



Meta-analysis of human connection to nature and proenvironmental behavior

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Abstract: Understanding what drives environmentally protective or destructive behavior is important to the design and implementation of effective public policies to encourage people's engagement in **proenvironmental behavior (PEB)**. Research shows that a connection to nature is associated with greater engagement in PEB. However, the variety of instruments and methods used in these studies poses a major barrier to integrating research findings. We conducted a meta-analysis of the relationship between connection to nature and PEB. We identified studies through a systematic review of the literature and used Comprehensive Meta-Analysis software to analyze the results from **37 samples ($n = 13,237$) and to test for moderators**. A random-effects model demonstrated a positive and significant association between connection to nature and PEB ($r = 0.42$, 95% CI 0.36, 0.47, $p < 0.001$). People who are more connected to nature reported greater engagement in PEB. Standard tests indicated little effect of publication bias in the sample. There was significant heterogeneity among the samples. Univariate categorical analyses showed that the scales used to measure connection to nature and PEB were significant moderators and explained the majority of the between-study variance. The geographic location of a study, age of participants, and the percentage of females in a study were not significant moderators. We found that a deeper connection to nature may partially explain why some people behave more proenvironmentally than others and that the relationship is ubiquitous. Facilitating a stronger connection to nature may result in greater engagement in PEB and conservation, although more longitudinal studies with randomized experiments are required to demonstrate causation.

Keywords: connectedness to nature, conservation behavior, ecological behavior, human-nature relationship

Metaanálisis de la Conexión Humana con la Naturaleza y el Comportamiento a Favor del Ambiental

Resumen: El entendimiento de los conductores del comportamiento de protección o destrucción ambiental es importante para el diseño e implementación de políticas públicas que fomenten la participación de las personas dentro del comportamiento a favor del ambiente (PEB, en inglés). Las investigaciones muestran que la conexión con la naturaleza está asociada con una mayor participación en el PEB. Sin embargo, la variedad de instrumentos y métodos que utilizados en estos estudios presentan una barrera importante para la integración de los resultados de las investigaciones. Realizamos un metaanálisis de la relación entre la conexión con la naturaleza y el PEB. Identificamos estudios por medio de una revisión sistemática de la literatura y utilizamos software de Metaanálisis Completo para analizar los resultados de 37 muestras ($n = 13,237$) y para examinar a los moderadores. Un modelo de efectos azarosos demostró una

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asociación positiva y significativa entre la conexión con la naturaleza y el PEB ($r = 0.42$, 95% CI 0.36, 0.47, $p < 0.001$). Las personas que están más conectadas con la naturaleza reportaron una mayor participación en el PEB. Las pruebas estándares indicaron un efecto menor del sesgo de publicación en la muestra. Hubo una heterogeneidad significativa entre las muestras. Los análisis univariados categóricos mostraron que las escalas usadas para medir la conexión con la naturaleza y el PEB fueron moderadores significativos y explicaron la mayoría de la varianza entre estudios. La ubicación geográfica de un estudio, la edad de los participantes, y el porcentaje de mujeres en un estudio no fueron moderadores significativos. Encontramos que una conexión más profunda con la naturaleza puede explicar parcialmente por qué algunas personas se comportan más a favor del ambiente que otras y que dicha relación es ubicua. La facilitación de una conexión más fuerte con la naturaleza puede resultar en una mayor participación en el PEB y en la conservación, aunque se requieren estudios más longitudinales con experimentos aleatorios para demostrar la causalidad

Palabras clave: comportamiento de conservación, comportamiento ecológico, conectividad con la naturaleza, relación humano-naturaleza

摘要: 理解保护环境和破坏环境行为背后的驱动力, 对于设计和实施有效的公共政策以鼓励人们参与环保行动至关重要。已有研究表明, 与自然的联系和环保行动参与度之间存在相关性。然而, 这些研究使用了各种各样的工具和方法, 导致这些研究结果难以整合。因此, 我们对人与自然的联系和环保行为之间的关系进行了荟萃分析。我们通过系统文献综述筛选出相关研究, 并用综合荟萃分析软件分析了 37 个样本 ($n = 13,237$) 的研究结果以检验干扰变量。随机效应模型显示, 亲近自然与环保行为之间有显著的正相关关系 ($r = 0.42$, 95% CI 0.36, 0.47, $p < 0.001$)。更亲近自然的人自我报告的环保行为参与度也更高。标准检测分析表明, 样本中的研究发表偏差的影响很小, 而各样本间存在显著的异质性。单变量分类分析结果显示, 用于测定人与自然的联系和环保行为的尺度是重要的干扰变量, 解释了大部分的研究间差异。而研究地点、参与者年龄和性别都不是显著的干扰变量。我们还发现, 与自然更深层次的联系可能部分解释了为什么有些人更环保, 而且其间的相关性普遍存在。促进人与自然更紧密的联系或能推动人们更多地参与环保和保护行动, 尽管仍需要更多包含随机实验的纵向研究来证明因果关系。【翻译: 胡怡思; 审校: 聂永刚】

关键词: 保护行为, 人与自然的联系, 亲近自然, 生态行为

Introduction

Environmental degradation, perhaps humanity's greatest current challenge (e.g., IPCC 2014), is largely anthropogenic and driven by habitat destruction, invasive species, pollution, overharvesting, and human overpopulation (Wilson 2002). Attempts to promote sustainable lifestyles or conservation behaviors must therefore focus on changing people's behavior (Ehrlich & Kennedy 2005; Schultz 2011). Understanding what motivates environmentally protective or destructive behavior can be used to encourage proenvironmental behavior (PEB) and conservation and inform government policies requiring broad-based public support.

