slightly different inclusion criteria to those used by Capaldi et al. (2014), in that studies were excluded if they did not use validated measures, or were Master's theses, conference proceedings or unpublished data.

2.3 Coding Procedure

A coding form was developed for the review by the main author. Information collected included year, publication type, country, target population, population characteristics (gender, age), type of analysis, measure(s) of NC, measure(s) of well-being used, study design and setting. Two researchers coded the studies independently, and then resolved any differences by discussion. Levels of agreement between the two reviewers was high—Cohen's Kappa for the main categorical variables (year of study, type of publication, country, target population) was 0.87. For those samples with more than one measure of NC or well-being, weighted average effect sizes were calculated. Twenty-five papers met the inclusion criteria (see Fig. 1 for the meta-analysis flow chart), and a total of fifty effect sizes from 34 samples were included in the meta-analysis (30 effect sizes were included in the HWB meta-analysis, and 20 included in the EWB meta-analysis).

2.4 Statistical Methods/Analytic Approach

Two separate meta-analyses were undertaken, one each for HWB and EWB. Pearson's product-moment correlations (r) were used to determine effect size for the relationship of NC and well-being. The correlation coefficients were converted in Fisher's Z values before being meta-analysed. Data were entered into Meta-Essentials (Van Rhee et al. 2015), and random-effects models were used to calculate mean effect sizes. Effect sizes between 0.10 and 0.29 are considered small, those between 0.30 and 0.49 are moderate, and those of 0.50 and above are deemed to be high (Cohen 1992).

Cochran's Q and I^2 were used to assess variability. A significant Q value (i.e. one with a p value of less than 0.10) indicates significant heterogeneity among effect sizes. The I^2 statistic assesses the extent of variability in effect sizes; values between 1 and 49 indicate low heterogeneity, 50–74 moderate heterogeneity, and 75–100 high heterogeneity. In the case of significant heterogeneity, moderator analyses were undertaken.

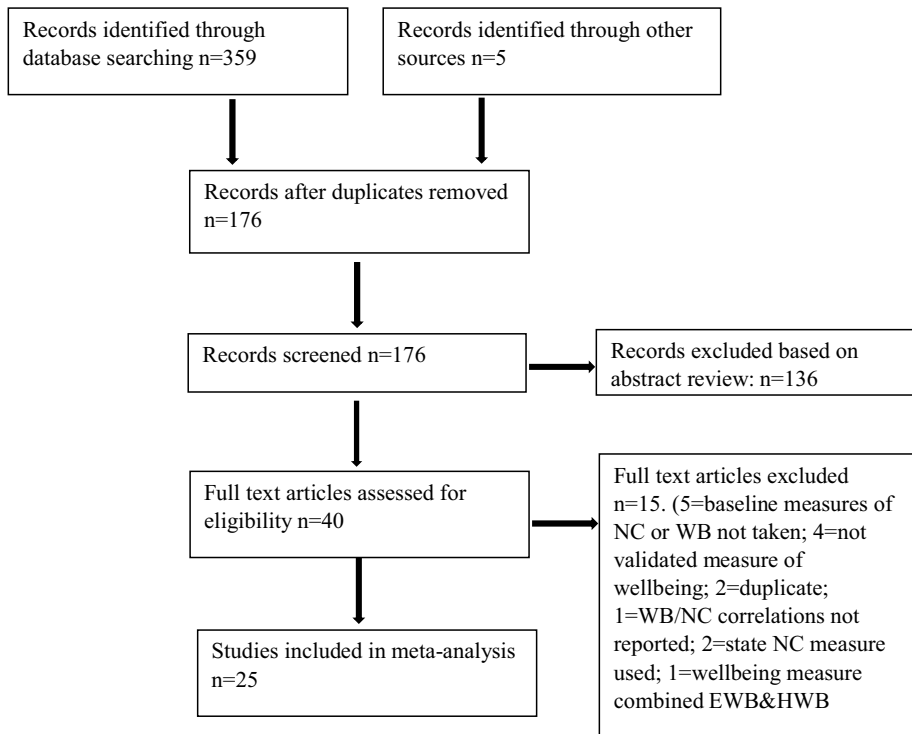


Fig. 1 Meta-analysis flow chart

3 Results

3.1 Overview of Included Studies

Twenty-five studies were identified with a total of 34 samples (see Table 1 for descriptive information) dating from 2004 to 2016. Eighteen studies were from peer reviewed journals, five were PhD theses, one study was classed as 'grey literature' (i.e. not available through the usual bibliographic sources such as databases or indexes) and one classed as a book chapter. Of the 34 samples, thirteen (38%) were from Canada, nine (26%) from Europe, eight (24%) from the United States and one each from Australia, India, Colombia and Hong Kong. The percentage of females ranged from 39.2 to 86.6% and average age ranged from 11 to 63.42 years. Of the target population, 44% of samples were of adults/community, 34% college/University students, 15% mixed adults and students, and one sample (3%) was of children. The target population was not stated for one sample. Measures of NC and well-being included in the meta-analysis are given in Tables 2 and 3.

Table 1 Summary of included studies

Study	Sample number	N	Location	Mean age (years)	% Female	Type of publication
Cervinka et al. (2012)	1.1	94	Austria	37.3	57.4	Peer reviewed journal
Cervinka et al. (2012)	1.2	119	Austria	36.0	52.1	Peer reviewed journal
Cervinka et al. (2012)	1.5	101	Austria	34.3	54.5	Peer reviewed journal
Creedon (2012)	2	187	USA	35	72	PhD thesis
Howell et al. (2011)	3.1	452	Canada	22.17	69.4	Peer reviewed journal
Howell et al. (2011)	3.2	275	Canada	20.39	68	Peer reviewed journal
Howell et al. (2013)	4.1	311	Canada	22.7	68	Peer reviewed journal
Howell et al. (2013)	4.2	227	Canada	23.29	63	Peer reviewed journal
Kumar et al. (2014)	5	80	India	Age range 20–30	Not stated	Peer reviewed journal
Leary et al. (2008)	6	148	USA	Not stated	Not stated	Other
Loureiro and Veloso (2014)	7	268	Portugal	32 (gp 1) 33 (gp 2)	58.2	Peer reviewed journal
Marselle (2013)	8	1647	UK	87% aged 55 or older	66	PhD thesis
Mayer and Frantz (2004)	9	135	USA	36	74.2	Peer reviewed journal
Nisbet (2011)	10	207	Canada	27.81	77.8	PhD thesis
Nisbet and Zelenski (2013)	11.1	184	Canada	19.48	67.4	Peer reviewed journal
Nisbet and Zelenski (2013)	11.2	145	Canada	42.37	39.2	Peer reviewed journal
Nisbet and Zelenski (2013)	11.3	354	Canada	20.03	59.9	Peer reviewed journal
Okvat (2011)	12	50	USA	63.42	84	PhD thesis
Pensini et al. (2016)	13	141	Germany	22.43	65	Peer reviewed journal
Reist (2004)	14	357	Canada	36.42	66	PhD thesis
Richardson et al. (2015)	15	775	UK	11	47.5	Grey literature
Richardson et al. (2016)	16	2203	UK	41.03	86.6	Peer reviewed journal
Schultz and Tabanico (2007)	17	39	USA	Not stated	67.5	Peer reviewed journal
Scopelliti et al. (2016)	18	300	Colombia	43.47	50.3	Peer reviewed journal
Tam (2013)	19	322	Hong Kong	20.36	45.8	Peer reviewed journal

Table 1 (continued)

Study	Sample number	N	Location	Mean age (years)	% Female	Type of publication
Trigwell et al. (2014)	20	216	Australia	35.32	71.1	Peer reviewed journal
Webber et al. (2015)	21	171	UK	50	67	Peer reviewed journal
Windhorst and Williams (2015)	22	308	Canada	98% aged between 18 and 24	79	Peer reviewed journal
Wolsko and Lindberg (2013)	23.1	256	USA	30.11	62.9	Peer reviewed journal
Wolsko and Lindberg (2013)	23.2	223	USA	33.30	61.4	Peer reviewed journal
Zelenski and Nisbet (2014)	24.1a	331	Canada	20.5	71.3	Peer reviewed journal
Zelenski and Nisbet (2014)	24.1b	415	Canada	32.3	79.7	Peer reviewed journal
Zelenski and Nisbet (2014)	24.2	204	Canada	Mean in the 25–34 range	60	Peer reviewed journal
Zhang et al. (2014)	25	1108	USA	44.08	44.4	Peer reviewed journal