An individual's connection to nature may motivate their engagement in PEB (Mayer & Frantz 2004). Conversely, a lack of connection to nature has been blamed for people's apathy toward environmental degradation and protection (Pyle 2003). In humans, as the closeness of relationships between individuals increases, empathy and willingness to help increases (Cialdini et al. 1997), and this phenomenon may extend to human-nature relationships. That is, a close bond with nature may foster empathy for the natural world, which in turn may motivate caring and altruistic behavior (Schultz 2000).

Individuals' subjective evaluations of their relationships with nature can be conceptualized as connection

to nature. The theoretical basis of connection to nature comes from the biophilia hypothesis (Fromm 1964; Wilson 1984), ecopsychology (Roszak 1995; Bragg 1996), and psychological research into interpersonal relationships. Expanding self-identity to include the natural environment and experiences of belonging with nature are key elements in defining connection to nature. Connection to nature can be considered a values-based attitude (Brügger et al. 2011), and it has qualities similar to personality traits in that it differs between individuals and groups, is relatively stable over time and in different situations, but can change (Mayer & Frantz 2004; Nisbet et al. 2009). Connection to nature can also be a state. It can be increased or decreased in the short-term, for example, with exposure to nature (Mayer et al. 2009). However, change may require long-term or repeated exposure (Schultz & Tabanico 2007).

One might expect a person with a strong connection to nature to behave proenvironmentally. However, even though there is generally a high level of concern about environmental problems and support for environmental protection, there has not been widespread movement toward more sustainable lifestyles (Fox et al. 2006). This gap is partially explained by barriers a person encounters when engaging in PEB, such as personal cost (finance and time) and lack of structural support (recycling schemes and efficient public transport), or knowledge (e.g., type

of PEB that is useful). It is unclear whether the same gap exists with connection to nature and PEB.

Operationalization of Connection to Nature and PEB

There are at least 17 different scales that measure connection to nature (Tam 2013a). The items in these scales reflect 3 interrelated dimensions of human relationships with nature: affect (feelings toward nature), cognition (knowledge and beliefs about nature), and behavior (actions and experiences in nature). Some scales measure connection to nature as a single dimension. These unidimensional scales can emphasize an emotional attachment to nature (Kals et al. 1999; Mayer & Frantz 2004; Perkins 2010). For example, the connectedness-to-nature scale was designed to assess people's affective sense of connectedness or kinship with nature (Mayer & Frantz 2004). In contrast, Schultz (2002) argues that connection to nature is inherently cognitive and defines it as the "extent to which an individual includes nature within his/her cognitive representation of self" (Schultz 2002:67). Other scales are multidimensional. For example, the nature relatedness scale (Nisbet et al. 2009) has 3 dimensions (NR-self, NR-perspective, and NR-experience) that encompass affective, cognitive, and experiential aspects of the human-nature relationship. The scales have 1–40 items. Most are self-report surveys requiring responses on a 5- to 7-point Likert-type scale, and 3 include pictorial components (Schultz 2002; Dutcher et al. 2007; Davis et al. 2009). These different scales are highly correlated and can be loaded onto a single factor and correlate similarly with criterion variables (Tam 2013a). Thus, the scales may measure the same underlying construct of connectedness to nature. There is a small amount of divergence among some scales in their association with criterion variables, such as subjective well-being and PEB. Differences between cognitive and noncognitive components of connection to nature may explain this divergence (Tam 2013a).

The scales measuring connection to nature are positively associated with meaningful differences in individual personality traits, such as conscientiousness, extraversion, agreeableness, and openness (Nisbet & Zelenski 2013; Tam 2013a), well-being (e.g., Capaldi et al. 2014), environmental attitudes (e.g., Schultz et al. 2004; Brügger et al. 2011), and PEB (e.g., Mayer & Frantz 2004; Nisbet & Zelenski 2013; Whitburn et al. 2018). Most of investigations into connection to nature and PEB have been in adults. However, there is a small body of evidence that shows similar results with children (Roczen et al. 2014; Collado et al. 2015; Otto & Pensini 2017).

We defined PEB broadly as "actions which contribute to environmental protection and/or conservation" (Axelrod 1993:153). Scales measuring PEB aim to capture whether an individual generally behaves proenvironmentally and includes self-reported and objectively

measured PEB. Objectively measured PEB is rare because of the difficulty in discreetly observing behavior, but it has been achieved in measuring energy usage (e.g., Frantz & Mayer 2014) and recycling behavior (Whitburn et al. 2018). The most common way to measure PEB is through self-report surveys adapted from other scales (e.g., Kaiser 1998; Schultz & Zelezny 1998; Whitmarsh & O'Neill 2010). The scales measuring PEB vary from 6 to 97 items, contain ≥ 1 dimension, and vary in their internal reliability and factor analysis of their multiple dimensions (Markle 2013).

Although all studies report a positive association between connection to nature and PEB, the strength of this relationship varies ($r = 0.14$ – 0.68). The diversity of scales poses a barrier to integrating results across studies and scales. Further, it is unclear how variation in scales measuring connection to nature and PEB affect the relationship between these 2 variables.

There have been 2 meta-analyses (Hines et al. 1987; Bamberg & Möser 2007) of sociopsychological determinants of PEB, but they did not include connection to nature. We sought to provide a quantitative synthesis of the current research on the relationship between connection to nature and PEB and to examine the effect of moderators on this relationship.

Through meta-analysis, we aimed to provide an estimate of the size of the relationship between connection to nature and PEB, determine whether there was significant variability across our sample, and examine possible moderators. Moderators instruments used to measure connection to nature and PEB; geographic location of samples (the strength of the relationship can vary with location [Tam 2013a]); and age and gender of study participants (being older and female is associated with greater environmental attitude and PEB [Kollmuss & Agyeman 2002; Whitmarsh & O'Neill 2010]). We tested data for publication bias to determine whether the sample was broadly representative of the extant research.