Table 2 Nature connectedness measures included in the meta-analysis

Measure	Citation	Sample number ^a
Allo-inclusive identity scale	Leary et al. (2008)	3.2, 4.1, 6
Connectedness to nature scale (CNS)	Mayer and Frantz (2004)	1.1, 1.2, 1.5, 3.1, 3.2, 4.1, 4.2, 5, 7, 8, 9, 12, 13, 18, 19, 20, 21, 23.1, 23.2, 25.1
Inclusion of nature in self (INS)	Schultz (2002)	10, 13.2, 14, 16, 17, 19, 24.1a, 24.1b
Nature relatedness scale (21 items) (NR-21)	Nisbet et al. (2009)	2, 3.2, 4.1, 11.1, 11.2, 11.3, 19
NR-6 (short form)	Nisbet and Zelenski (2013)	10, 13.2, 22, 24.1a, 24.1b, 24.2
Connection to nature index	Cheng and Monroe (2012)	15
Commitment to nature (COM)	Davis et al. (2009)	19
Connectivity with nature (CWN)	Dutcher et al. (2007)	19
Emotional affinity toward nature (EATN)	Kals et al. (1999)	19
Environmental identity (EID)	Clayton (2003)	19

^aSample number comprises the number of the included paper (prefix); if included papers reported more than one study the study number used by that paper is given as the suffix. (In paper 24, study 1, the student and community samples were reported separately; hence these have been numbered 24.1a and 24.1b respectively)

3.2 Main Results

A total of 50 effect sizes were recorded, 20 effect sizes for the relationship between EWB and NC, and 30 for the relationship between HWB and NC. The total sample size for studies with EWB was 4758 (range 50 to 452) and HWB was 11,638 (range 39 to 2203).

Figure 2 shows the forest plot for the meta-analysis with EWB. There was a small mean effect size of $r=0.24$, 95% CI (0.20, 0.27). Variability across samples was significant ($Q=41.55$, $p<0.01$) and moderate ($I^2=54.28\%$). Figure 3 shows the forest plot for the meta-analysis with HWB. There was a small mean effect size of $r=0.20$, 95% CI (0.17, 0.23). This effect size is similar to the one reported in Capaldi et al. (2014) ($r=0.18$ (0.15–0.22)). Variability across samples was significant ($Q=124.37$, $p<0.001$) and high ($I^2=76.68\%$).

3.3 Moderator Analyses

Moderator analyses were undertaken to determine if gender or age accounted for the variability. Average age was not a significant predictor of effect size for either HWB (slope = 0.00, SE = 0.00, $Z=0.81$, $p=0.42$) or EWB (slope = 0.00, SE = 0.00, $Z=1.64$, $p=0.10$). Percent female was not a significant predictor of effect size for either HWB (slope = 0.00, SE = 0.00, $Z=0.24$, $p=0.81$) or EWB (slope = 0.00, SE = 0.00, $Z=0.51$, $p=0.61$).

Table 3 Well-being measures included in meta-analysis

Type of well-being	Measure	Citation	Sample number ^a
Hedonic well-being	Affective mood state	Ajzen and Driver (2001)	17
	Emotional wellness scale	Diener and Biswas-Diener (2008)	19
	General happiness single item	Abdel-Khalek (2006)	16
	Positive and negative affect schedule	Watson et al. (1988)	5, 7, 8, 10, 11.1, 11.2, 11.3, 12, 18, 24.1a, 24.1b, 24.2
	Steen happiness index	Seligman et al. (2005)	4.1, 4.2
	Mental health continuum short form (14 item)—emotional well-being	Keyes et al. (2008)	4.1, 4.2, 22
	Multi-dimensional comfort scale (MDPF)—current mood	Steyer et al. (1997)	1.1
	SF-36 health survey (mental well-being)	Bullinger and Kirchberger (1989)	1.5
	Satisfaction with life scale	Diener et al. (1985)	1.2, 5, 6, 9, 10, 14, 19, 25
	Scale of positive and negative experience	Diener et al. (2010)	23.1, 23.2
	Subjective happiness scale (SHS)	Lyubomirsky and Lepper (1999)	10, 19
	Student life satisfaction scale	Huebner (1991)	15
	Quality of life, enjoyment and satisfaction questionnaire (Q-LES-Q-SF)	Endicott et al. (1993)	12
	Keyes 40-item measure of well-being—emotional well-being	Keyes (2005)	3.1, 3.2, 4.1, 4.2

Table 3 (continued)

Type of well-being	Measure	Citation	Sample number ^a
Eudaimonic well-being	Vitality scale from the short-form (SF-36) health survey	Bullinger and Kirchberger (1989)	1.5, 12
	Psychological well-being inventory	Ryff (1989)	3.1, 3.2, 4.1, 4.2, 10, 11.1, 11.2, 11.3, 13, 20, 24.1a, 24.1b, 24.2
	Questionnaire for eudaimonic well-being (QEWB)	Waterman et al. (2010)	21
	Subjective vitality scale	Ryan and Frederick (1997)	10, 11.1, 11.2, 11.3, 23.1, 23.2, 24.1a, 24.1b, 24.2, 4.1
	General life purpose scale	Byron and Miller-Perrin (2009)	4.1, 13
	Meaning in life questionnaire (presence)	Steger et al. (2006)	4.1, 4.2
	Meaningful life measure	Morgan and Farsides (2009)	23.1, 23.2
	Flourishing scale	Diener et al. (2010)	3.1, 3.2
	Keyes 40-item measure of well-being—psychological well-being	Keyes (2005)	
	Mental health continuum short form (14 item)—psychological well-being	Keyes et al. (2008)	22

^aSample number comprises the number of the included paper (prefix); if included papers reported more than one study the study number used by that paper is given as the suffix. (In paper 24, study 1, the student and community samples were reported separately; hence these have been numbered 24.1a and 24.1b respectively)

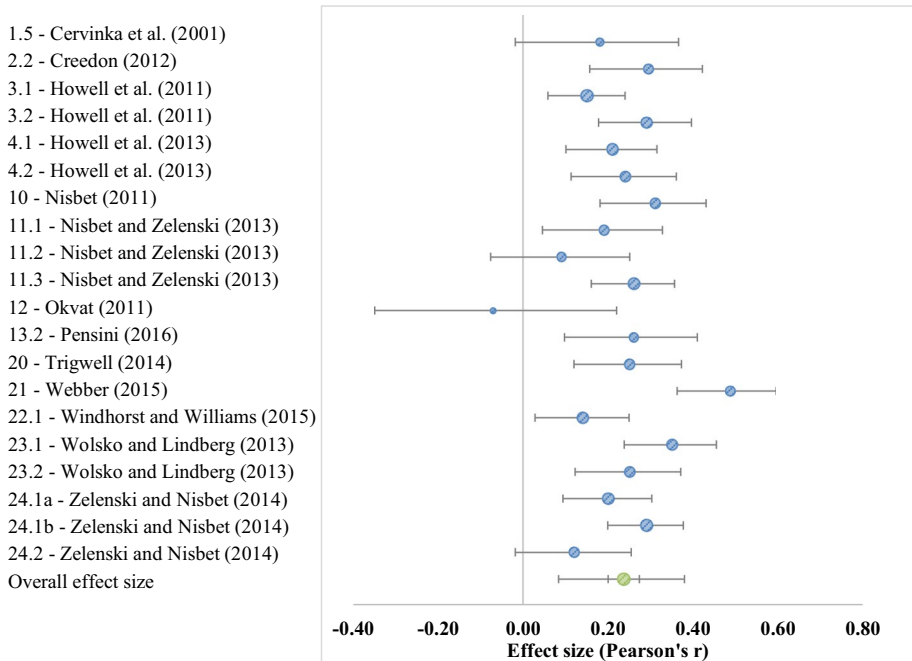


Fig. 2 Effect size for the relationship between NC and EWB

3.4 Publication Bias Analyses

Publication bias was initially examined by a funnel plot of effect size against standard error; the funnel plot for the effect sizes for both HWB and EWB appeared to be asymmetrical, an indication of possible bias. This was explored further using two more tests for publication bias: the Begg test (Begg and Mazumdar 1994) and the Egger test (Egger et al. 1997). For EWB, the Begg and Mazumdar adjusted rank correlation ($\tau = -0.07$, $p = 0.65$) and Egger's coefficient (intercept = -2.29 , $t = -1.42$, $p = 0.24$) were both non-significant, indicating no bias. Similarly, for HWB, both the Begg and Mazumdar adjusted rank correlation ($\tau = -0.09$, $p = 0.49$) and Egger's intercept (intercept = -1.37 , $t = -1.13$, $p = 0.27$) were also non-significant, again indicating no bias.