Methods

We searched electronic databases (Web of Science, Science Direct, ProQuest Science and Technology, PSYCH-Info, ProQuest Dissertations, and Theses Global) for combinations of the following keywords: *connection to/with nature*, *connectedness to nature*, *nature relatedness*, *inclusion of nature in self*, *disposition to connect with nature*, *environmental identity*, *emotional affinity toward nature*, *connectivity to nature*, *commitment to nature and connection to nature index*; *pro-environmental*, *environmental*, *ecological*, *environmentally friendly*, *environmentally responsible*, and *conservation and sustainable behavior*. Abstracts of promising studies were examined and the full-text located of studies that merited further investigation. We manually examined reference sections of papers

that met the inclusion criteria for additional studies. We contacted study authors if connection to nature and PEB were measured but their relationship was not reported.

Studies were included in the meta-analysis if they examined the relationship between connection to nature and PEB; included an effect size or information to calculate an effect size (Pearson's correlation coefficients were preferred. However, Fischer's *Z* scores, used to calculate the effect size, can also be calculated from sample size and significance level in studies, where the correlation coefficient is not provided [e.g., Gosling & Williams 2010]); and included a self-report assessment of explicit connection to nature and an assessment of PEB.

Connection to nature was measured by 12 different scales (Table 1). When ≥ 1 scale of connection to nature was used, we selected the scale that was the main focus of the study rather than alternative scales used to provide the evidence of convergent validity (e.g., Mayer & Frantz 2004; Davis et al. 2009; Brügger et al. 2011). We also selected explicit rather than implicit scales (Geng et al. 2015) because the implicit measure of connection to nature is poorly correlated with other scales and may measure a different concept (Brügger et al. 2011). We selected the nature-relatedness scale from Tam's (2013a) comparative study because he concluded it was perhaps the most reliable scale. This scale and its short form (NR-6) were treated as a single scale when calculating the overall and moderator effects because NR-6 is derived from and strongly correlated to the nature-relatedness scale and both scales show very similar associations with PEB (Nisbet & Zelenski 2013). This decision was supported by the results of our moderator analyses. The nature-relatedness scale had a correlation with PEB of 0.51, the NR-6 of 0.50, and when the scales were analyzed as a single entity, $r = 0.51$.

We came to a consensus on how to rate and classify the content of each scale and also considered the authors' description of the scale. Each item was categorized as cognitive (associated with thoughts and beliefs, e.g., "I

have a deep understanding of how my actions affect the natural world." [Mayer & Frantz 2004] or nature is part of a person's cognitive representation of self [Schultz 2002]); affective (associated with emotions, e.g., "I feel a deep love for nature." [Perkins 2010] or "I feel very connected to all living things and the earth." [Nisbet et al. 2009]); or behavioral or experiential (associated with experiences in nature, e.g., "I take notice of wildlife wherever I am." [Nisbet et al. 2009] or "I get up early to watch the sunrise." [Brügger et al. 2011]).

Researchers measured PEB with 8 different scales, including multidimensional latent constructs of self-reported PEB, single-dimensional self-reported PEB, and observed PEB. The multidimensional scales contained items that measure PEB in the areas of energy and water conservation, waste avoidance, and recycling, transport, purchasing (anticonsumerist behavior), self-education, and social or political actions in various combinations. Studies with one-dimensional scales, which measure similar behaviors, were combined for the analyses. These scales were self-reported behavioral measures, such as native vegetation protection in farmland (Gosling & Williams 2010) and proenvironmental gardening and farming (Sanguinetti 2014; Dresner et al. 2015). When authors reported ≥ 1 PEB measure, we selected for analysis the scale that most closely reflected multidimensional self-reported PEB. For example, actual commitment to ecological behavior (which measured self-reported PEB) was selected over verbal commitment (Nisbet & Zelenski 2013) and environmentalism (Mayer & Frantz 2004; Nisbet & Zelenski 2013). Perkins (2010) and Beery and Wolf-Watz (2014) reported correlation coefficients between connection to nature and individual items of their PEB scales. The weighted mean of the effect size of the PEBs was calculated to avoid double-counting participants. Some studies measured the relationship of connection to nature and behavioral intentions or willingness to engage in PEB. Although the theory of planned behavior (Ajzen 1991) incorporates intention as the immediate antecedent of behavior, there is only

Table 1. The 12 connection-to-nature scales (in chronological order of development) included in the meta-analysis of connection to nature and proenvironmental behavior.

<i>Author</i>	<i>Scale</i>	<i>Country of origin</i>
Kals et al. 1999	emotional affinity toward nature	Germany
Schultz 2002	inclusion of nature in self	U.S.A.
Clayton 2003	environmental identity	U.S.A.
Mayer & Frantz 2004	connectedness to nature	U.S.A.
Dutcher et al. 2007	connectivity with nature	U.S.A.
Davis et al. 2009	commitment to the natural environment	U.S.A.
Nisbet et al. 2009	nature relatedness	Canada
Perkins 2010	love and care for nature	Australia
Brügger et al. 2011	disposition to connect with nature	Switzerland
Nisbet & Zelenski 2013	NR-6 (nature relatedness - short form)	Canada
Tam 2013b	dispositional empathy with nature	China
Beery & Wolf-Watz 2014	environmental connectedness	Sweden

a moderate correlation between behavioral intentions and behavior (Bamberg & Moser 2007; Grimmer & Miles 2017). Behavioral intentions may capture a different concept than self-reported behavior. Therefore, studies reporting intention or willingness to engage or an interest in engaging in PEB were excluded. Samples were independent (i.e., individual participants were included only once). Longitudinal interventions required reporting the effect size before an intervention was implemented.