3.5 Additional Meta-analyses on Specific Well-Being and Nature Connectedness Measures

To further investigate the relationship between NC and well-being, separate meta-analyses were also conducted on the three most common NC measures used (CNS, INS and NR), and, where this information was available, on the subscales of the various well-being measures. The results are summarised in Table 4.

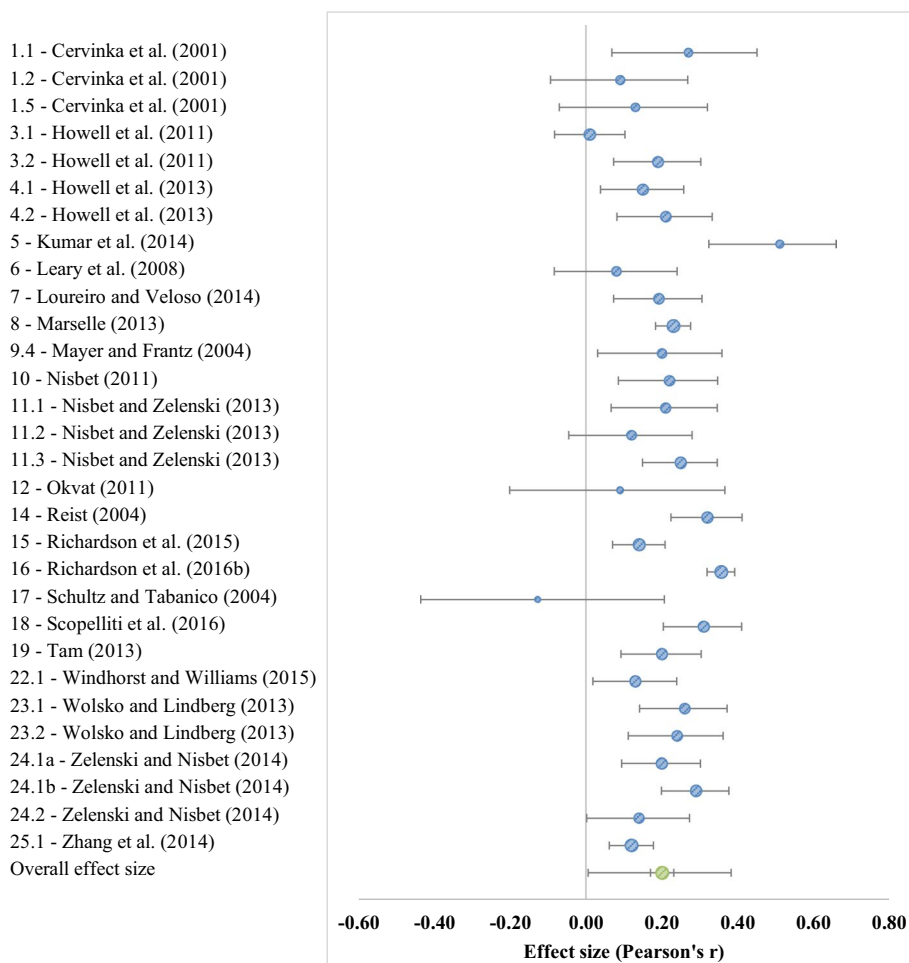


Fig. 3 Effect size for the relationship between NC and HWB

3.5.1 Effect Sizes for the Well-Being Measures

Nine samples were identified for the subscales of personal growth ($n=2197$), autonomy ($n=2197$), and vitality ($n=2141$); twelve samples were included for purpose in life and meaning ($n=2922$), and four samples with $n=686$ for each of environmental mastery, self-acceptance and positive relations with others. There was a small mean weighted effect size for all the EWB subscales except for personal growth which had a moderate mean effect size of $r=0.31$ (0.27 – 0.35). The next largest effect size was for vitality $r=0.25$ (0.20 – 0.30), which compares to the vitality effect size of $r=0.24$ (0.19 – 0.29) reported in Capaldi's meta-analysis (Capaldi et al. 2014). The personal growth effect size was significantly larger than the effect sizes for autonomy ($r=0.20$), purpose in life and meaning ($r=0.20$), self-acceptance ($r=0.17$), positive relations with others ($r=0.16$) and environmental mastery ($r=0.12$) (Table 4).