The following information was collected (if available) for each sample: authors' names, publication year, geographic region (North America, South America, Europe, Australasia, and Asia), measure of connection to nature and PEB, effect size, sample size, significance of effect, percentage of female, and age of participants. A number of potentially eligible studies did not report statistics needed for the meta-analysis, and data could not be obtained from the authors.

We assessed the possibility of publication bias by examining funnel-plot symmetry, which displays effect sizes (as Fischer's Z) plotted against SE. An unbiased sample shows a symmetrical cloud of data points around the overall effect size in a pattern resembling a funnel (Borenstein 2005). We used Egger et al.'s (1997) regression test to quantify asymmetry in the funnel plot. We undertook a trim and fill analysis (Duval & Tweedie 2000) to determine the adjusted effect, taking into account bias seen in the funnel plot. Finally, we calculated the fail-safe N s. Rosenthal's (1991) N is the number of missing samples with an effect size of 0 that are needed to render the current overall effect nonsignificant. Orwin's N (1983) takes into account samples that have a negative effect size.

Data Analyses

Comprehensive Meta-Analysis software (version 3) (Borenstein 2014) was used to calculate the overall effect size and to assess whether the effect size depended on any moderator variables. Fischer Z transformations were used to determine the effect size (Hedges & Olkin 1985) because some of the reported correlations between connection to nature and PEB were >0.30 (Borenstein et al. 2009). The Fischer's Z scores were converted to correlation coefficients for ease of use.

Random effects models were used because we expected the effect size to vary randomly among studies (Hedges & Vevea 1998). Separate univariate categorical analyses were used to obtain an effect size for each subgroup of moderator variables. Moderators included measures of connection to nature and PEB, geographic location of samples, age group of participants, and percentage of female participants. We selected pooled variance for the moderator analyses because we expected variance to

be comparable across subgroups, and because there were <5 samples in some of the subgroups, pooling increased accuracy of the τ^2 (variance of true effect sizes across studies) (Borenstein et al. 2009). Random effects metaregression with method-of-moments estimation was used to assess whether the continuous covariate, percentage of females, moderated the relationship between connection to nature and PEB.

No outliers were identified in the sample (Hanson & Bussi re 1998). Although Cochran's Q was significant ($Q = 406.59$), when the sample with the lowest ($r = 0.14$ [Beery & Wolf-Watz 2014]) or highest ($r = 0.66$ [Otto & Pensini 2017]) effect size was removed from the meta-analysis, the Q statistics did not decrease by 50% ($Q = 264.66$ and 375.59 , respectively).

Results

Sample Characteristics

Thirty-seven independent samples were identified from 26 studies to 3 June 2018. The total sample was 13,237 individuals (adults, university students, and children) from 11, mostly western, countries (Table 2).

Relationship Between Connection to Nature and PEB

The relationship between connection to nature and PEB was positive and moderately sized across samples: $r = 0.42$; 95% CI 0.36, 0.47; $p < 0.001$ (Fig. 1). Thus, connection to nature was relatively higher among people who reported greater participation in PEB. Sample heterogeneity was significant among effect sizes: $Q(36) = 406.59$, $p < 0.001$. A substantial portion of total variance was attributable to systematic differences in effect size between samples ($I^2 = 91.15$); hence, it was important to investigate moderator variables.

Publication bias had only a minor influence on observed effect size. The distribution of samples around the observed effect was approximately symmetrical with an absence of a few samples on the mid to low right-hand side of the funnel plot. Egger's regression coefficient was not significant (intercept = -0.20 ; 95% CI -2.56 , 2.15 ; $t(35) = 0.17$; $p = 0.86$ [2 tailed]), indicating a lack of bias in the data. Rosenthal's fail safe N indicated that an additional 8952 samples with a 0 effect size would be required for our effect size to be nonsignificant. Orwin's fail-safe N showed that 293 missing samples would be needed to make the correlation nonsignificant. The trim and fill analysis inputted 2 samples to the right of the mean and produced an adjusted effect of $r = 0.45$ (95% CI 0.43, 0.46), which is slightly stronger than our observed effect.

Table 2. Summary of studies used in the meta-analysis of connection to nature and proenvironmental behavior.