Table 4 Meta-analysis results

Nature connectedness measure	Well-being measure	r (95% CI LL-UL)	Q	I ²	No samples	n
All NC measures	EWB	0.24 (0.20–0.27)	41.6	54.28	20	4758
	HWB	0.20 (0.17–0.23)	124	76.68	30	11,638
NR only	EWB	0.22 (0.18–0.26)	16.9	40.97	11	2921
	HWB	0.19 (0.16–0.22)	11.2	10.59	11	3056
CNS only	EWB	0.26 (0.21–0.32)	27.4	63.5	11	2423
	HWB	0.20 (0.16–0.24)	43.7	65.65	16	5867
INS only	EWB	0.27 (0.21–0.33)	4.34	30.81	4	1094
	HWB	0.27 (0.19–0.35)	30.1	80.07	7	3874
All NC measures (HWB subscales)	Positive affect	0.25 (0.21–0.29)	63.1	68.32	21	7961
	Life satisfaction	0.17 (0.13–0.21)	27.2	52.24	14	4530
All NC measures (EWB subscales)	Vitality	0.25 (0.20–0.30)	15.5	48.36	9	2141
	Personal growth	0.31 (0.27–0.35)	12.5	35.97	9	2197
	Autonomy	0.20 (0.16–0.25)	15.5	48.33	9	2197
	Purpose in life/meaning	0.20 (0.17–0.23)	12.2	9.54	12	2922
	Environmental mastery	0.12 (0.05–0.19)	3.69	18.65	4	686
	Self-acceptance	0.17 (0.09–0.24)	4.46	32.67	4	686
	Positive relations others	0.16 (0.08–0.23)	4.21	28.71	4	686

Of the HWB subscales, the mean weighted effect size for positive affect was $r=0.25$ (0.21–0.29) and that for life satisfaction was $r=0.17$ (0.13–0.22). These results compare to the effect sizes reported in Capaldi et al. (2014) of $r=0.22$ (0.19–0.25) for positive affect and $r=0.16$ (0.11–0.20) for life satisfaction.

3.5.2 Effect Sizes for the Nature Connectedness Measures

There was a small mean weighted effect size for all NC measures and EWB, and for all NC measures and HWB (Table 4). The effect sizes for HWB were similar to those reported in Capaldi et al. (2014) of CNS $r=0.18$, NR $r=0.18$ and INS $r=0.25$.

4 Discussion and Conclusion

The purpose of this review was to explore the relationship between NC and EWB by means of a meta-analysis and to compare this with the relationship between NC and HWB. The data showed a small positive correlation between NC and EWB, indicating that individuals who are connected to nature are more likely to be flourishing and functioning well psychologically. However, the hypothesis that NC would be more strongly associated with EWB than it is with HWB was not supported, and there may be a number of possible explanations for this. Firstly, it is worth considering that the way EWB has been defined for the purposes of this study (i.e. based on Ryff's definition (1989)) may not be sufficiently comprehensive. For example, Huta (2015) identified a number of aspects of eudaimonic functioning—including self-regulation, ethics, contribution, and thoughtfulness—that are

not included in the definition used by Ryff (1989). It may be that future studies, exploring the relationship between NC and these other aspects of EWB, can add to our understanding. Secondly, Huta and Waterman (2014) highlight the distinction between well-being measures based on cognitive-affective experiences and those based on ways of functioning. They suggest that using measures from different categories may lead to difficulties in making direct comparisons between eudaimonia and hedonia (Huta and Waterman 2014). The fact that, in this review, the EWB measures tended to fall into the 'functioning' category, whereas the HWB measures tended to be based more on experiences, may have resulted in any true differences being obscured. Perhaps future research addressing these conceptual and definitional issues may help clarify the findings of this review.

Although the difference between the respective effect sizes for EWB and HWB was not significant, there were effect size differences between the EWB subscales. All the well-being subscales had small positive correlations with NC, with the exception of personal growth which had a moderately positive relationship. In addition, the effect size for personal growth was significantly larger than all the other eudaimonic subscales, except for vitality, and was also significantly larger than the effect size for life satisfaction. These findings suggest that, in order to further explore the relationship between NC and EWB, it may be fruitful to focus on specific aspects of EWB rather than on composite measures.

There is evidence that NC mediates the relationship between exposure to nature and EWB (Mayer et al. 2009; Pensini et al. 2016; Webber et al. 2015), which would be consistent with a causal mechanism whereby nature exposure leads to increased NC, which in turn leads to improved EWB. However, another study has found that NC does not moderate the effect of nature exposure on EWB (as measured by elevating experience) (Passmore and Howell 2014), which implies that NC may not play a part in promoting EWB. It is also possible that, if a causal association does exist, it is in the other direction, with EWB leading to increased NC; or it may be that the relationship between NC and EWB is bi-directional.

A number of authors have suggested that NC may benefit EWB because it provides a route through which basic psychological needs can be met (e.g. Cleary et al. 2017; Howell and Passmore 2013; Nisbet et al. 2009). As described in Ryan and Deci's self-determination theory, three basic psychological needs—autonomy, competence and relatedness—are considered essential for psychological growth, integrity and well-being (Ryan and Deci 2000). It is plausible that NC provides a route through which these basic needs are met and so leads to increased EWB. For example, the basic psychological need for relatedness could be met by being exposed to nature which in turn is known to increase feelings of connectedness to nature (e.g. Weinstein et al. 2009). Howell and Passmore (2013) suggested that the relationship between nature affiliation and well-being could be mediated by a greater sense of social connectedness, and nature connection has been found to promote pro-social behaviour such as altruism and generosity (Weinstein et al. 2009). It also seems likely that nature connection promotes a form of relatedness distinct from social (human) connectedness and important in its own right (Cleary et al. 2017). This is supported by research from Zelenski and Nisbet (2014), who found that the concept of nature relatedness was distinct from other forms of relatedness—including connectedness with family and friends—and was a significant and distinct predictor of happiness.

In relation to increasing autonomy, nature could be a route through which individuals are enabled to express their personal distinctiveness, and not feel constrained by external influences such as the values imposed by society (Howell and Passmore 2013; Ridder 2005). Ridder's (2005) concept of a 'nature-inspired autonomy' describes the importance of recognising the value of naturalness as a means of gaining a personal sense of freedom

and escaping from the dissatisfaction caused by extrinsic influences of society. The freedom and autonomy felt in wild nature enables individuals to reinforce their own intrinsic beliefs and values, to gain perspective on the things that really matter, and to feel inspired (Ridder 2005). There is some empirical support for this idea: Weinstein et al. (2009) found that, when asked to view scenes from nature or from 'non-nature' (such as cityscapes), participants who were more immersed in the nature scenes felt a greater sense of autonomy; by contrast, participants who were immersed in the non-nature scenes felt reduced autonomy.

Competence needs could be met through learning about natural environments and ecosystems, as well as through enhanced self-knowledge and self-development gained from being connected to nature. Outdoor learning, outdoor play and wilderness expeditions have all been linked with improved well-being, cognition, personal, social and emotional development, as well as higher achievement and increased motivation to learn (Lovell 2016a).

The association of vitality with NC can also be linked with the fulfilment of psychological needs. Ryan and Frederick (1997) considered that vitality is a part of the 'fully-functioning' person and should therefore be linked with agency and growth, and with the need for autonomy, competence and relatedness. They found supporting evidence that vitality is associated with self-actualisation and self-determination, as well as mental health and self-esteem (Ryan and Frederick 1997).

In this review, NC had a significantly stronger association with personal growth than most of the other aspects of EWB, which raises the possibility that our relationship with nature may have a particularly important role in furthering psychological growth and development. Ryff described personal growth as perhaps the nearest of all her six subscales to EWB because it is specifically concerned with self-realisation and is akin to Maslow's concepts of self-actualisation and self-transcendence (Koltko-Rivera 2006; Ryff and Singer 2008). Huta and Ryan (2010) expected that, since eudaimonia is oriented towards excellence and growth, it would be related to uplifting experiences (such as contact with the natural world) which stretched people beyond their usual boundaries. Such 'elevating experiences' are 'where a person feels awe, elevation to a higher level of awareness and a connection with some greater whole' (Huta and Ryan 2010, p. 740). NC has been found to correlate strongly with the value of self-transcendence (Tam 2013) and also to predict transcendent and awe-inspiring experiences, particularly in wild nature (Davis and Gatersleben 2013). The 'higher order' emotions such as awe and wonder, which are often associated with transcendent experiences, could be a key mediating influence in the relationship between NC and personal growth. Awe has been defined as 'an emotional response to perceptually vast stimuli that overwhelm current mental structures, yet facilitate attempts at accommodation' (Shiota et al. 2007, p. 944). Thus, the sense of awe felt in nature could lead to an expansion in individuals' mental structures and frames of reference, as well as an expanded sense of self, and so foster personal growth. This would be consistent with Fredrickson's broaden and build theory of positive emotions (Fredrickson 2004). Likewise, the association that NC has with meaning and purpose in life is also in accord with the idea that self-change is brought about when people accommodate new experiences after having contact with nature: people often describe awe-inspiring experiences in nature as giving them a sense of perspective on their life, goals, and purpose (Silvia et al. 2015).