Study ^a	n	Connection-to-nature scale	Dimensions in connection-to-nature scales ^b		Proenvironmental behavior scale ^c	Location	Age group	% female ^d	Source ^e
Clayton 2003	73	environmental identity	A + C + B		PEB	U.S.A.	student	-	B
Mayer & Frantz 2004 S2	65	connectedness to nature	A + C		PEB	U.S.A.	student	58.8	J
Mayer & Frantz 2004 S4	135	connectedness to nature	A + C		PEB	U.S.A.	adult	74.2	J
Mayer & Frantz 2004 S5	57	connectedness to nature	A + C		PEB	U.S.A.	student	-	J
Schultz et al. 2004	98	inclusion of nature in self	C		PEB	U.S.A.	student	60	J
Raudsepp 2005	987	emotional affinity toward nature	A		PEB	Estonia	adult	-	B
Dutcher et al. 2007	513	connectivity with nature	A + C		PEB	U.S.A.	adult	21	J/T
Davis et al. 2009 S1	71	commitment to the natural environment	A + C		GEB [*]	U.S.A.	student	63.4	J
Gosling & Williams 2010	131	connectedness to nature and connectivity with nature	A + C		vegetation protection on farm	Australia	adult	14	J
Perkins 2010 S4	235	love and care for nature	A		PEB	Australia	adult	58	J
Brügger et al. 2011	1186	disposition to connect with nature	A + B		GEB [*]	Switzerland	adult	45.2	J
Hoot & Friedman 2011	195	connectedness to nature	A + C		PEB	U.S.A.	adult	46.2	J
Nisbet & Zelenski 2013 S1	184	nature relatedness	A + C + B		ecology scale ^{**}	Canada	student	67.4	J
Nisbet & Zelenski 2013 S3	354	nature relatedness	A + C + B		ecology scale ^{**}	Canada	student	59.9	J
Nisbet & Zelenski 2013 S4 A	84	NR-6 (nature relatedness short form)	A + C		ecology scale ^{**}	Canada	adult	78.6	J
Nisbet & Zelenski 2013 S4 B	123	NR-6	A + C		ecology scale ^{**}	Canada	student	77.2	J
Tam 2013a S1	322	nature relatedness	A + C + B		ecological behavior [^]	Hong Kong	student	45.3	J
Tam 2013a S2	185	nature relatedness	A + C + B		ecological behavior [^]	U.S.A.	adult	63.8	J
Tam 2013b S1	288	dispositional empathy with nature	A + C		ecological behavior [^]	Hong Kong	student	45.1	J
Tam 2013b S2	172	dispositional empathy with nature	A + C		ecological behavior [^]	U.S.A.	adult	62.2	J
Tam 2013b S3	104	dispositional empathy with nature	A + C		ecological behavior [^]	Hong Kong	student	66.3	J
Tam 2013b S4	175	dispositional empathy with nature	A + C		ecological behavior [^]	Hong Kong	student	47.4	J
Tam 2013b S5	78	dispositional empathy with nature	A + C		ecological behavior [^]	Hong Kong	student	30.8	J

Continued

Table 2. Continued.

Study ^a	n	Connection-to-nature scale	Dimensions in connection-to-nature scales ^b		Proenvironmental behavior scale ^c	Location	Age group	% female ^d	Source ^e
			Connection-to-nature scale	Dimensions in connection-to-nature scales ^b					
Beery & Wolf-Watz 2014	1374	environmental connectedness	A + C	A + C	PEB	Sweden	adult	-	J
Roczen et al. 2014	1907	disposition to connect with nature	A + B	A + B	GEB*	Germany	adolescent	57	J/PC
Sanguinetti 2014	477	inclusion of nature in self	C	C	gardening, farming, or animal husbandry	U.S.A.	adults	60	J
Dresner et al. 2015	165	environmental identity	A + C + B	A + C + B	proenvironmental gardening	U.S.A.	adult	50	J
Geng et al. 2015	113	connectedness to nature	A + C	A + C	CSEBQ*	China	student	44.3	J
Pereira & Forster 2015	74	connectedness to nature	A + C	A + C	PEB	Australia	student	75.0	J
Collado et al. 2015	107	emotional affinity toward nature	A	A	PEB	Spain	children	54.9	J
Barbaro & Pickett 2016 S1	308	connectedness to nature	A + C	A + C	PEB***	U.S.A.	student	68	J
Barbaro & Pickett 2016 S2	296	connectedness to nature	A + C	A + C	PEB***	U.S.A.	adult	60	J
Soliman et al. 2017	230	connectedness to nature	A + C + B	A + C + B	observed PEB	Canada	student	70.2	J
Forstmann & Sagioglou 2017	1487	nature relatedness			PEB***	U.S.A.	adult	61.4	J/PC
Otto & Pensini 2017	255	disposition to connect with nature	A + B	A + B	GEB*	Germany	children	-	J/PC
Whitburn et al. 2018	405	disposition to connect with nature	A + B	A + B	GEB*	New Zealand	adult	62	J
Rosa et al. 2018	224	connectedness to nature	A + C	A + C	PEB	Brazil	students	62.5	J

^aAbbreviations: S, study; Sx (A, community sample; B, undergraduate student sample).^bAbbreviations: A, affect; C, cognition; B, behavior or experience.^cAbbreviations and symbols: PEB, proenvironmental behavior; GEB, general-ecological-behavior scale; CSEBQ, college student environmental behavior questionnaire; *, adapted from Kaiser

(1998); **, ecology scale, actual commitment (Maloney et al. 1975); †, adapted from Kaiser (1998) and Schultz & Zelezny (1998); ***, adapted from Whitmarsh and O'Neill (2010).

^dData unavailable (-).^eAbbreviations: J, peer-reviewed journal; R, report; T, PhD dissertation; B, book chapter; PC, personal communication with author.

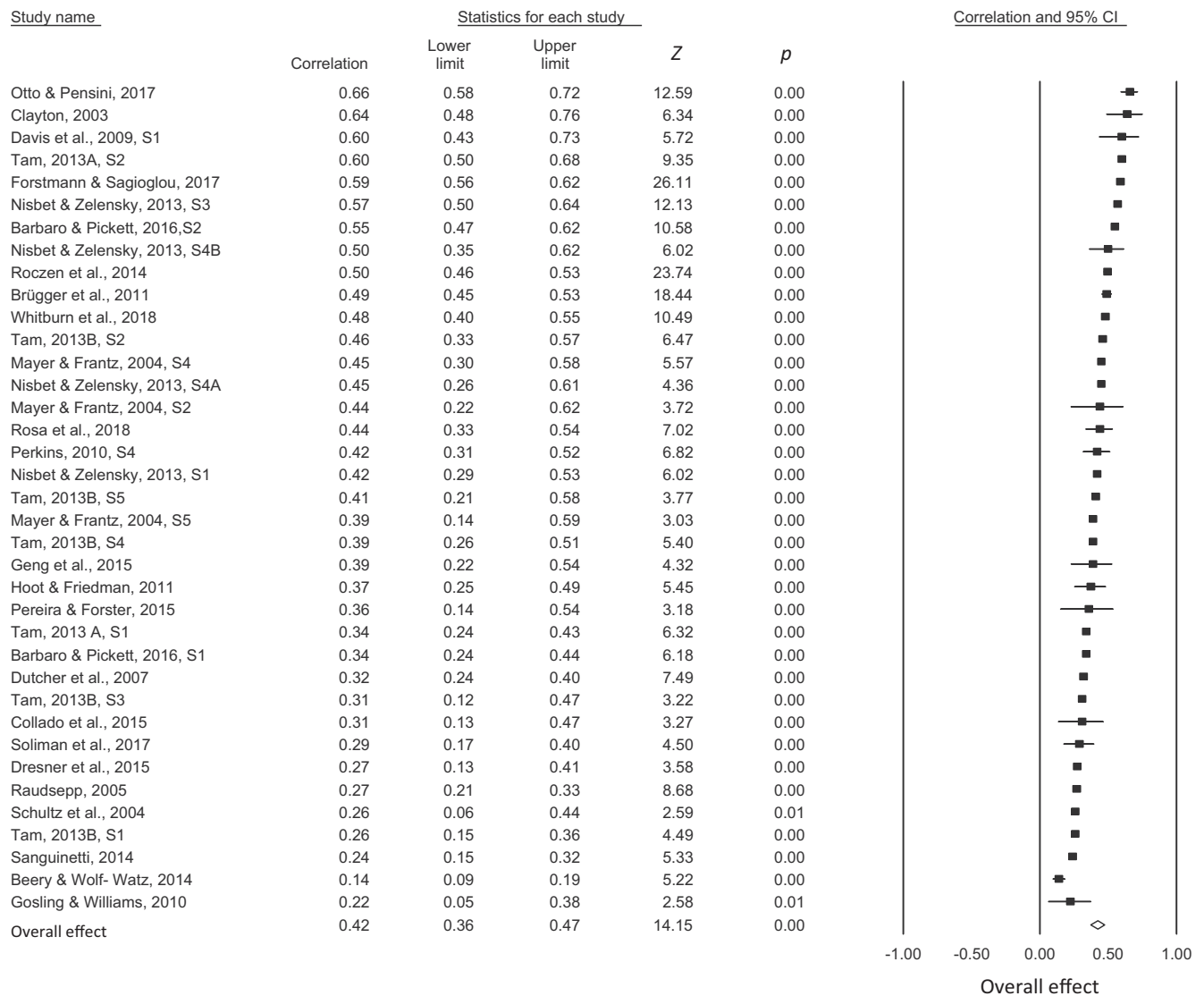


Figure 1. Overall relationship (r) between connection to nature and proenvironmental behavior and the relationships for individual samples (Sx, study number; A, community sample; B, undergraduate sample). Lower and upper limits are 95% CI values. Samples are listed from strongest to weakest correlations.

Relationship Moderators

The scale used for connection to nature significantly moderated the overall effect ($Q[10] = 36.29, p < 0.001, n = 37$) and explained 69% of the between-sample variation (Table 3). Mean effect sizes for the types of connection to nature ranged from 0.14 to 0.60 (Table 3). The relationship was strongest for commitment to the environment ($r = 0.60$) and weakest for inclusion of nature in self ($r = 0.25$). Environmental connectedness included 0 in the 95% CIs, indicating a nonsignificant relationship. Results for moderator subgroups with few samples can be problematic. We repeated the moderator analysis for connection-to-nature scales with ≥ 3 samples per subgroup. The results were robust to the change in

threshold of inclusion: $r = 0.45, Q(3) = 13.62, p = 0.001, R^2 = 0.37, n = 27$.

Multidimensional scales that contained affect and behavior or affect and cognition and behavior had the strongest relationship with PEB ($r = 0.52$ and 0.50 , respectively) (Table 3). These included disposition-to-connect-with-nature, nature-relatedness, and environmental-identity scales. The one-dimensional cognitive scale had the weakest relationship ($r = 0.25$). The content and dimensions of the connection-to-nature scales (affective, cognitive, or behavioral) significantly moderated the relationship between connection to nature and PEB: $Q(4) = 15.90, p < 0.001, R^2 = 0.46, n = 37$. This result held when we tested subgroups with ≥ 3

samples: $r = 0.46$, $Q(2) = 12.21$, $p < 0.001$, $R^2 = 0.40$, $n = 27$.

Number of items in a scale also moderated the relationship. Scales with a moderate number of items (20–29) (i.e., nature relatedness and environmental identity) had the strongest relationship with PEB ($r = 0.55$); those with < 9 items had the weakest ($r = 0.29$) (environmental connectedness, connectivity with nature, and inclusion of nature in self) (Table 3): $Q(3) = 28.6$, $p < 0.001$, $R^2 = 0.47$, $n = 37$.

Scales used to measure PEB also moderated the overall relationship between connection to nature and PEB ($Q[5] = 15.53$, $p < 0.01$, $n = 37$) and explained 52% of the between-sample variance (Table 3). The relationship with connection to nature for the types of PEB ranged from 0.25 to 0.51. The scales based on Whitmarsh and O'Neill (2010) had the strongest relationship with connection to nature ($r = 0.51$). Other self-reported PEB scales (ecology, general ecological behavior, and general PEB scales) fell in the midrange ($r = 0.36$ – 0.49) and observed PEB (Soliman et al. 2017) was at the low end of the range ($r = 0.29$). Results were robust to change in the threshold of inclusion of ≥ 3 samples: $r = 0.42$, $Q(4) = 14.4$, $p = 0.01$, $R^2 = 0.53$, $n = 36$. Scales used to measure connection to nature and PEB together explained 75% of between-study variance: $Q(15) = 53.75$, $p = 0.001$.