4.1 Future Research

In general, more well-controlled studies are needed which explore the direction of the relationship between NC and well-being. Furthermore, much NC research has used composite

measures of well-being which may mask potential differences among the well-being sub-scales. More nuanced studies exploring the links between NC and specific aspects of EWB, such as personal growth, would help tease any differences apart.

There is a general lack of research on children's well-being and nature connection—in this review all but one of the included studies was of adults. Childhood experience may be an important route by which individuals become connected to nature in the first place (e.g. Lovell 2016b), and experiences in nature may enhance optimal child development (Kellert 2002). The association found in this review of NC and personal growth in adults would suggest that nature's effect on childhood development may be equally—if not more—important. Orr (1993) speculated that there could be a window of opportunity in childhood for connecting to nature, similar to the window of opportunity for language development. If this is the case, the consequences for nature disconnection in childhood could be long-term, and not easily repaired by experiences in adulthood. Conducting longitudinal studies which follow individuals over their life-course would help address this gap.

Additional research is needed to explore which particular qualities of nature may affect HWB and EWB. It is possible that different types of nature elicit different emotions and, by implication, could affect different types of psychological functioning. For example, familiar nature may be more likely to lead to feelings of calm and contentment and thus be more restorative (Richardson et al. 2016b), whereas unfamiliar objects in nature—those that transcend previous knowledge—may be more likely to produce awe and wonder than familiar objects (Keltner and Haidt 2003) and thus stimulate new ideas and experiences. Nature-induced awe may be triggered by large natural objects, such as mountains or vistas, by natural events such as storms, or by objects with infinite repetition such as fractals, waves and patterns in nature (Keltner and Haidt 2003). Factors such as the degree of naturalness of an environment (the extent to which it is free of human intervention) may also be important in the relationship with EWB (Ridder 2007). Furthermore, there is evidence that levels of actual or perceived biodiversity (Dallimer et al. 2010; Fuller et al. 2007; Luck et al. 2011), or the degree of landscape heterogeneity (Fuller et al. 2007; Jorgensen and Gobster 2010), are linked with well-being and these aspects are therefore worthy of further investigation.

It is also worth exploring how different patterns of nature exposure may affect the relationship between NC and well-being. For example, there is evidence of a dose-response effect between frequency of visits to nature and EWB, but not HWB (White et al. 2017). By contrast, the same study found that self-reported HWB (as felt on the previous day) was significantly related to a visit to nature that day, but that EWB was not. Thus, two possible nature exposure mechanisms may be at work—a short-term restorative effect linked to HWB, and a longer-term (additive) effect of increased visit frequency linked to EWB, possibly due to greater NC developing over that time. Dose-response and short and long-term effects of nature exposure are important variables to be explored in further research.

Finally, most of the research on NC and its association with well-being has been undertaken in westernised societies. Although there is some evidence that the association of NC and well-being persists across non-westernised cultures (e.g. Capaldi et al. 2017; Tam 2013), there are cultural differences in the way in which humans perceive and value nature (Olivos and Clayton 2016), and so our understanding remains limited.

4.2 Limitations

A common aspect of correlational studies is that the direction of effect and causality remains unclear. Furthermore, a lack of representativeness of the study population could

have resulted in bias—most studies comprised non-random and/or self-selected adult subjects. Males were generally under-represented, and a high proportion of the studies were of students. However, the moderator analyses indicated that neither age nor percent female were significant predictors of effect size indicating that the results were not affected by these factors. In addition, a number of the included studies involved participants who were either park visitors, exercised in natural settings, or were gardeners, and it is conceivable that these participants may have had higher than average NC. This may have resulted in range restriction and thus attenuation of reported effect sizes.

4.3 Conclusion

This review has shown that NC is associated with EWB, and one aspect of EWB—personal growth—appears to have a significantly stronger relationship with NC than most other EWB subscales. These results signal the important role NC may play in contributing to positive psychological functioning and highlight the possibility that different aspects of EWB may relate to NC to varying extents. Multiple pathways—perhaps mediated by a range of emotions and elicited by different aspects of nature—may be involved in the relationship between NC and EWB.

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