The correlation between connection to nature and PEB was strongest for children ($r = 0.51$) and weakest for students ($r = 0.41$) and adults ($r = 0.40$). Neither age group ($Q[2] = 1.29$, $p = 0.53$, $n = 37$) (Table 3) nor participant mean age ($Q[1] = 0.00$, $p = 0.96$, $n = 37$) were significant moderators. All age subgroups had ≥ 3 samples.

The relationship between connection to nature and PEB was strongest in samples from North and South America ($r = 0.44$) and Europe ($r = 0.41$) and weakest for Asia ($r = 0.35$) and Australasia ($r = 0.38$). However, the geographic location of samples did not influence strength of the relationship between connection to nature and PEB: $Q(4) = 1.78$, $p = 0.78$, $n = 37$ (Table 3). Similarly, metaregression showed the percentage of females in the samples was not a moderator of the relationship: $Q(1) = 3.70$, $p = 0.06$, $n = 32$.

Discussion

The relationship between connection to nature and PEB was positive, significant, and moderately sized ($r = 0.42$). Individuals more strongly connected to nature demonstrated a greater engagement in self-reported PEB. This relationship held across gender, geographic location, and age group. Our findings support the stance that feeling deeply connected to nature influences how individuals treat it and has implications for increasing general PEB and biodiversity conservation. Our meta-analysis comple-

ments Capaldi et al.'s (2014) meta-analysis, which quantified the relationship between connection to nature and happiness. They found connection to nature had a small, positive association with vitality and life satisfaction. Together, these meta-analyses suggest that a close connection with nature is beneficial for human and environmental well-being. Publication bias did not greatly influence observed effect in our analysis; thus, we have confidence in the observed effect we found.

The large amount of heterogeneity in the data set was largely explained by the scales used to measure connection to nature and PEB (which together explained 75% of between-study variance). It is somewhat surprising that scales measuring connection to nature moderated the relationship with PEB. If, as Tam (2013a) demonstrated, these scales measure an underlying core construct of connectedness to nature, one would expect the scales to demonstrate a consistent association with PEB. The multidimensional scales with a moderate number of items and affective and behavioral or affective, behavioral, and cognitive dimensions had the strongest association with PEB. The disposition-to-connect-with-nature and full nature-relatedness scales incorporated these qualities. The single-item, cognitive scale (inclusion of nature in self) had one of the lowest associations with PEB. Our findings support Tam's suggestion that the distinction between cognitive and noncognitive scales may be important. Furthermore, multidimensional scales may capture more of what it means to be connected to nature and therefore better predict PEB. Multidimensional scales also allow a detailed analysis of how their various dimensions relate to PEB and how they are affected by interventions aimed to increase connection to nature. Our results indicated that cognition, affect, and behavior were important components of connection to nature in its relationship with PEB. Addressing participant knowledge and beliefs alongside building an emotional and experiential connection to nature may be required in interventions to motivate greater PEB.

The way PEB was operationalized was also a significant moderator of the relationship. The multidimensional scales that measured general PEB and covered several domains of behavior had the strongest association with connection to nature. There was a fairly consistent relationship with connection to nature across these multidimensional scales (means fell within 95% CI of the scale with the highest association with connection to nature, 0.39–0.61). People do not consistently engage with a wide range of PEBs, and some behaviors (e.g., recycling) generally require less effort than others (political activism or using public transport). Multidimensional scales can reduce measurement error and produce generalizable results (Epstein 1983; Kirkpatrick 2003). Aggregating PEBs across several dimensions can capture a more realistic picture of a person's general PEB than measuring a single behavior.

Table 3. Effect of moderators on the relationship between connection to nature and proenvironmental behavior.

Moderators ^a	k	n	Effect size		95% CI		Test null (2 tailed)		Test of model
			r		lower	upper	Z	p ^b	
Connection to nature scales									
commitment to the natural environment	1	71	0.60		0.37	0.76	4.44	0.001	
disposition to connect with nature	4	3753	0.53		0.45	0.60	10.98	0.001	
nature relatedness	7	2739	0.51		0.44	0.57	12.33	0.001	
environmental identity scale	2	238	0.44		0.27	0.58	4.82	0.001	
love and care for nature	1	235	0.42		0.21	0.59	3.78	0.001	
connectedness to nature scale	11	1828	0.39		0.32	0.45	10.50	0.001	
dispositional empathy with nature	5	817	0.36		0.26	0.46	6.58	0.001	
connectivity with nature	1	513	0.32		0.12	0.50	3.07	0.001	
emotional affinity toward nature	2	1094	0.28		0.13	0.43	3.52	0.001	
inclusion of nature in self environmental connectedness	2	575	0.25		0.08	0.40	2.92	0.001	
test of model	1	1374	0.14		-0.06	0.33	1.38	0.17*	
Dimensions of connection to nature scales	37	13,237							$Q(10) = 36.29, p < 0.001, R^2 = 0.69$
affect + behavior	6	3960	0.52		0.43	0.60	9.97	0.001	
affect + cognition + behavior	7	2770	0.50		0.41	0.57	10.06	0.001	
affect + cognition	19	4603	0.37		0.31	0.43	11.27	0.001	
affect	3	1329	0.33		0.18	0.47	4.20	0.001	
cognition	2	575	0.25		0.05	0.43	2.45	0.011	
test of model	37	13,237							$Q(4) = 15.90, p < 0.001, R^2 = 0.46$
Number of items in scales of connection to nature									
1-9	10	3176	0.32		0.22	0.41	6.04	0.001	
10-19	18	4108	0.43		0.38	0.48	14.11	0.001	
20-29	7	2860	0.57		0.50	0.64	12.44	0.001	
30+	2	3093	0.49		0.34	0.62	5.67	0.001	
test of model	37	13,237							$Q(3) = 28.60, p < 0.001, R^2 = 0.47$

Continued

Table 3. Continued.

Moderators ^a	k	n	Effect size		95% CI		Test null (2 tailed)		Test of model
			r		lower	upper	Z	p ^b	
PEB scales									
PEB (Whitmarsh & O'Neill) [*]	3	2091	0.51		0.39	0.61	7.26	0.001	$Q(5) = 15.53, p = 0.01, R^2 = 0.52$
ecology scale ^{**}	4	745	0.49		0.37	0.59	7.23	0.001	
general ecological behavior ^{***}	13	5261	0.46		0.40	0.52	12.54	0.001	
PEB general [†]	13	4137	0.36		0.29	0.43	9.13	0.001	
observed PEB	1	230	0.29		0.02	0.52	2.13	0.03	
pro-environmental gardening or farming	3	773	0.25		0.09	0.36	3.12	0.001	$Q(2) = 1.29, p = 0.53, R^2 = 0.00$
test of model	37	13,237							
Age group									
children	3	2269	0.51		0.32	0.48	8.96	0.001	
students	18	2941	0.41		0.33	0.49	9.17	0.001	
adults	16	8027	0.40		0.32	0.48	8.96	0.001	$Q(1) = 0.00, p = 0.96, R^2 = 0.00$
test of model	37	13,237							
Mean age (years)	29								
test of model									$Q(4) = 1.78, p = 0.78, R^2 = 0.00$
Geographic location									
North America	20	5272	0.44		0.37	0.51	10.76	0.001	
South America	1	3045	0.44		0.09	0.69	2.45	0.01	
Europe	6	5816	0.41		0.28	0.53	5.68	0.001	
Australasia	4	845	0.38		0.20	0.53	4.05	0.001	
Asia	6	1080	0.35		0.20	0.48	4.47	0.001	
test of model	37	13,237							$Q(1) = 3.70, p = 0.06, R^2 = 0.10$
Percent female	32								
test of model									

^a Abbreviations and symbols: PEB, proenvironmental behavior; *, adapted from Whitmarsh & O'Neill (2010); **, ecology scale, actual commitment (Maloney et al. 1975); ***, adapted from Kaiser (1998); †, from mixed sources.

^b * Nonsignificant effect size.

In contrast to what we expected based on the literature, the demographics we tested were not significant moderators of the relationship between connection to nature and PEB. The age group or mean age in years of participants and the percentage of females did not affect the strength of the relationship. This was unexpected because generally being older and female is associated with greater PEB (Kollmus & Agyeman 2002). Undergraduates are often used as a convenient population in research. There are some concerns that, as a population, undergraduates may not be representative of the general adult population and study results may therefore not be generalizable. We found no significant difference in results for students and adults, indicating that these concerns may be unwarranted in this area of research. The lack of geographic location as a moderator contradicted cross-cultural studies that report that the way individuals relate to the natural environment is culturally patterned (Milfont & Schultz 2016), perhaps because extant research centers on urban populations in western countries. Nature connectedness needs to be investigated in nonwestern cultures.

Our study has some limitations. The correlation we found does not mean causation. A stronger connection to nature may indeed motivate greater PEB. Conversely, individuals who participate in more PEB may develop a stronger connection to nature, or other variables may be involved. However, our findings do consolidate existing research and provide a solid grounding to justify future longitudinal research into changing PEB by strengthening individuals' connection to nature (Schultz 2011). Differences in the strength of the relationship between connection to nature and engagement in PEB may also be attributable to items in the scales that indirectly measure PEB, which could result in a stronger correlation. For example, several scales include an item on how a person's actions affect the environment (nature-relatedness, environmental-identity, and commitment-to-nature, and connectedness-to-nature scales). These scales did correlate more strongly with PEB than the scales without such items.

Connection to nature and PEB are measured by self-report. Reliance on self-reports threatens construct validity (i.e., metrics used may not measure what they are intended to) and can lead to inflated associations between variables measured via the same method due to shared method variance. However, observing actual PEB is difficult because most actions are not carried out in public and observing a single behavior is not a valid measure of general PEB (Frantz & Mayer 2014). We focused on the direct relationship between connection to nature and PEB. However, the relationship may be indirect. For example, the relationship between connection to nature and PEB is partially mediated by environmental attitudes, the use of nature for psychological restoration (Whitburn et al. 2018), and environmental values (Pereira & Forster 2015)

and fully mediated by biospheric concerns (Gosling & Williams 2010). It is useful to identify mediators that facilitate the relationship between connection to nature and PEB to determine types of interventions that may motivate greater PEB.

Conservation science has successfully identified the biological values and processes affected by anthropogenic activity, and has successfully mitigated some human impacts. However, conservation efforts are continually undermined by human behavior (Fox et al. 2006). Conservation actions are human behaviors (Schultz 2011); therefore, it is vital to understand how social and psychological factors influence such behaviors (Mascia et al. 2003). Our findings support Schultz's (2011) suggestion that promoting stronger connections to nature could increase individuals' proenvironmental and conservation behaviors. Our results showed that people with a stronger connection to nature are more likely to engage with a range of PEBs, including conservation of energy and water, anticonsumerism, proenvironmental political activism, and financial support for environmental organizations. Future longitudinal studies (ideally randomized experiments) could provide evidence of a causative relationship between connection to nature and PEB. A recent longitudinal study demonstrated the amount of time spent in nature as a 6-year-old is related to environmental attitudes and behavior as a young adult (Evans et al. 2018). Although time in nature is not connection to nature, it may be indicative of the relationship one might expect if connection to nature is causative of PEB. The usefulness of existing interventions, such as environmental education, aimed at strengthening connection to nature as a way to motivate greater engagement in PEB needs evaluation.

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